# DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF MANGO GRADER

A thesis
Submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI – 413 722, DIST. AHMEDNAGAR, MAHARASHTRA, INDIA**

In partial fulfillment of the requirements for the degree

of

**MASTER OF TECHNOLOGY**
(AGRICULTURAL ENGINEERING)

In

**AGRICULTURAL PROCESS ENGINEERING**

By

**RAJENDRA SAHEBRAO DAHATONDE**
B. Tech. (Agril. Engg.)

**AGRICULTURAL PROCESS ENGINEERING**
COLLEGE OF AGRICULTURAL ENGINEERING
**MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI (413 722)**
**DIST. AHMEDNAGAR , M. S. (INDIA)**

**2004**

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Approved by

**Dr. H. G. More**
(Chairman and Research Guide)

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**AGRICULTURAL PROCESS ENGINEERING**
**COLLEGE OF AGRICULTURAL ENGINEERING**
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**2004**

# CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or any other person
to any other University
or Institute for
Degree or
Diploma.

Place : MPKV, Rahuri
Dated : 30 / 1 / 2004

(Dahatonde R. S. )

# DEDICATION

*Affectionately Dedicated*

*To Beloved Parents*

*and*

*Teachers*

**Dr. H. G. More**
M. Tech. (Agril. Engg.) Ph. D. (U. K.)
Professor and Head,
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## CERTIFICATE

This is to certify that the thesis entitled **"DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF MANGO GRADER"**, submitted to the faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in partial fulfillment of the requirement for the award of the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **AGRICULTURAL PROCESS ENGINEERING** embodies the results of *bonafide* research work carried out by Shri. Rajendra S. Dahatonde under my guidance and supervision.

The results embodies in this thesis have not been submitted to any other university or institute for the award of Degree or Diploma.

The assistance and help received during the course of this investigation has been duly acknowledged.

Place :- MPKV, Rahuri
Date : 30 / 1 / 2004.

**(H. G. More)**
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Dean,
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Place : MPKV., Rahuri
Date : 30/ 1 /2004.

**(H. G. More)**

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Place : MPKV, Rahuri
Dated : 30/ 1 /2004

(Dahatonde R. S. )

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# ABBREVIATIONS

| Abbreviations | | Description |
|---|---|---|
| % | : | Per cent |
| °C | : | Degree celsius |
| Anon | : | Anonymous |
| Cm | : | Centimetre (s) |
| DF | : | Degree of freedom |
| *et al.* | : | And other |
| FCRD | : | Factorial Completely Randomised Design |
| Fig. | : | Figure |
| g | : | Gram |
| G | : | Gap |
| G.I. | : | Galvanised iron |
| ha | : | Hectare |
| hrs | : | Hours |
| I | : | Inclination |
| I.S. | : | Indian standards |
| i.e. | : | That is |
| kg | : | Kilogram (s) |
| M.S. | : | Mild steel |
| min | : | Minute |
| mm | : | Millimetre (s) |
| Mt. | : | Million tonne (s) |
| N.S. | : | Non significant |
| No. | : | Number |
| S | : | Speed |
| S.S. | : | Sum of square |
| S.E. | : | Standard error |
| sec | : | Second (s) |
| *viz.*, | : | Namely |

# ABSTRACT

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**DESIGN, DEVELOPMENT AND PERFORMANCE EVALUATION OF MANGO GRADER**

by

**Rajendra S. Dahatonde**

Mahatma Phule Krishi Vidyapeeth, Rahuri,
Dist. Ahmednagar (Maharashtra )
2004

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|---|---|---|
| **Research Guide** | **:** | **Dr. H. G. More** |
| Department | : | Agril. Process Engineering |

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A prototype mango fruit grader has been designed, developed and its performance evaluated. The effect of three different speeds of conveyor belt (105, 63 and 45 rpm), three inclination of conveyor belt with roller frame assembly (10, 15 and 19°) and three gaps between conveyor belt and idler (53-103 mm) on capacity and efficiency of machine was studied. The effect of capacity and efficiency on performance index was also evaluated.

The mango fruits of cv. Alphanso were graded into three grades based on their average size (62.02 to 85.93 mm) and weights (124.86 to 300.0 g). The sphericity of fruits ranged between 89.16 to 90.71 %. The maximum efficiency of 77 % at $S_3I_3G_2$ combinations ($S_3$ = 45 rpm, $I_3$ = 19° and $G_2$ = 54-99 mm) gave capacity of 740 kg/hr. The performance index at maximum efficiency (77 %) was 2.70.

The overall dimension of machine is 1500 mm x 610 mm x 440 mm and the approximate cost of machine proposed is Rs. 15430/-. The cost of mechanical grading was found Rs. 21.11 per tonne of Alphanso fruits. The ratio of cost for manual to mechanical grading was worked out to be 9.47:1.

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# Introduction

# 1. INTRODUCTION

Adoption of horticultural crops has improved the economic status of Indian farmers considerably. Seasonal availability of fruits and vegetables has been extended to year round, increasing per capita consumption from 40 to 85 g of fruits and 95 to 175 g of vegetables. The horticulture sector contributes more than 20 % from mere 8.0 % of area to the gross domestic product of agriculture. India accounts for 10.1 % of total world production of fruit crops. The fruit production has risen from 5.5 million tonnes in 1952 to 43.25 million tonnes in 1997-98 and 44.0 million tonnes in 1998-99 (Varshney *et al.* 2002).

Mango (*Mangifera indica* L.) originating in the Indo-Burma region is the most popular tropical fruit, cultivated prominently in the plain areas of India. Mango is the national fruit of India and is rightly known as the king of fruits. Owing to its attractive colour, excellent taste, exotic flavour, exemplary nutritive value, health promoting properties and its delicacy for the table of rich as well as food for million of poor people during summer (Salunke and Desai, 1989).

The mango is a major fruit crop of India which contributes around 40 per cent of total fruit production in India. The estimated annual production of mango was 9.78 million tonnes from the cultivated area of 1.4 m ha in 1998-99. The export of mango is 44429.33 MTS in 2001-02 which economic value is 80.99 Rs. crores (APEDA 2001-02).

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Normally fruits are grown in particular regions depending upon their agro climatic conditions and transported to the other parts of country or world. After harvesting of fruits a group of unit operations are performed before they reach the ultimate users. In this group of unit operation grading is one of the most important unit operation which involves overall balanced assessment of all those properties of the material which affects its acceptance as food and as working substance for the processor.

Increasing demand for basic food, energy and nutrition required for full development due to increase in population, compels the world to think over and plan the things accordingly. Increasing food production upto desired level and its efficient quantitative as well as qualitative processing will be the right solution to the said problem. This necessities development of processing equipments and disseminating the same along with up to date knowledge to the farmers.

Cleaning, sorting and grading are the important post harvest processes, related to the market, as it provides basis for buying and selling. In market, size of any fruit has been considered as the main sorting criteria for selling. Colour of the fruit and maturity stand next to it. Still in our country, sorting is not given much attention to the extent it actually needs. Probably, the knowledge and facility are the two factors that matter.

Sorting can be performed either manually or by mechanical means. Though manual sorting is universal, looking to the rate of work done, efficiency, cost of production, labour problems such as their rising costs and availability, it is indispensable to go for mechanical means of sorting of fruits.

The consumption of fruits and vegetables has increased rapidly as the people have become calorie conscious. Consequently, area under fruit crops is growing day by day. Transportation facilities have provided good markets nearer to the farmers field. In market, grading provides basis for buying and selling. To meet these grades, requires equipments for sorting and grading.

The size of produce is probably the characteristic most commonly used in separating solid materials into grades. Many grades are based on size with additional consideration given to quality factors. The size of the various grades of agricultural products may be based on diameter, length, width, thickness and minimum diameter or maximum diameter.

Sorting of agricultural products is carried out all over the world by mechanical, electrical or electronic means of devices. The most common mechanical means of sorting devices are screens, divergent belts, perforated belts, conveyor belt, weight cupts etc. Separation is also achieved by using principles of rolling resistance, impact forces, bouncing characteristic, resonance etc.

All these necessitate the development of mechanical means of sorting with size of the product as a criteria. This fact has been backed by Bryan (1974) and showed by test results that mechanically assisted manual grading has potential commercial value as it would permit workers to perform near peak efficiency, throughout the season. Therefore a low cost mango grader based on the conveyor belt principle was developed with the following objectives :

1. To design, develop and fabricate mango grader.
2. To study the performance of mango grader.
3. To study the effect of machine parameters (speed, inclination and gap) on capacity and efficiency.
4. To study the cost economics of mango grading.

Chapter Opener Page

# Review of Literature

# 2. REVIEW OF LITERATURE

This chapter reviews design, development and performance of different types of grader used in the market as well as research fabrications. They are enlisted in the following chapter.

Various researchers developed so many types of graders according to market demand and processing aspects. Generally grading is done on the basis on size, shape, weight, colour etc. Here a number of studies have demonstrated the application of various types of sorter and grader used in the processing of different types of fruits and vegetables and other agricultural products. The review regarding to the developments is presented in this chapter under different categories.

## 2.1 Size Grading

Houston (1957) studied new criteria for fruit sizing and noticed that various physical properties of the fruits such as diameter, circumference and cross- sectional area could be used as sizing criteria.

Hunter *et al.* (1958) studied apple sorting methods and equipment's i.e. sorting tables include one with a flat belt, one with longitudinal spiral rolls and one with reverse rotating rubber rollers moving over a plywood frame. Modification as the test proceeds included addition of sorting lanes, variables forward speed of rolls and ultimately a new design called the float roll table. The surface of this table consists of small rubber covered rolls extending across the table. The forward motion is controlled by varying the speed at which the rolls move down the table, the rotating speed of the fruit is controlled by varying the rate at which the rolls rotate. The cost of labour for sorting a given amount of fruit was lowest for the float roll table and highest for the belt table. When sorting fruits of good quality, the relative efficiency of various types of equipment was apparent.

Dickens (1962) constructed a peanut sizer using the divergent roller principle for size classification, in which the product are metered at the high end junction of the inclined paired rollers and moved down. Speed and inclination of the roller effect speed passage through the varying clearance width between the rollers. The size classes were collected in the catch pan.

Kesar (1965) noticed that most of sizing machine use the fruit diameter as a sizing criteria.

Van German (1965) developed a spiral tomato-grading machine. With this machine the tomato pass down a chute onto a spiral guide and drop through the appropriate opening of a rotating disc. Upto 1400 kg can be graded in a hour. Two or three persons are needed to operate the machine.

Burt and Patchen (1966) developed and tested unitized sorter, brusher, sizer for apples, which used rotating forward moving brushes instead of roller as in the conventional roller conveyor. The unit includes a conveyor for lifting fruit from the float tank to the brush conveyor. The conveyor includes lane formers, which position the apples for placement on the synchronized brush roller. Apples remained between the same pair of brushes and in the same lane as they moved through the complete unit for sorting, brushing and sizing. Advantages claimed by the developers include minimum transfer of fruit from one section to another which reduce fruit damage, control of rate and direction of fruit rotation and less floor-space requirement than for conventional grading and sizing lines.

Burt (1967) fabricated a brush sizer and sorter for apple. Very gentle handling was achieved by using soft polyurethane roller, to lift the fruits from the float tank and to drop them in two lanes on a belt of soft rotating brushes. The first 3 m (10 ft) of travel was past sorters, who removed culls and placed second grade fruit between two lanes. A section followed where brushes rotate at a appropriate speeds for polishing and wipping. Then in the sizing section the brushes begin to separate, so that the small apples fall between them first and the larger apples at the end. The brushes moved on through a cleaning processes and the fruits rolled down a peddled incline to take away belt.

Goodman and Hamann (1968) designed, developed and tested a machine to field size sweet potatoes. The sizing of roots was accomplished by having them rides in a V, which had on open bottom that gradually increased in width from the front to the rear of the unit. The sides of V were made up of round, clear vinyl plastic belting driven by step one sheaves keyed to a 2.5 diameter shaft mounted in pillow block bearing and driven by roller chain from a hydraulic motor. The belts near the top of the V have a greater linear velocity than those near the bottom. The effect of this differential speed was to cause any object, such as a root, that fall on the sizing belts to rotate until its long axis was parallel to the belts. At this time the root would roll to the bottom of the V. The capacity of the unit was 160 bushel/hour with belt speed of 27.5 m/min. Damage was minor and within acceptable limits, while passing over sizing mechanism. Potatoes were graded in 2.5 to 6.0 cm and 5.0 to 15.0 cm grades.

Grover and Pathak (1972) designed and developed a wire belt type of potato sizer capable of sizing the tuber into four sizes. The prototype was operated with 2-hp electrical motor. The output was found to be 20 to 24 q. per hour with 1 to 10 per cent of brushing and about 94 per cent of sizing efficiency.

Brantley *et al.* (1975) developed a multiple belt adjustable V size grader for use in stationary sweet potato and cucumber packing line application and tested for reliability and endurance in commercial operation. Results showed that product damage was negligible and average sizing accuracy (with wobble) was 95 to 98 per cent for sweet potatoes and 94 per cent for cucumbers. Best results were obtained with a sizing belt speed of 1.07 m/s, orienting the belt at velocity ratio 2.25: 1, product feed rate less than 2040 kg/h, though feed rates upto 2610 g/h did not produce excessive error.

Verma and Kalkat (1975) designed and developed an expanding pitch rubber spool potato sizer. A prototype of potato sizer comprises of mainly a sizing conveyor containing rubber spool and two identical driving rollers with helical groves of gradually increasing pitch. The performance of expanding pitch rubber spool potato sizer was studied at three different speed of sizing bed corresponding to the helical shaft speed of 190, 110, and 75 rpm. The result showed that there was not appreciable difference in the percentage variation of tuber weight collected in different size grade at different speeds. The output of potato sizer was found to be about 25 bags per hour. The overall performance of the sizer was found to be quite satisfactory.

Morgon and Constantin (1976) developed a compact laboratory seed separator to operate without the limitation of screens. The separator grader was designed primarily to sort kernels of cereal grains. It adjusts to permit selection of numerous size classes on ascending order. The range of each size class can be changed to meet a requirement for a variety of kernel dimensions. The divergent roller are mounted side by side in an inclined position. One roller is rotable while the other one is stationary but adjustable so that the spacing between the rollers can be controlled. Seeds are metered through a vertical plastic cone to the high-end junction of the paired rollers. The seed moved down the inclined-paired roller for separation according to size range. The roller speed can be varied by changing diameter of the v belt drive sheaves. The angle of inclination of the paired roller can be varied through a range of 0 to 7 degree of control flow rate of seed along the roller length. The separator grader proved effective in uniformly sizing cereal grains.

Naugle and Brien (1976) carried out engineering analysis of a mechanised fruit grading table. The results of the study showed that by using the mechanized table system, saving in the amount of labour requirement for manual grading would be realised. Use of spiral drum subsampler could effectively replace the interim.

Bryan (1978) reported that the mechanically assisted manual grading process improved effectiveness of removal of unwholesome or "cull" fruit during the unloading of oranges at a processing plant. In this process, most culls were separated mechanically by differences in bouncing behaviour into a side stream containing less than 15 per cent of the total fruit flow. Only the small side stream then required manual grading before storing fruit in bins. When this process was used, efficiency of manual grading was almost twice that of conventional procedure because the stream requiring inspection was small and the concentration of the culls was 5 to 15 times that in the original fruit. The process was demonstrated on 1/3 commercial scale in a pilot fruit receiving system at a citrus processing plant.

Frank *et al.* (1978) developed a research tool for sorting strawberries by size. A sorter consisting of a box shaped frame 47 X 47 X 62 cm, with five removable drawers was constructed of 6 mm clear plexiglass. The top four drawers from a stack of sieves. The top drawers had a mesh of 3.81-cm diameter and the bottom one 1.91-cm.

McClure *et al.* (1979) investigated an inclined vibrating plate as tomato sorter. Separation into red and green fractions was successful for a angle of tilt of $40^{O}$ at a frequency of 72 h and amplitude of 0.18 cm, because the green tomatoes bounce down while the red tomatoes slide up the incline.

Bryan *et al.* (1980) reported that the mechanically assisted manual grading was effective for sorting oranges that contained higher number of decayed fruits that could be removed by conventional grading procedure at usual unloading rates. A mechanical separator diverted most of the unwholesome orange by differences in bouncing behaviour into a small side stream that contained less than 10 per cent of the original fruit stream. Only the side stream required manual grading before storing fruit in bins. The process was particularly effective for grading loads of mechanically harvested oranges that contained 75 per cent decayed fruit.

Singh (1980) developed differential belt speed expanding pitch type potato grader. The main components of the grader were feed conveyor, frame, grading unit, collection platform and power transmission unit. The grader required 1 hp to drive its various components at full load. The maximum separation efficiency at optimum speed (35 rpm of grader shaft, 4.4 m per min of belt speed, 17.24 qt per hour of feed rate) was found to be 87 per cent.

Gadakh and Gangarde (1981) tested the groundnut grader for effect of speed and angle of inclination of roller on feeding rate and separation efficiency. They graded the groundnut pods of varieties

JL-24 and SB-11 into four different size grades at various combination of speed (360, 440 and 560 rpm) and angle of inclination (3.5°, 6.0°, and 9.0°) of roller. They observed that as the speed and angle of inclination of roller increased, the feed rate increased in variety JL-24. However, this relationship was not holding good in variety SB-11. While separation efficiency decreased when angle of inclination of roller increased. The overall efficiency of the grader was observed to be 71.2 per cent.

Akinaga *et al.* (1982) developed a multipurpose sorter for fruits and vegetables. It was a simple computerized sorter in which sorting was done on the basis of dimension of the fruits and vegetables (e. g. length, width). Accuracy of the sorter was compared with manual sorting, found to be satisfactory.

Farher and Bruter (1983) described apparatus for sorting fruit and vegetables. It comprising roller mounted on traction elements, guides and an inclined board. To reduce susceptibility to damage of the fruit, by preventing them from jamming the output section, there was a bracket the output region turning the roller.

A prototype plus grader was developed at Silsoe College, U. K. (Anonymous, 1984). It uses the diverging belt principle and achieves an acceptable level of grading accuracy. Circular section belts running in L. shaped guides were used to minimise the damage and bloom removal. In orchard trial approximately 80 per cent of the fruits were graded into required category, with misalignment of fruit on the belts accounting for remaining 20 per cent which were graded by their lengths rather than widths. A larger version of orchard model with four lanes of divergent belt gave adequate through-put for packhouse requirements. A method of aligning the fruits using flexible rubber guides was found to be satisfactory, the four belts were operated at the same speed to avoid belt speed differential. The belts and divides required careful seting to achieve an accuracy of 90 per cent of the fruits falling within a tolerance band of ± 5 mm in diameter.

Kirienko (1984) analysed the accuracy of dimensional sorting of potatoes. Accuracy was calculated for belt, roller and sieve sorters and for sorting by linear parameter of length, width, thickness and size (of the square cells of a sieve sorter) good agreement was obtained between calculated and experimental results. Accuracy of sorting in terms of tuber width on a roller type sorter was not significantly better than that obtaining using other linear dimensions and it was concluded that productivity and the amount of damage should be used as determining factors in choice of method.

Firus and Unbekannt (1985) described the potato grading accuracy. Grading characteristics at the limit of the set size accuracy were examined in terms of tuber size range, it was noted that separation function is independent of the size composition of the tuber mixture to be separated. Separation function was used to demonstrate that criteria of separation accuracy (proportion of undersized tuber mixture in a graded lot, losses of market size tubers, overall grading accuracy and degree of separation) are dependent upon the size composition of the mixture to be separated.

Baab and Rohlfing (1986) developed a rational method for sorting sweet cherries. An inclined, adjustable sorting table was illustrated and described. It increased sorting efficiency by 60 to 70 per cent compared with previous methods. Using a moving belt for fruit sorting worked well technically but sorting decreased after 2 to 3 hours after the sorters became tired.

Rusalimov (1986) studied grading walnuts according to the minimum diameter of their mean cross section. A prototype grader consisting of two inclined, counter-rotating roller was constructed. Optimum parameter for self-cleaning and nut transport were determined. A roller diameter greater than or equal to 96 cm and angle of inclination $12.2^{O}$ were required to achieve grading with an accuracy of 90.32 per cent at minimum nut diameter of mean cross section 21.3 to 35.6 mm. Graders with two and four channels processed 2 and 4 t nuts per shifts, respectively.

Posselius and Cox (1988) developed portable melon sizer for research plots. It was designed and tested by using divergent roller concept to grade cantaloupe melons. Grading made by an experienced scientist, an inexperienced novice and the mechanized sizer, were compared. The mechanical system was significantly faster than the novice and made a similar number of sizing errors to the expert.

Department of Agricultural Process Engineering, Dr., PDKV.,Akola (Anonymous,1989), developed a hand operated orange size grading machine which was based on tapering roller principle. The taper roller required for this grader was fabricated from mango wood. A handle was provided to rotate the roller meshed by gears at one end, and to operate the feeding mechanism. The collecting chutes were made out of gunny bags. Rest of the mechanism was similar to the separation part of the previous machine. The total 160 oranges consisting of 40 of each four grade were mixed and fed to grader. The distributed lot was collected and was passed through the measuring rings, to confirm its size individually. Six replications were given with same fruits. The results showed that the new orange grader has around 80 per cent separation efficiency with 5000 oranges per hour capacity.

Nevkar (1990) developed and tested the divergent roller type grader for effect of roller speed, angle of inclination of roller, gap between the rollers on capacity and separation efficiency. The fruits were graded into four different size grades at various combination of speed (195, 216 and 278 rpm), and angle of inclination ($4.59^0$, $5.6^0$ and $6.1^0$) of roller and gap between the roller (2.83- 5.00, 2.84- 5.20 & 2.87- 5.40 cm) for lemon fruits and (3.07- 7.00, 3.13- 7.20, & 3.16- 7.40 cm) for chiku fruits. He observed that the capacity of the machine increased with increase in roller speeds, inclination of roller and gap between the roller. A decreasing trend observed for separation efficiency with increase in roller speed, angle of inclination and gap between the roller for both fruits. The overall separation efficiency for lemon fruits was 71.71 per cent and 66.75 per cent for chiku fruits. The overall sorting capacity for lemon fruits was 603.94 kg per hour and for chiku was 1189.92 kg per hour.

Patil and Patil (2002) designed, developed and tested performance of sapota fruits grader. The machine developed was of divergent roller type. The performance of fruit grader was seen with respect to its capacity and separation efficiency. The effect of roller speed and gap between the roller on capacity and separation efficiency was also studied. Three roller speeds (300, 360 and 450 rpm) and three different gap between the roller (3.0- 5.5, 3.3- 6.5 and 3.6 – 7.5 cm) were taken for testing the performance of machine. The maximum capacity of 1800 kg per hr. and minimum capacity of 1152 kg per hr., were obtained for sapota fruits. The overall machine sorting capacity for sapota was 1727 kg per hr. The maximum and minimum separation efficiency were 87 per cent and 54 per cent, respectively. The overall separation efficiency of the machine was 72 per cent.

Onion and Garlic research station, Rajgurunagar, Pune designed and developed a divergent roller type of onion grader (Anonymous, 2002). Separation of onion is achieved on the basis of size. The roller with spacing of 35 – 80 mm from feed end to discharge end between the roller. The spacing between the roller increases feed end to rear end The onion were graded into four different grades. The capacity of the grader was 500 kg/hr. Sized onions passing between the roller were collected in separate compartment.

## 2.2 Screen Grading

Shyam *et al.* (1979) conducted sorting of potatoes into different size graded by mechanical sieving. They studied the effect of various parameters on the performance of the experimental power operated sieves for sorting potatoes into four different size grades. Results indicated that screen efficiency and blinding of sieves increased with decrease in sieve speed, stroke length and sieve slope. Screen efficiency was also increased with feed rate in the lower range but decreased as the feed rate was progressively increased. High screen efficiency upto 93.67 per cent was obtained by providing little manual assistance to take care of blinding of sieves. However, tuber damage was consistently high.

Dickens (1980) studied the effect of screening and screen opening on the market value and quality of farmer's stock peanuts. Three samples of Virginia type farmers stock peanuts were collected at three different locations in North Carolina and were sized over conveyor belt spaced 4.68 mm, 6.25 mm, 7.81 mm, 9.38 mm, 10.94 mm and 12.50 mm apart. The amount of foreign material, loose-shelled kernels and pods, which rode each spacing were determined. The kernels shelled from each segregation of pods and the kernels in each segregation of loose shelled kernels were graded to determine the size distribution, the amount of splits, the count per pound, the amount of damage and the amount of minor defects. The potential market value and quality of shelled peanuts produced from the farmers stock peanuts that rode each roller spacing was also determined. The effects of screening farmers stock peanut was studied in relation to the quality of shelled peanuts for edible purposes.

Hann *et al.* (1987) studied grading and sorting of potatoes using a square mesh riddle system with reference to uniformity, accuracy, damage and capacity. Quality sorting by hand selection, semi-automatic and electronic methods was discussed. Ergonomic aspects of hand sorting, densities of potatoes to be sorted, disposal arrangement for reject potatoes, positioning of inspectors, sorting table construction and attainable sorting capacity were included.

Shyam *et al.* (1988) developed a simple indigenous manual and power operated mechanical size grader with and without feed conveyor attachments and used successfully for sorting seed potatoes at the Central Potato Research Institute, Simala. The machine worked on the conventional principle of sieving. It comprised a steel frame, a set of two or three oscillating sieves, a power transmission unit, a stationary sieve feeding chute, sorting platform and bag filling device. The average field performance, power source, labour requirement and estimated operational costs of the manual and power operated size graders were noted.

Shyam *et al.* (1990) designed and developed a potato grader. Design consideration, constructional details, method of operation and performances have been reported. On an average, the grader sorted 20 to 25 q/h of seed potato into 4 to 5 sizes employing 0 to 14 attendants. The screen efficiency of the oscillatory sieves ranged from 80 to 90 per cent and average tuber damage was to be within 2 per cent.

## 2.3 Weight Grading

Allshouse and Stephenson (1969) developed a handling and sorting system for certain fruits and vegetables. A spiral roller was constructed using a roller of 2-inch diameter aluminium pipe. Foam rubber spirals were tried, but counterbalance weight until such time as the weight of fruit causes the beam to tip, discharging the fruit into padded chutes in weight categories.

Furletov (1984) developed a conveyor brush potato separators which incorporated an endless belt convered with rubber bristles. Potatoes, remaining on the surface of the bristles because of their relative lightness, were removed by two counter revolving rollers mounted parallel to the conveyor belt rollers. The pick-up principle was demonstrated theoretically and experimentally to the superior to a single cylinder brush mounted at an angle to the movement of the conveyor or belt mounted brush-scrapers set at an angle to the movement of the conveyor. Optimal separation was 75 to 85 per cent at 6 to 7 kg $s^{-1}$.

Zaltzman *et al.* (1985) studied quality sorting of agricultural products based on density and reviewed the relationship between quality and density of agricultural commodities. The potential of quality sorting with fluidized bed separation for small density differences was described.

Meylor and Finn (1994) described a flotation grading system for seperating of fruit or vegetable pieces with different specific gravity. In which desirable pieces have a different specific gravity from the undesirable pieces, and all have a specific gravity about the same as that of water. The pieces were placed near the surface of a body of water in which a cloud of tiny air bubbles was maintained. As the bubbles floated to the surface, they encountered the articles and slightly increased their bouncy. The increase in bouncy was slight and uniform, so those particles having a density slightly greater than that of the water retained at the water surface, while those of slightly greater density sank to the bottom. The cloud of air bubbles was at atmospheric pressure to emerge from operation in a rapidly spinning rotor.

## 2.4 Electronic Colour Grading and Reflectance Grading

Powers *et al.* (1953) developed a successful experimental machine for sorting lemons colorimetrically into four classes prior to storage. There was no significant difference in spoilage between the machine stored and hand sorted fruits. The methods and apparatus used could be applied to sorting other fruits and vegetables.

Gaffney (1973) studied citrus grading by automation. The technique involved measuring the amount of light reflected from skin defects compared with that reflected from the normal fruit surfaces. In studies on light reflectance characteristics of citrus fruits with a double beam recording spectrometer and reflectance attachment, a reflectance difference of at least 15 per cent between defective and normal fruit surfaces was recorded. For each fruit variety a single wavelength bond was formed that could be used for detecting difference between the various defects and the normal fruit surfaces.

Heron and Zachariah (1974) studied an automatic sorting of processing tomatoes. A wide belt high capacity concept of colour sorting was introduced. The sorter viewer observed three possible states, unriped tomato (rejects), riped tomato (no action) and background. The amount of background observed by the viewer when a tomato was only partially in view was determined by the inherent focusing of a sorter-viewer. Test results showed that it was possible to increase the scanning speed (for increased capacity) to desired levels without detrimental effects on sorting accuracy.

Stephenson (1974) developed an electronic detection and high-speed rotary gate controls for sorting machine harvested tomatoes. First on a sequence of operation, a means of singulation of fruits was accomplished, followed by scanning of each fruit for colour by reflected light. Photocell sensors, an integrated circuit comparator and a controlled rotary gate detect and reject green fruit at speeds up to eight fruits per fruit per channel. Sorting accuracies of 98 to 95 per cent were obtained with sorting speeds up to six fruits per second per channel. Performance at higher speeds showed reduction in sorting accuracies.

Anon (1980) reviewed an electronic colour sorter for sorting of fruits. 'Electrosort' system of the Decco Tibelt Company, for hard fruit, tomatoes, peaches, plums, avocados, potatoes, lemons, papayas, pineapples, washed and/or waxed fruit comes into the colour sorter scanner, separated into individual container for each fruit and weighted, the greater than 12 size breaks and 5 colour separation allows sorting into up to 48 selection standards, with automatic packing and completely accurate grading. The food machinery corporation system used an electronic scanning and a central control unit also receiving weight and size data and steering the fruit (in individual cups) towards a packing line at a speed of 300 cups/lane/min. The Komen and Kuin Engg. BV colour sorter which can be installed independently of any existing system, with capacity 400-1000 kg/h, depending on the product (cherries, peeled, carrots, potatoes, almonds, mushrooms, silverskin onions, pommes fruites, olivers).

Kodaira (1982) described a fruit and vegetables sorter with a video sensor. The system is mainly composed of a colour sensor, which differentiates the colour of materials, the television camera, which differentiates shape and size of material and mechanical instruments for classification of materials and for calculation control.

Nahir and Ronen (1986) introduced tomato grading by impact force response. Some theoretical consideration based on Newton's laws of motion was presented, a mathematical model for tomatoes at time of impact was discussed and solutions for measurements and grading error evaluations were proposed. A mechanical separation system (conveyor, measuring impact or separating mechanism, data processing section) indicated that the impact force response method was equal or superior to conventional methods for grading tomatoes in terms of weight, stiffness and colour.

Barresi and Blandini (1988) developed automatic citrus grading devices. An automatic machine grades oranges in real time, according to quality and appearance by optical methods. Laboratory and field trials results suggested that a reduction of upto 70 per cent workers in citrus packhouses was possible.

Delwiche *et al.* (1989) developed a single lane firmness sorting system, which conveyed fruit horizontally at constant speed (76.6 cm/sec) and caused them to impact on a rigid surface. Approximately 74 per cent of the peaches were sorted into correct firmness range.

## 2.5 Mango Graders Developed in India

Various types of graders developed in India at various places for grading the fruit. The review of the above grader is given by Dr. B. Ranganna, Professor and Research Engineer, GKVK, Bangalore.

### 2.5.1 Mango grader, PHT scheme, UAS, Bangalore

Post harvest scheme developed mango grader (Anonymous,2002). The separation of fruits is achieved based on the width and breadth of the mango fruit (Fig. 2.1). The main components of the grader are frame, feed hopper, grading section, collection unit and power transmission system. Four grades of fruit could be obtained with average size as Grade I > 100 mm, Grade II 85 – 100 mm, Grade III 65-85 mm and Grade IV < 65 mm. The grader required 1.5 hp electric motor to drive the grader.

### 2.5.2 Mango grader, IIHR, Bangalore

Mandhar and Kumaran at the Indian Institute of Horticultural Research, Bangalore developed a mango grader (Anon., 2002). This grader achieved separation by the rolling of mangoes around the axis of the minimum mass inertia (Fig. 2.2). Mangoes could be graded into three categories with the help of collecting chutes. Three grades are separated based on the opening size and the fourth grade consisted of overflow mangoes. Mangoes can be graded according to their dimensions. But grade four yielded a mixed lot of grade three and larger size mangoes due to some overrunning from the grade three slots. So it is found necessary to pass this lot once again through the grader.

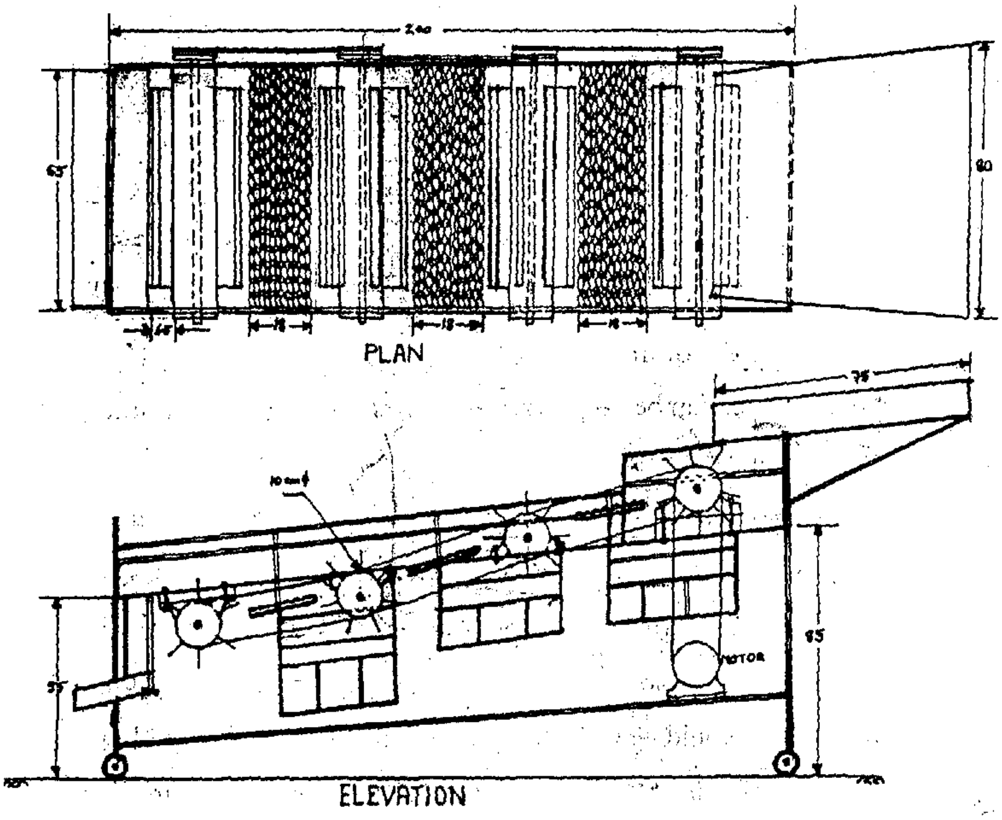


Fig. 2.1 Design and development of Mango grader, PHT Scheme, UAS, Bangalore.

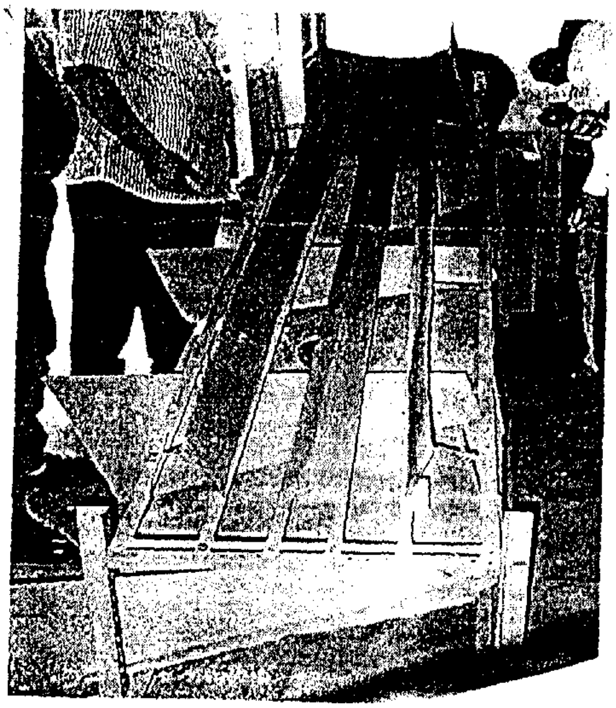

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Fig. 2.2 Design of Mango grader, IIHR, Bangalore.

### 2.5.3 Differential speed V- belt type mango grader

Pandey developed differential speed V- belt type of mango grader (Fig. 2.3). The grading is accomplished on basis of physical dimensions of mango (Anon., 2002). The mangoes are graded into according to size and gets collected in the respective collection chute as they are moved on the graded section. Testing of the grader was done with mixed variety of mango and Dasharay variety of mango. The speed of the grader shaft was kept at 20, 25, 30, 35 and 40 rpm for testing. The result showed that a maximum separation efficiency of 81.18 per cent occurred for mixed variety mangoes and 85.39 per cent for Dasharay mangoes at a grader shaft speed of 25 rpm and a feed rate of 7 and 7.5 q/hr respectively.

### 2.5.4 GKVK fruit grader, Bangalore

Department of Agril. Engg., GKVK, Bangalore developed GKVK fruit grader (Anon, 2002). The separation is achieved on the basis of size. The grading assembly consists of 5 PVC pipes, having an expanding opening along the grader (Fig. 2.4). The grader section can be given varying slopes by adjusting the lower end of the frame. The grader was tested for sweet oranges and mango. For sweet oranges, the overall efficiency was found to be 87.5 per cent at the opening of 6.4 – 8.5 cm with 8 °. For mango, the overall efficiency was found 74.3 per cent at the opening of 3.5 – 6 cm with 8° and for mango, the overall efficiency was found 82.4 per cent. The combination of opening of 8.5 – 10.5 cm with 8° gave the best efficiency.

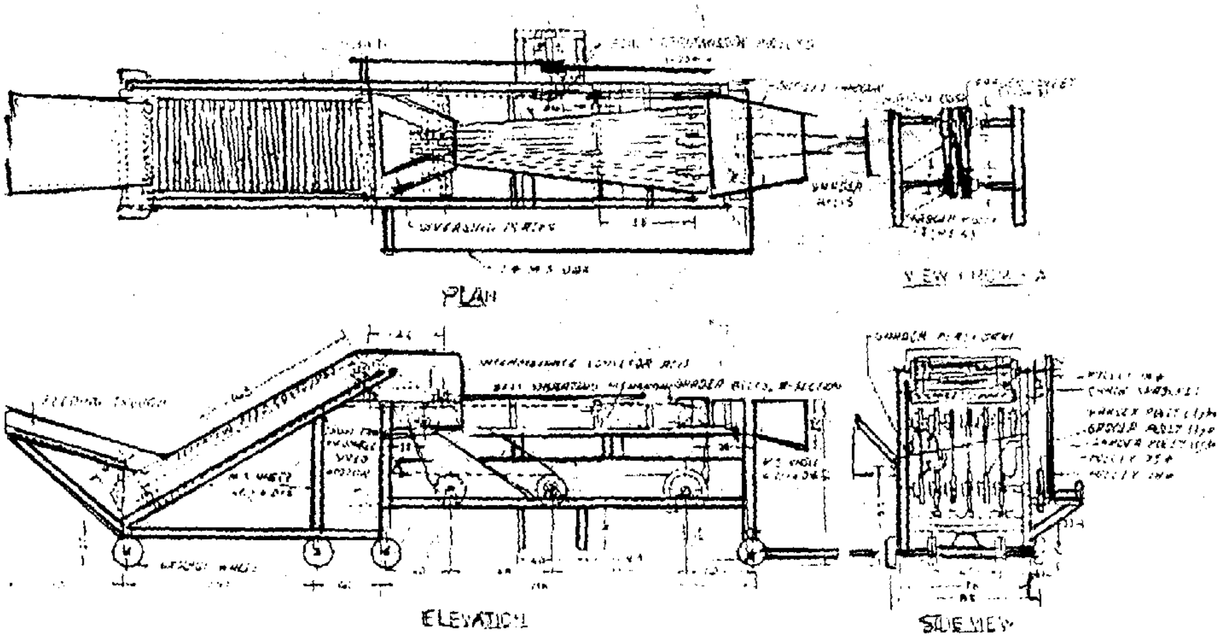


Fig. 2.3 Differential speed V- belt type Mango grader (Pantnagar).

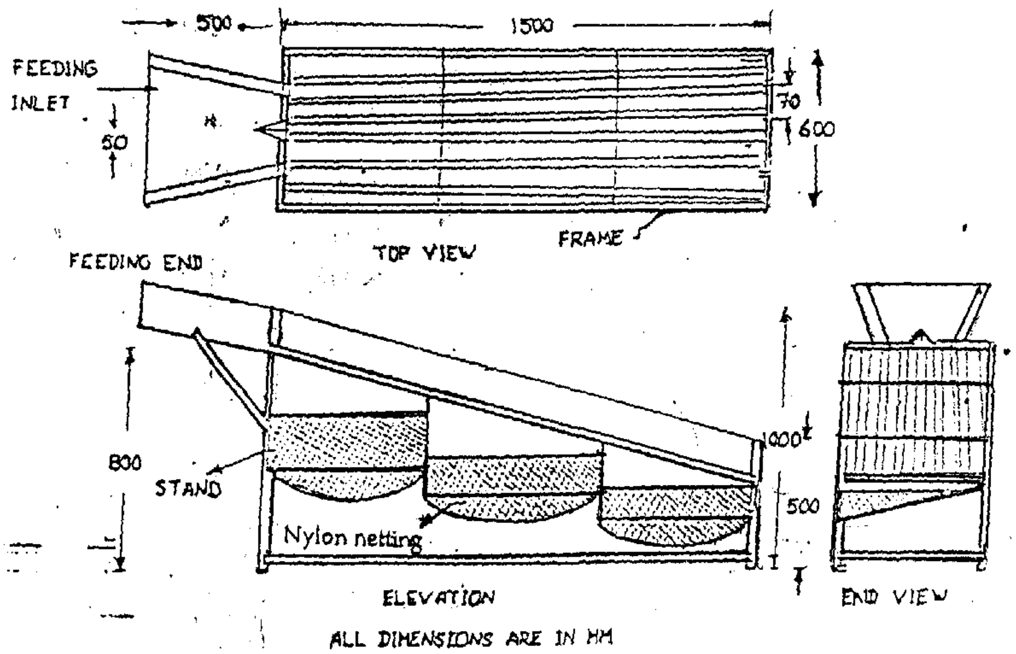


Fig. 2.4 GKVK fruit grader (Bangalore)

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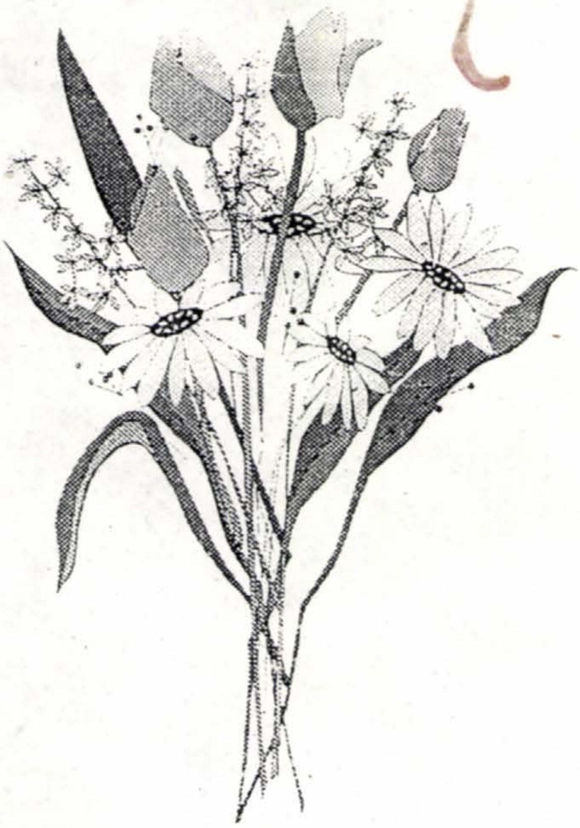


# Material and Methods

# 3. MATERIAL AND METHODS

A prototype of fruit grading machine was developed at the department of Agricultural Process Engineering, MPKV., Rahuri and tested for grading of mango fruits for its performance with respect to its capacity and efficiency.

The machine works on the principle of conveyor belt. As the name indicates, the conveyor belt the main grading part of the machine, convey as they travel from feed end to rear end. The material to be graded was carried out on and between the conveyor belt and idler. Since the distance between the conveyor belt and idler increases systematically, the smaller fruits will drop at the beginning of travel between the conveyor belt and idler and the larger fruits will be carried further upto suitable clearance between the conveyor belt and idler. As conveyor belt rotates the turning conveyor belt and idler helps the fruits to pass through the space without damage. The continuous rotation of conveyor belt gives an opportunity to individual fruits to register its maximum dimension with the spacing between the conveyor belt and idler. The design details of the grading machine is given in Fig. 3.1.

The grading machine (Conveyor belt type) consists of mainly:

i) Grading unit.
ii) Feeding unit.
iii) Collection unit.
iv) Power transmission unit and drive mechanism.

### 3.1 Grading Unit

Grading unit consists of
i) Main frame
ii) Conveyor belt with roller frame assembly
iii) Idler
iv) Flap (guide/stopper)

### 3.1.1. Main Frame

The main frame of the grading unit was fabricated in rectangular shape with an overall dimension of 1500 x 610 x 440 mm on which the all accessories are mounted (Fig. 3.2). The frame was made by using 51 x 25 mm square M. S. pipe. The grading frame was given original slope by using supporting rubber wheels. Main frame is divided in to three parts hopper supporting main frame, power transmission unit main frame and idler supporting main frame (Fig. 3.3).

### 3.1.2. Conveyor belt with roller frame assembly

Rubber belt was used as a conveyor belt. The overall length of conveyor belt for conveying is 1300 mm (Fig. 3.4). The conveyor belt and idler were mounted exactly below the feeding unit. Roller frame assembly is between the two drum rollers. Drum roller having width 260 mm with 90 mm diameter. In roller frame assembly fourteen rollers are fixed having diameter 30 mm. For free movement of rollers bushes were provided. The conveyer belt rotates over the drum roller with the help of roller frame assembly which is fixed at feed end and rear end. The conveyer belt was rotated by using drum roller and pulley arrangement

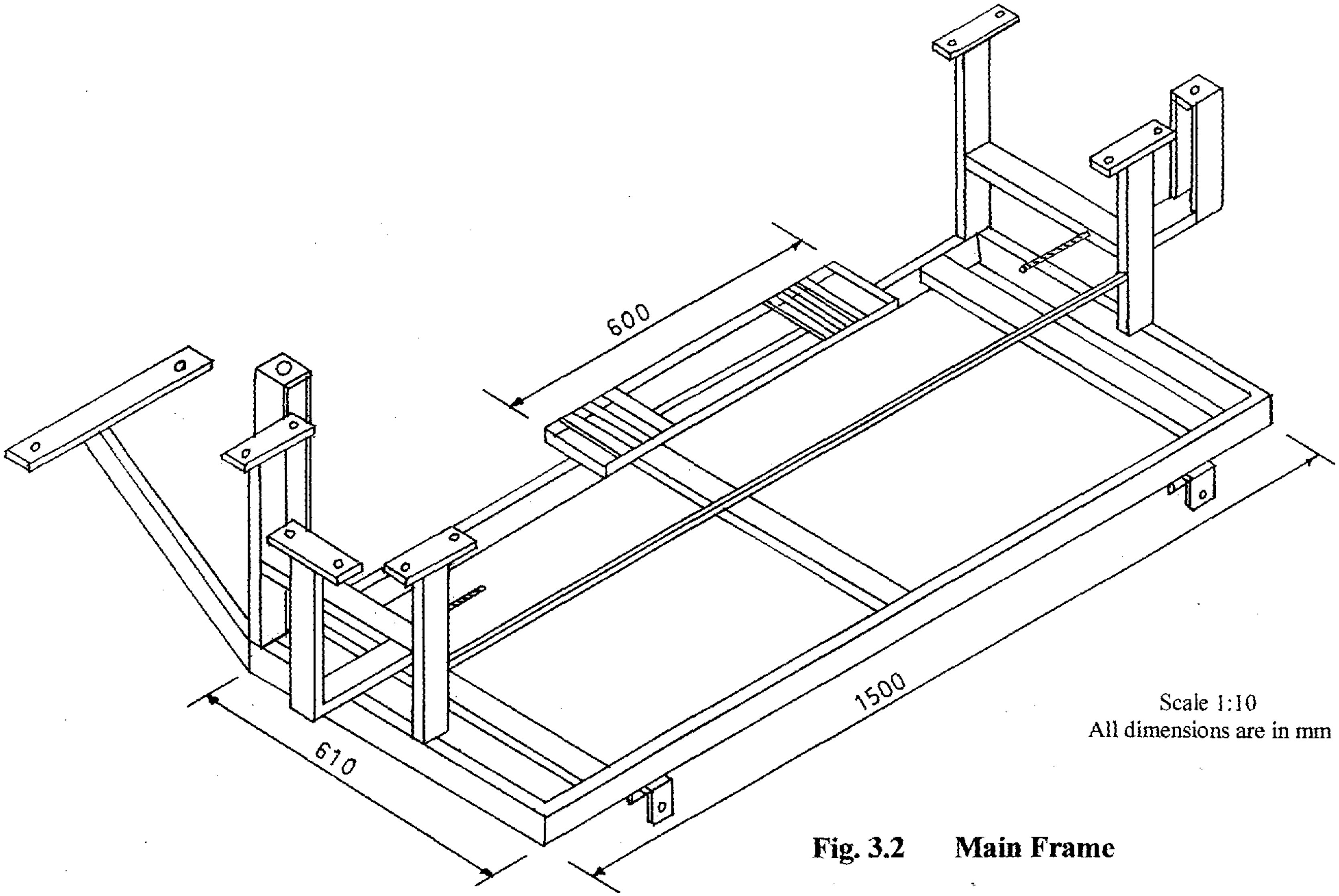



**Fig. 3.2 Main Frame**

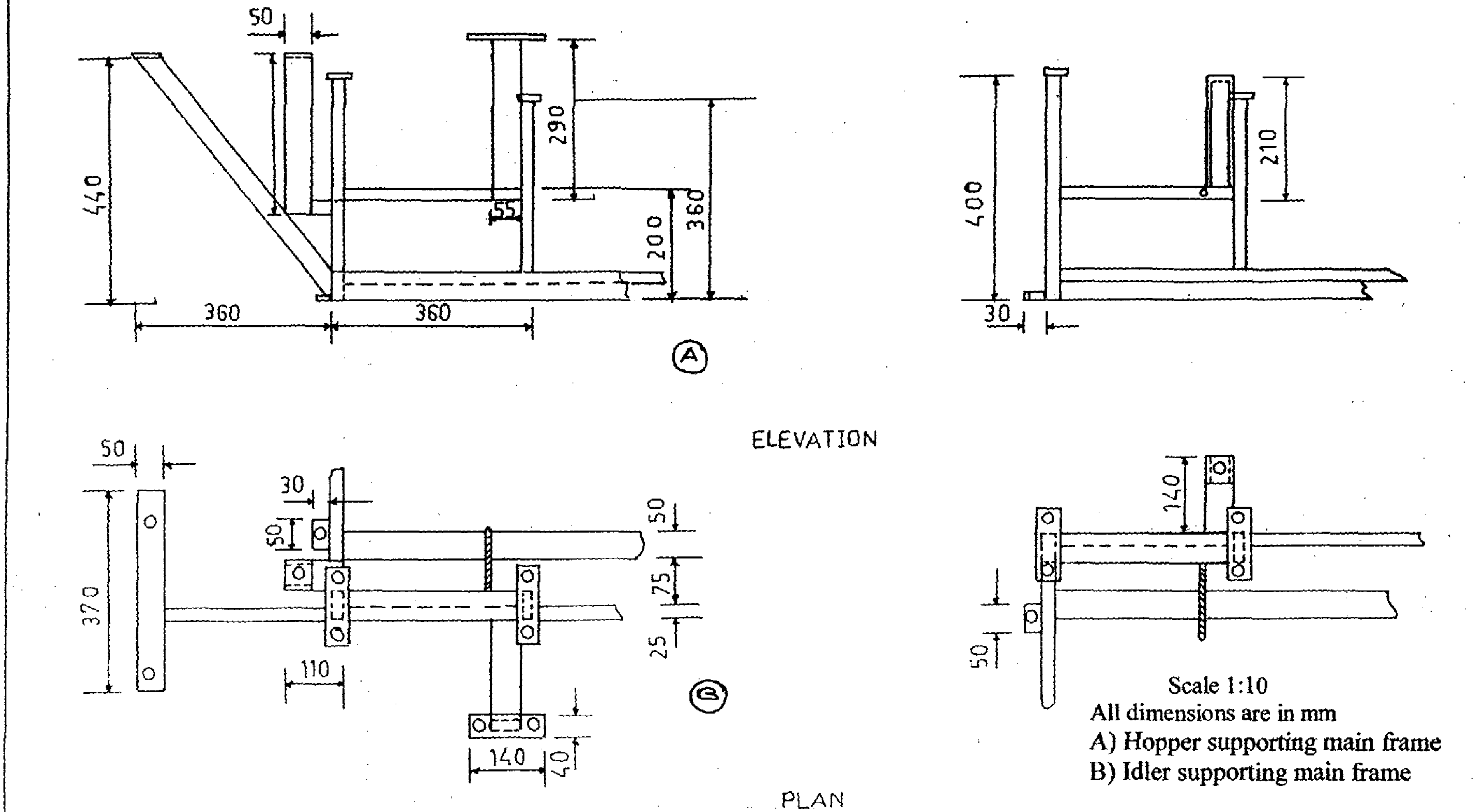



**Fig. 3.3 Hopper and Idler supporting main frame**

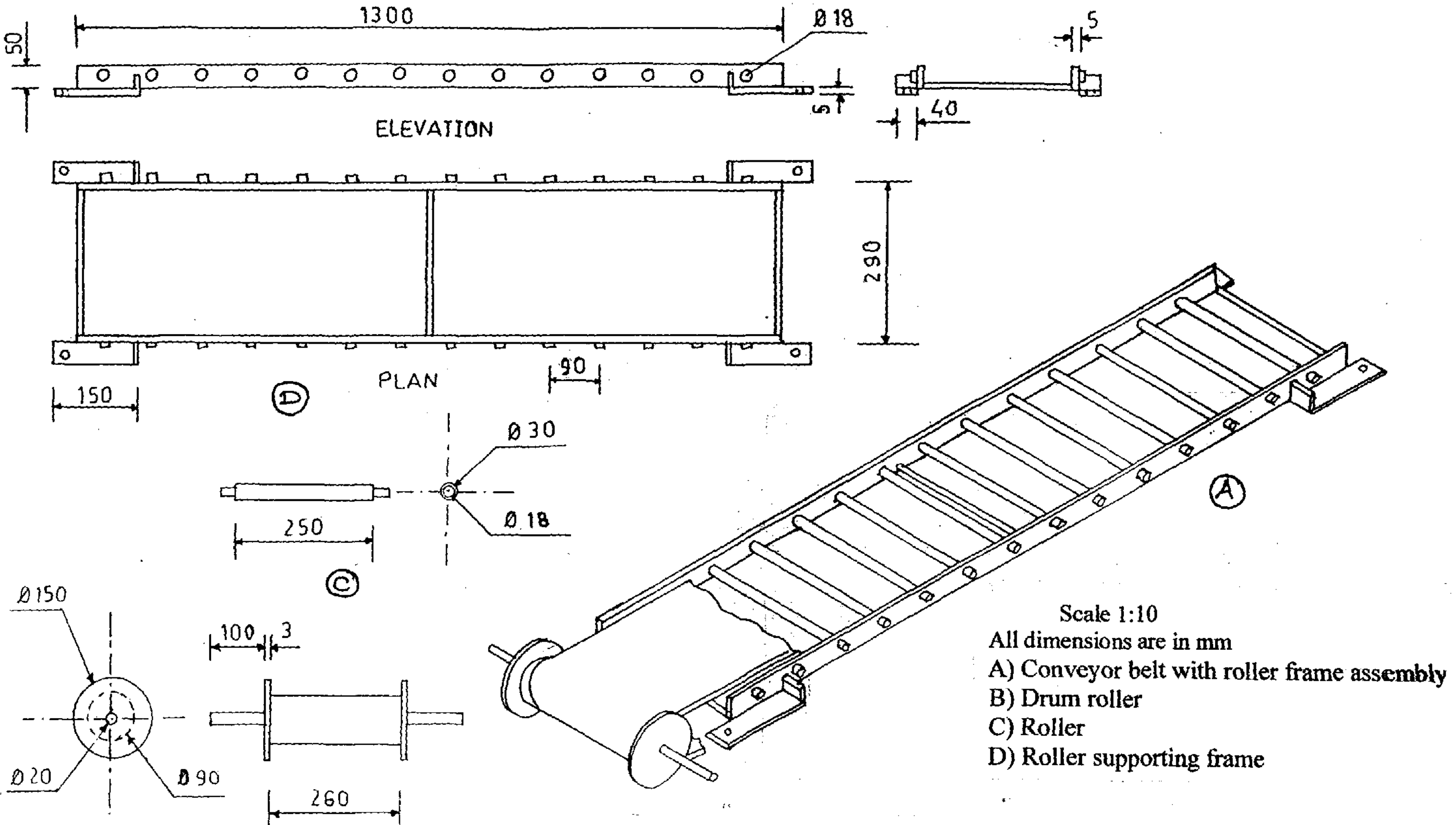



**Fig. 3.4 Grading conveyor belt**

provided at the feed end, while rear end was attached to revolving drum roller. The drum roller were connected to the power transmission unit while the other end was movable or free to rotate. The progressive increasing gap between the conveyor belt and idler was achieved by adjusting the rear end as well as feed end of the idler as per requirement. The provision was provided at the rear end to increasing the gap upto maximum size of fruit available in the grading sample.

### 3.1.3. Idler

G. I. pipe (OD = 25 mm) was used as idler. The overall length of idler was 1950 mm (Fig. 3.5). Idler was mounted on main frame with the help of pedestal at both end. Feed end and rear end of idler can be adjusted by a screw arrangement.

### 3.1.4 Flap (guide/stopper)

The flaps were made of G. I. sheet of thickness 1.2 mm. The overall dimension of flap were 200 x 130 mm, respectively. The flaps were connected to hopper at the feed end known as guide and another flap was connected at feed end and the third at rear end known as stopper was placed at the rear end to avoid dropping of fruits outside. Flaps could be adjusted as per requirement by using nut and bolt arrangements.

## 3.2 Feeding Unit

The feeding mechanism consists of a feeding hopper. The feeding hopper was fabricated by using G. I. sheet and was of trapezoidal shape (Fig. 3.6). The feeding unit/hopper was fabricated in G. I. sheet

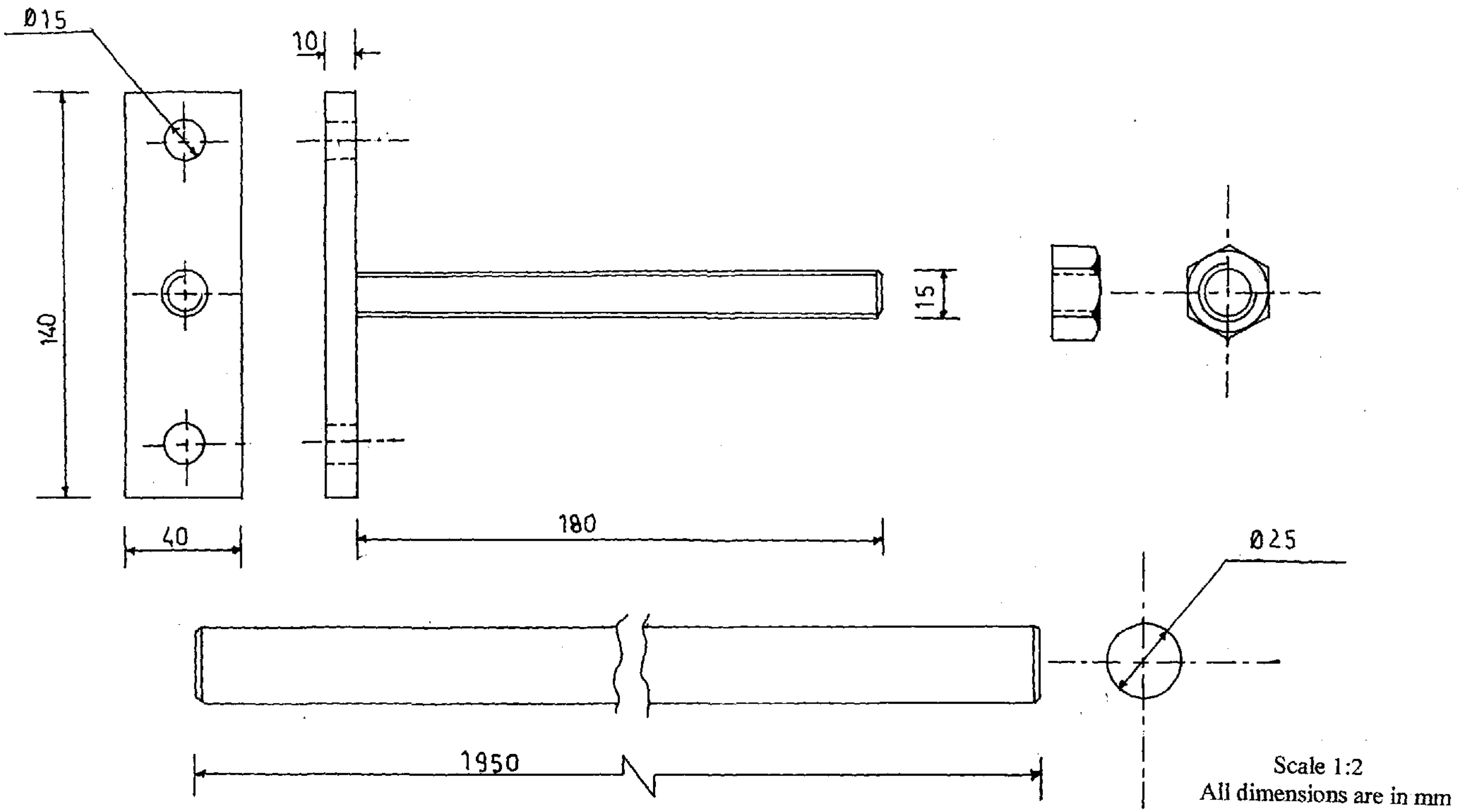



**Fig. 3.5 Idler**

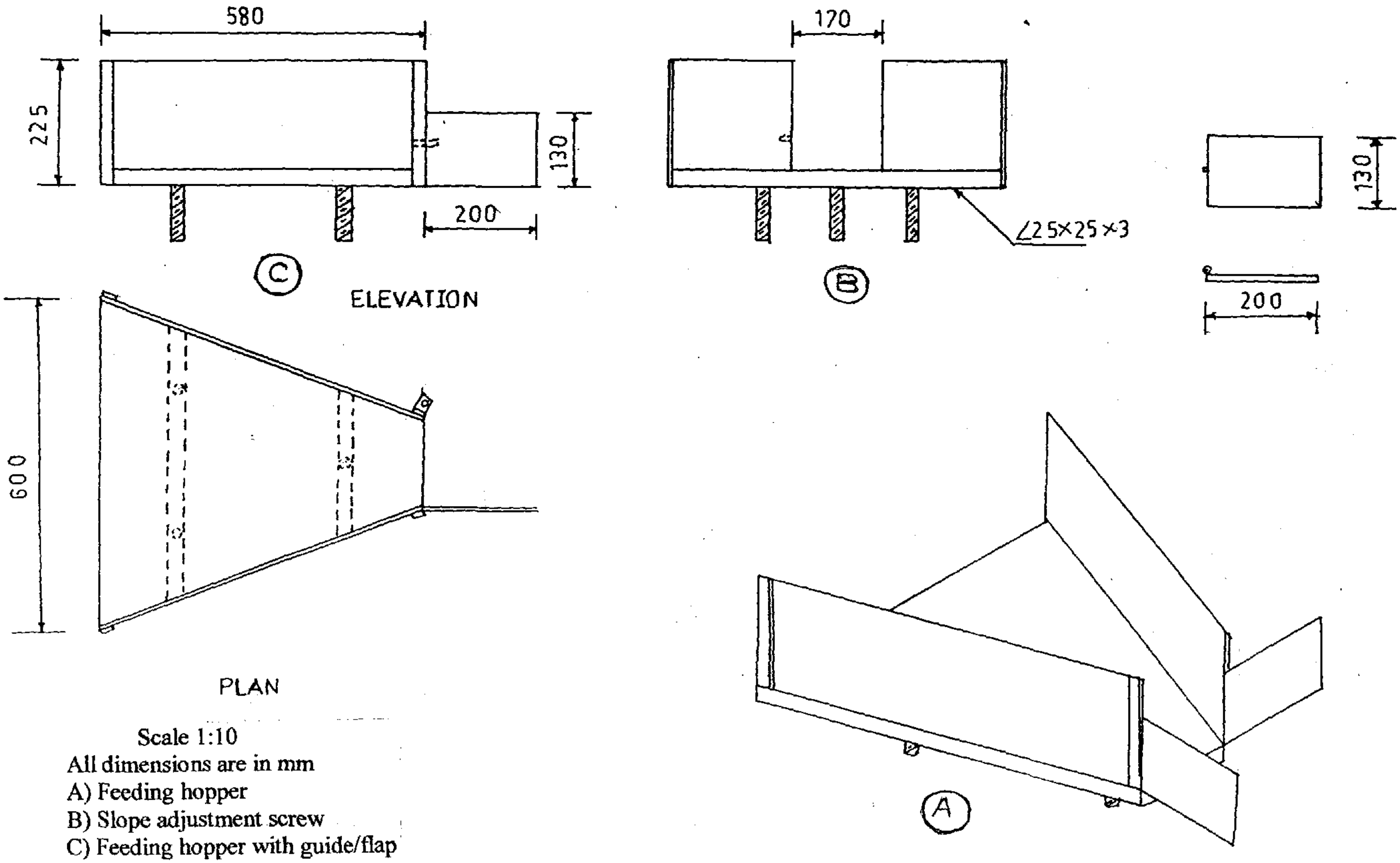



**Fig. 3.6 Feeding unit**

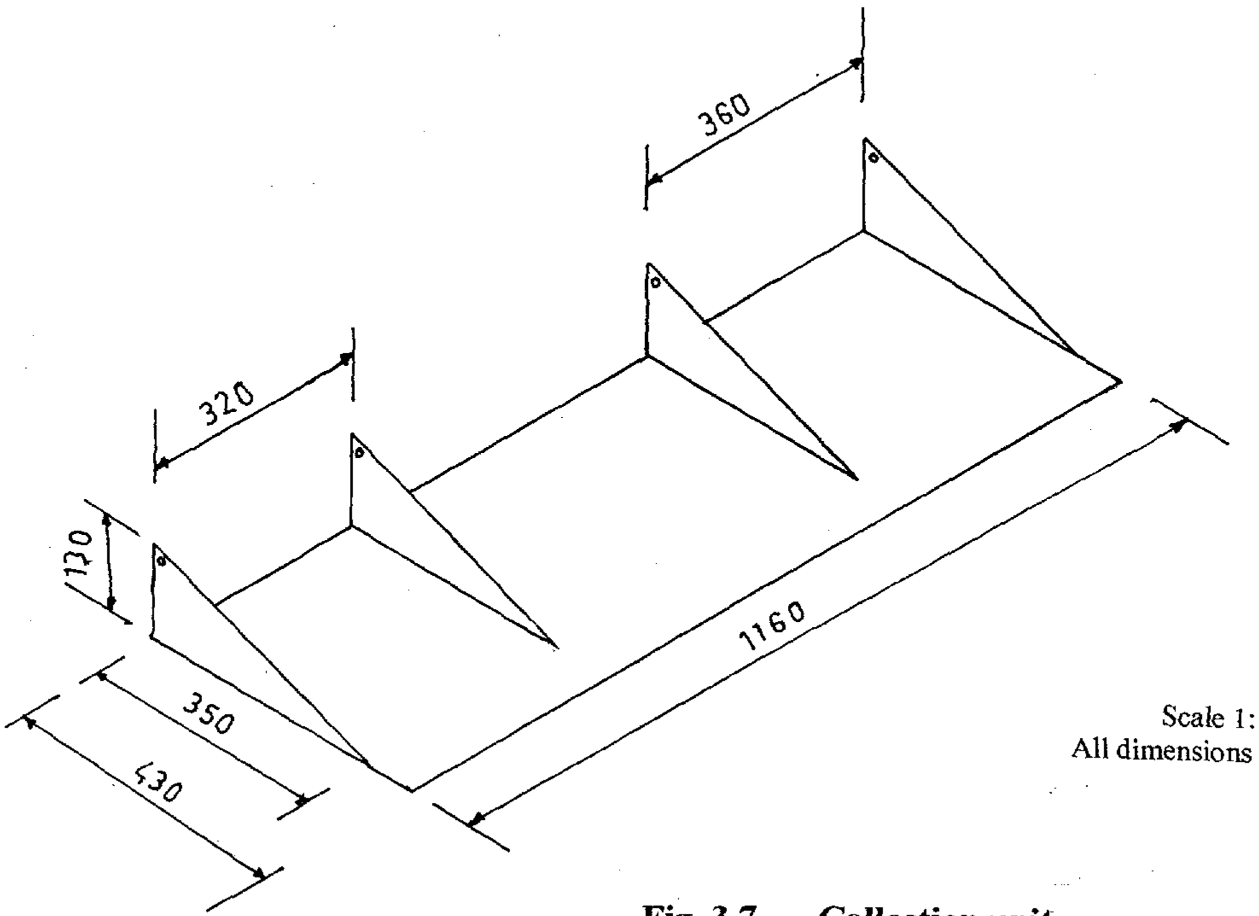
having 1.2 mm thickness. The feeding unit was mounted on the upper side of the main frame. A trapezoidal shaped sloping platform was essential to provide natural slope for easy feeding of fruits. The opening of the hopper was kept just above the conveyor belt.

The slope of the hopper can be easily adjusted by the slope adjustment screw. The opening of the hopper was such that only single fruits will come on the conveyor belt . The overall dimensions of the feeding unit were 580 mm x 600 mm x 225 mm. A felt cloth (i.e. Hotlone) was fixed over the hopper acts as a cushioning material to avoid damage of fruits and bouncing of fruits.

### 3.3 Collection Unit

The increasing spacing between the conveyor belt and idler from feed end to the rear end allowed the fruits to grade into three different sizes which were dropped on collection platform. The collection platform was partitioned into three compartments, at the distance of 320 mm, 480 mm and 360 mm, respectively from feed end to the rear end (Fig. 3.7).

The collection platform was made of cloth. The collection platform was mounted on the main frame just below the conveyor belt and idler. The overall dimension of the collection platform was 1160 mm x 430 mm x 130 mm. The main function of divider or wall in the collection unit was to avoid intermixing of fruits of different grades. These dividers make the channels for the separation of fruits, when the fruits were dropped on the collection platform, these were collected on the respective channels.

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All dimensions are in mm

**Fig. 3.7 Collection unit**

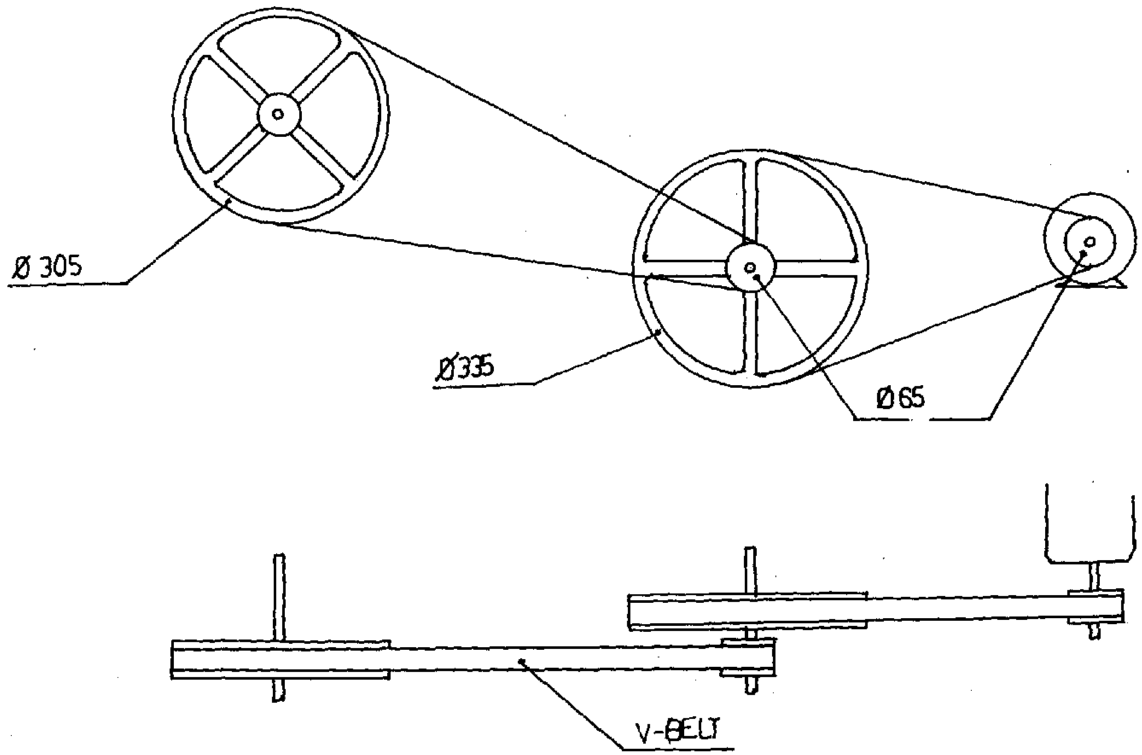
Collection unit was made of cloth so that it acts as a cushioning material and avoids bouncing and damage of fruits due to impact.

## 3.4 Power Transmission Unit and Drive Mechanism

A power transmission unit was fabricated by using M. S. angles and electric motor with belt and pulleys (Fig. 3.8). The power transmission unit could be divided into two parts. Drum roller-pulley arrangement and speed reduction unit. One-hp single phase electric motor was used as the power unit.

The two drum roller (OD= 90 mm and width 260 mm) were fitted on the main frame by using bearing pedestal and the conveyor belt was mounted on the roller. The drum roller was made up of G. I. material. These drum roller were rotated by means of pulley rotated by pulley mounted on same shaft.

The conveyor belt was driven by 1-hp single-phase electric motor through drum roller-pulley arrangement. Speed reduction required was achieved by using two stage reduction. The pulley, which rotates the drum roller, made replaceable. Thus changing only this pulley, three speed reduction operation was performed. The grading machine was operated at the speed of 105 rpm, 63 rpm and 45 rpm by using 152 mm, 254 mm and 355 mm pulleys, respectively. The motor was placed on the sliding platform in order to achieve the belt tightness as per requirement. The tilting arrangement was designed on the ground wheel (Fig. 3.9).

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All dimensions are in mm

**Fig. 3.8 Power transmission unit**

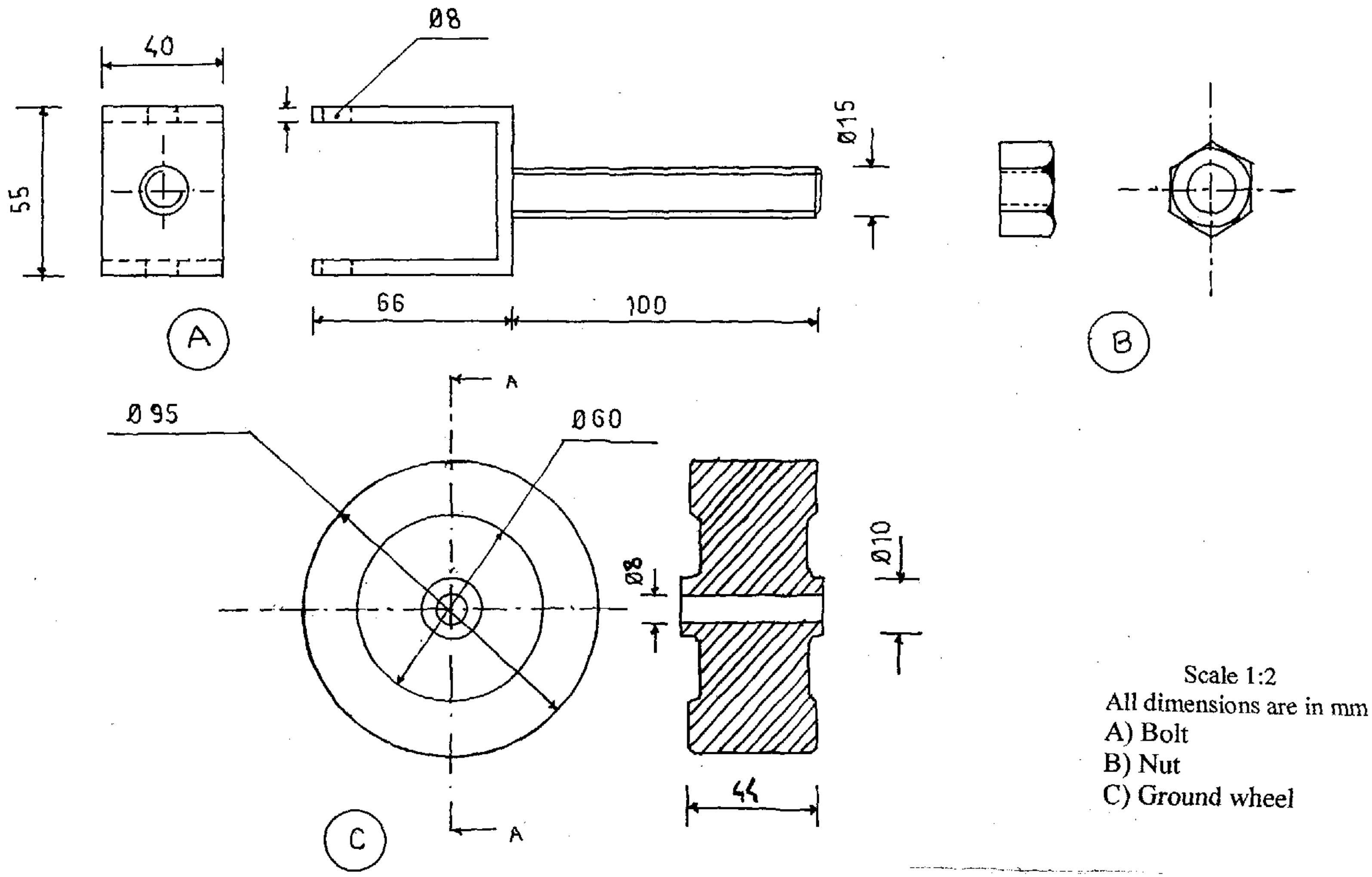


**Fig. 3.9 Tilting adjustment device**

### 3.5 Experimental variables

The following parameters were considered for the evaluation of the performance of the grader:

i) Speed of conveyor belt (105, 63 and 45 rpm)

ii) Inclination of conveyor belt with roller frame assembly (10 , 15 and $19^0$)

iii) Gap between the conveyor belt and idler ( 53-95, 57-99, 61-103 mm)

### 3.6. Grading Material

Mango (var. Alphanso) was used as a grading material for testing the performance of the machine. It was graded into three size grades at every combination of speed of conveyor belt, inclination of conveyor belt with roller frame assembly and gap between the conveyor belt and idler. Thus, in all twenty seven combination of machine parameters were tested. Three gap ranges tested for mango fruits were as given below.

| | Grade No. | Gap Range (mm) |
|---|---|---|
| $G_1$ (53- 95 mm) | $Gr_3$ | 53 - 64 |
| | $Gr_2$ | 64-83 |
| | $Gr_1$ | 86-95 |
| $G_2$ (57-99 mm) | $Gr_3$ | 57-66 |
| | $Gr_2$ | 66-86 |
| | $Gr_1$ | 86-99 |
| $G_3$ (61-103 mm) | $Gr_3$ | 61-70 |
| | $Gr_2$ | 70-88 |
| | $Gr_1$ | 88-103 |

### 3.7 Experimental Procedure

Engineering properties of fruits plays an important role in designing the equipments which are used post harvest operations. Shape and size are important parameters which govern design of graders. Size and sphericity is calculated by using following equations (Mohsenin, N. N. 1970).

#### 3.7.1 Size

It is the geometric mean of the three dimensions vs. length, breadth and thickness.

$$\text{Size} = (abc)^{1/3}$$

Where,

a = Major diameter, b= Cross diameter and c = minor diameter

#### 3.7.2 Sphericity

Isoperimetric property of sphere expresses shape factor of an object.

$$\text{Sphericity} = \frac{\text{Geometric mean diameter}}{\text{Major diameter}} = \frac{(abc)^{1/3}}{a}$$

#### 3.7.3 Unit weight

Weight of fruits is measured by using electronic weight balance.

### 3.8 Experimental Design

The grading machine was operated by keeping two parameters constant at a time and changing third one. Thus giving twenty seven combinations of machine parameters. Three different speeds of conveyor belt were combined with three different gaps of conveyor belt and idler and three different angle of inclination of the conveyor belt The time required for grading and weight of mango fruit at every combination were recorded and accordingly capacity was calculated.

For grading efficiency, the sample was taken in the ratio of 1:2:1 (Grade I: Grade II: Grade III) for different combination of machine parameters. By comparing, mean diameter of the fruit collected in any grade to that grade gap range, size of fruits under or over the gap range was decided. The procedure was replicated three times and average grading efficiency was calculated. The grading efficiency is calculated by using following equation (Nevkar, G. S. 1990).

$$Es = \frac{Wt - (Wu + Wo)}{Wt} \times 100 \qquad ...(3.1)$$

Where,

ES = Percentage grading efficiency of particular grade (%).

Wt = Total weight of the representative sample (gm).

Wu = Weight of under size fruits in that grade (gm).

Wo = Weight of over size fruits in that grade (gm).

The performance index of the conveyor belt type grader was calculated by using the following equation (Baldawa, S. S. and Mali, P. Y. 1993).

$$P.I. = \frac{\text{Efficiency x Capacity}}{\text{Unit cost of operation}} \qquad ....(3.2)$$

Where, Efficiency in fraction

Capacity in tonne/hr

Unit cost of operation in Rs./tonne

### 3.9 Statistical Analysis

The data was analyzed for the statistical significance of the treatment. Factorial Completely Randomised Design (FCRD-3) was used to test the significance (Nigam and Gupta, 1979). There are three factors for each of parameter tested as given below

Factor 1: Speed of conveyor belt

Levels = 3

$S_1$ = 105 rpm, $S_2$ = 63 rpm, $S_3$ = 45 rpm

Factor 2: Inclination of conveyor belt and idler

Levels = 3

$I_1$= 10°, $I_2$= 15°, $I_3$= 19°

Factor 3: Gap between the conveyor belt and idler

Levels = 3

$G_1$= 53 – 95 mm, $G_2$= 57 – 99 mm and $G_3$ = 61 –103 mm

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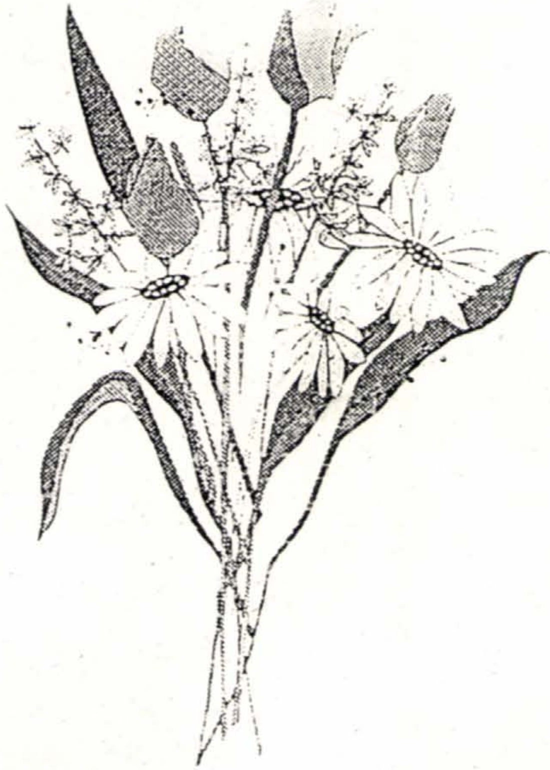

# Results and Discussion

# 4. RESULTS AND DISCUSSION

A mechanical mango fruit grader was designed developed and fabricated in the Department of Agricultural Process Engineering. The engineering properties of mango fruits *viz.*, dimension (major, intermediate and minor), sphericity, size and specific weight were determined and discussed in Section 4.1. The details of design, development and fabrication of the machine are presented and discussed in Section 4.2. Effect of machine parameters *viz.*, speed of conveyor belt, inclination of conveyor belt with roller frame assembly and gap between the conveyor belt and idler on capacity was studied and discussed in Section 4.3. The effect of machine parameters on its efficiency was calculated. The results are given and discussed in Section 4.4. The performance of the fruit grader was evaluated and discussed in Section 4.5. The cost economics of grading was determined and the results are discussed in Section 4.6

## 4.1 Some Engineering Properties of Mango Fruits

The data on engineering properties of mango fruit is tabulated in Table A.1(Appendix A). Eighty fruits were taken for measurement of dimensions (major, intermediate and minor), sphericity, size and specific weight. These fruit were categorised into three different grades based on size and weight and data is given in Table A.2 (Appendix A). Based on these results the range and average values of each property of Grade I, Grade II and Grade III fruits were determined and given in Table 4.1. The size, sphericity and unit weight were ranged between 46.2 to 94.7 mm,

**Table 4.1 Some engineering properties of mango fruits**

| Properties | Grade I | | | Grade II | | | Grade III | | |
|---|---|---|---|---|---|---|---|---|---|
| | Range | Average | S. D.(±) | Range | Average | S. D.(±) | Range | Average | S. D.(±) |
| Dimensions (axis) | | | | | | | | | |
| Major (a), mm | 89.4-106.3 | 94.9 | 4.36 | 76.3-88.6 | 84.57 | 2.99 | 52.8-79 | 69.03 | 7.37 |
| Intermediate (b), mm | 84.5-103.4 | 91.02 | 5.49 | 69.1-85.9 | 80.21 | 4.27 | 49.5-72.5 | 64.11 | 7.75 |
| Minor (c), mm | 64.2-77.3 | 73.36 | 3.77 | 60.4-76.6 | 66.88 | 3.43 | 37.8-64.4 | 53.18 | 6.56 |
| Size, mm | 80.9-94.7 | 85.93 | 3.62 | 70.7-81.1 | 76.73 | 2.97 | 46.2-71.8 | 62.02 | 6.82 |
| Sphericity, % | 84-93 | 90 | 2.22 | 87-94 | 90.78 | 1.76 | 82-95 | 89.16 | 2.90 |
| Unit Weight, g | 260-394 | 300.00 | 38.19 | 176-246 | 216.40 | 22.13 | 48-172 | 124.86 | 35.11 |

82 to 95 % and 48 to 394 g for all the grades respectively (Table A.1-Appendix A). The size, sphericity and unit weight for Grade I varied between 80.9 to 94.7 mm, 84 to 93 % and 260 to 394 g, respectively for Grade II varied between 70.7 to 81.1 mm, 87 to 94 % and 176 to 246 g respectively and 46.2 to 71.8 mm, 82 to 95 % and 48 to 172 g respectively for Grade III.

The average size found was 85.93 mm, 76.73 mm and 62.02 mm for Grade I, Grade II and Grade III fruits, respectively. The average sphericity of 90 %, 90.78 % and 89.16 % were found in case of Grade I, Grade II and Grade III fruits, respectively. The average unit weight of Grade I, Grade II and Grade III fruits were 300 g, 216.40 g and 124.86 g, respectively. The fruits in Grade I, Grade II and Grade III were taken as large, medium and small size fruits.

## 4.2 Design, Development and Fabrication of Mango Fruit Grader

A prototype of mango fruit grader was designed and developed in the Department of Agricultural Process Engineering MPKV, Rahuri. The machine consisted of main frame, grading conveyor belt, feeding unit, collection unit, power transmission unit frame, tilting adjustment device.

### 4.2.1 Main frame

The main frame of the machine was fabricated rectangular in shape. The overall dimensions of the main frame kept were 1500 mm x

610 mm x 440 mm. The frame was designed by using 51 x 25 mm M. S. square pipe.

Main frame is divided in to three parts hopper supporting main frame, power transmission unit main frame and idler supporting main frame. Hopper supporting main frame was designed at feed end. Its main function is to support the hopper whereas idler supporting main frame is at the rear end and its main function to support the idler .

**4.2.2 Feeding unit**

The feeding hopper was designed and is given trapezoidal in shape for fruit conveying. The feeding unit was made of 20 gauge G. I. Sheet. The overall dimensions of feeding hopper were 580 mm x 600 mm x 225 mm.

**4.2.3 Collection unit**

The collection unit was designed for collection of fruits. The collection platform was made up of cloth. The overall dimensions of the collection unit are 1160 mm x 430 mm x 130 mm.

**4.2.4 Idler**

Mild steel pipe was used for idler. The overall length of idler was 1950 mm. The outer diameter of idler was 25 mm. Pedestal bearing (25 mm $\phi$) was used for idler shaft.

**4.2.5 Grading conveyor belt with roller frame assembly**

Rubber belt was used for grading conveyor belt. The overall length of the grading conveyor belt was 2700 mm. The width of the conveyor belt was 250 mm. Roller frame assembly was made up by M. S. The dimension of roller frame assembly was 1300 mm x 290 mm. Roller frame assembly was placed between the drum rollers. Two drum rollers having width 260 mm and 90 mm diameter. Fourteen rollers having width 250 mm and diameter 30 mm was fitted in the roller frame assembly. Pedestal bearing (25 mm $\phi$) were used for the roller shaft.

### 4.2.6 Power transmission unit

The power transmission unit was designed and placed at the bottom of the main frame. To avoid accident during the grading of fruits. Speed reduction was done using two stage reduction assembly.

### 4.2.7 Tilting adjustment device

The tilting arrangement for the belt was designed and fixed on the ground wheel. The overall dimensions of the wheel stud were 166 mm x 50 mm .

### 4.2.8 Cost of mango grader

Schedule of quantities and rates of materials are given in Table B.1 (Appendix B). The material required for fabrication of grader costedRs 8177.5/-. Considering the fabrication cost (30 %) i.e. Rs. 2453.25/-, total cost of machine was Rs. 10,630/-. The total cost of machine including electric motor works out to be Rs. 15,430/-.

## 4.3 Effect of Machine Parameters on Capacity

The data on effect of machine parameters on the capacity of grader is tabulated and given in Table 4.2. The data shows that the capacity changed with respect to the speed of conveyor belt, inclination of conveyor belt with roller frame assembly and gap between conveyor belt and idler. For all machine parameters statistical analysis was done at 5 % level of significance (Table 4.3). The capacity varied between 597 to 1222 kg/hr for all the machine parameter combinations. The maximum capacity was found in case of $S_1I_3G_2$ ($S_1$ = 105 rpm, $I_3$ = 19 and $G_2$ = 57-99 mm). Whereas the minimum capacity was observed in case of $S_3I_1G_1$ ($S_3$ = 45 rpm, $I_1$ = 10° and $G_1$ = 53-95 mm).

The data on effect of inclination and gap between the conveyor belt and idler on capacity at various speeds is plotted and shown in Fig. 4.1. Each point represents average of three replications. Figure 4.1 (a) through Fig. 4.1 (c) shows that the capacity increased with increasing inclinations of conveyor belt with roller frame assembly and speed of conveyor belt for gap $G_1$ and $G_2$ and then further it is decreased for all speeds. The capacity also increased with increase in speed of conveyor belt. The maximum capacity was seen for speed $S_1$ (105 rpm) whereas the minimum capacity was observed for speed $S_3$ (45 rpm). The maximum capacity observed at inclination $I_3$ (19°) whereas the minimum capacity was obtained at inclination $I_1$ (10°), [Fig. 4.2 (a) to Fig. 4.2 (c)]. Figure 4.3 (a) to Fig. 4.3 (c) shows that the capacity increases with increase in the inclination and speed of conveyor belt for all gaps. Capacity increased with increasing the gap between the conveyor belt. The maximum capacity was found at gap $G_2$ ( 57mm to 99 mm) whereas the minimum capacity was found at gap $G_1$ (53 mm to 95 mm). The results of capacity were found in agreement with Nevkar (1990) and Patil and Patil (2002).

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**Table 4.2. Effect of machine parameters on capacity and efficiency**

| Roller speed (s ) rpm | Inclination (I) degree | Gap between Conveyor Belt (G), cm | Capacity, (kg/hr) | Efficiency (%) |
|---|---|---|---|---|
| $S_1$ | $I_1$ | $G_1$ | 766 | 51.02 |
| $S_1$ | $I_1$ | $G_2$ | 1161 | 67.08 |
| $S_1$ | $I_1$ | $G_3$ | 930 | 7.37 |
| $S_1$ | $I_2$ | $G_1$ | 814 | 52.82 |
| $S_1$ | $I_2$ | $G_2$ | 1193 | 71.24 |
| $S_1$ | $I_2$ | $G_3$ | 1036 | 62.31 |
| $S_1$ | $I_3$ | $G_1$ | 911 | 53.98 |
| $S_1$ | $I_3$ | $G_2$ | 1222 | 73.46 |
| $S_1$ | $I_3$ | $G_3$ | 1158 | 65.30 |
| $S_2$ | $I_1$ | $G_1$ | 618 | 57.84 |
| $S_2$ | $I_1$ | $G_2$ | 761 | 71.90 |
| $S_2$ | $I_1$ | $G_3$ | 652 | 62.47 |
| $S_2$ | $I_2$ | $G_1$ | 650 | 61.63 |
| $S_2$ | $I_2$ | $G_2$ | 810 | 73.88 |
| $S_2$ | $I_2$ | $G_3$ | 764 | 67.31 |
| $S_2$ | $I_3$ | $G_1$ | 738 | 66.40 |
| $S_2$ | $I_3$ | $G_2$ | 861 | 74.99 |
| $S_2$ | $I_3$ | $G_3$ | 805 | 70.24 |
| $S_3$ | $I_1$ | $G_1$ | 597 | 62.00 |
| $S_3$ | $I_1$ | $G_2$ | 695 | 72.45 |
| $S_3$ | $I_1$ | $G_3$ | 647 | 67.16 |
| $S_3$ | $I_2$ | $G_1$ | 616 | 64.99 |
| $S_3$ | $I_2$ | $G_2$ | 729 | 74.85 |
| $S_3$ | $I_2$ | $G_3$ | 658 | 68.01 |
| $S_3$ | $I_3$ | $G_1$ | 633 | 67.87 |
| $S_3$ | $I_3$ | $G_2$ | 740 | 77.00 |
| $S_3$ | $I_3$ | $G_3$ | 711 | 71.04 |

**Table 4.3.** ANOVA for capacity of grader

| Source | D. F. | S. S. | M. S. S. | $F_{cal}$ | $F_{tab}$ | Result |
|---|---|---|---|---|---|---|
| Speed (A) | 2 | 1873000 | 936400 | 441.522 | 3.17 | Significant |
| Inclination (B) | 2 | 150200 | 75110 | 35.414 | 3.17 | Significant |
| Interaction (A X B) | 4 | 23490 | 5872 | 2.769 | 2.54 | Significant |
| Gap (C) | 2 | 559200 | 279600 | 131.820 | 3.17 | Significant |
| Interaction (A X C) | 4 | 174400 | 43600 | 20.556 | 2.54 | Significant |
| Interaction (B X C) | 4 | 16170 | 4043 | 1.906 | 2.54 | N. S. |
| Interaction (A X B X C) | 8 | 13480 | 1685 | 0.794 | 2.11 | N. S. |
| Error | 54 | 114500 | 2121 | | | |
| Total | 80 | 2924000 | | | | |

| Source | S. E.(±) | C. D. at 5 % |
|---|---|---|
| Speed (A) | 8.863 | 25.19 |
| Inclination (B) | 8.863 | 25.19 |
| Gap (C) | 8.863 | 25.19 |
| Interaction (A X B) | 15.351 | 43.64 |
| Interaction (A X C) | 15.351 | 43.64 |
| Interaction (B X C) | 15.351 | 43.64 |
| Interaction (A X B X C) | 26.589 | 75.58 |

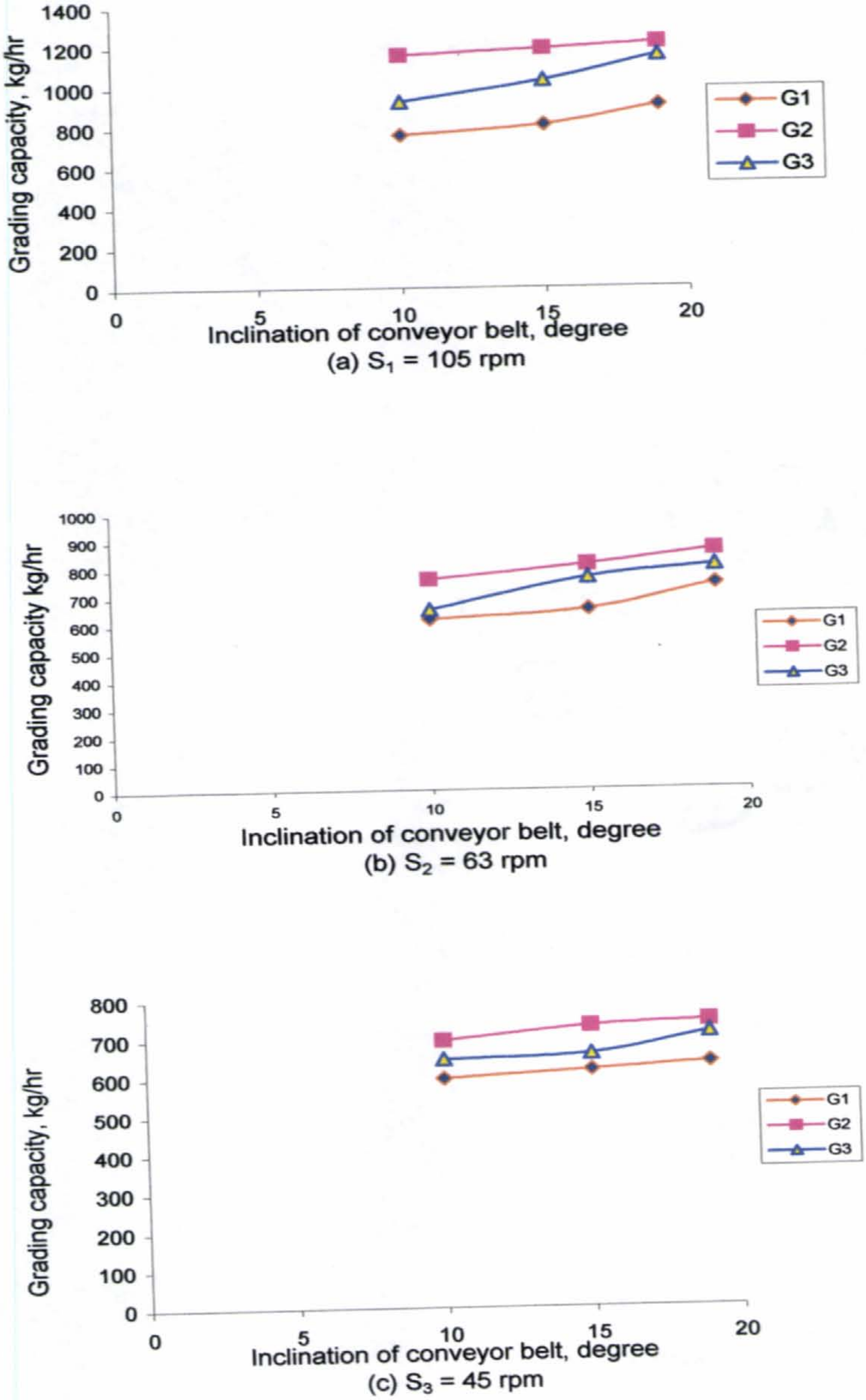
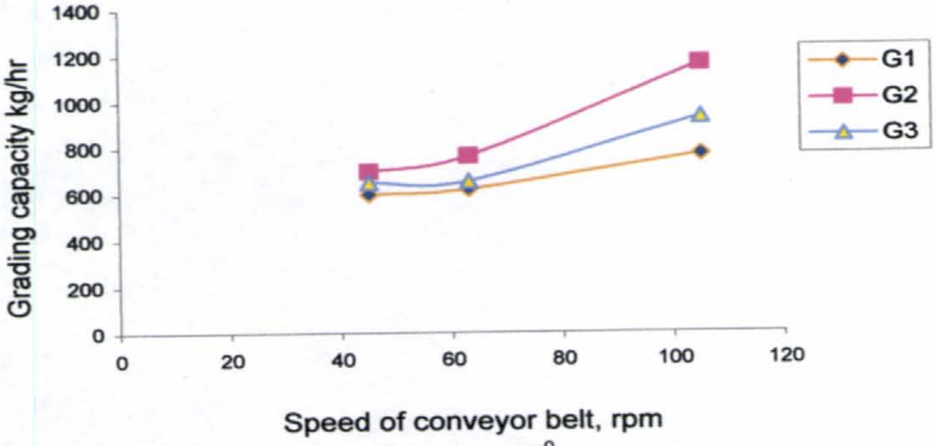
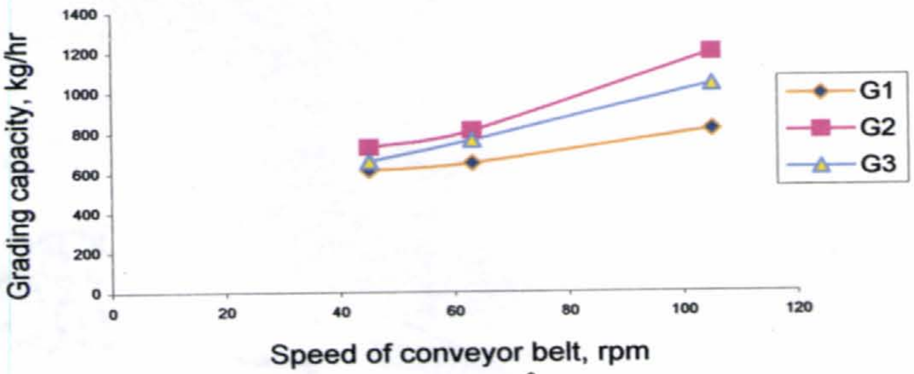


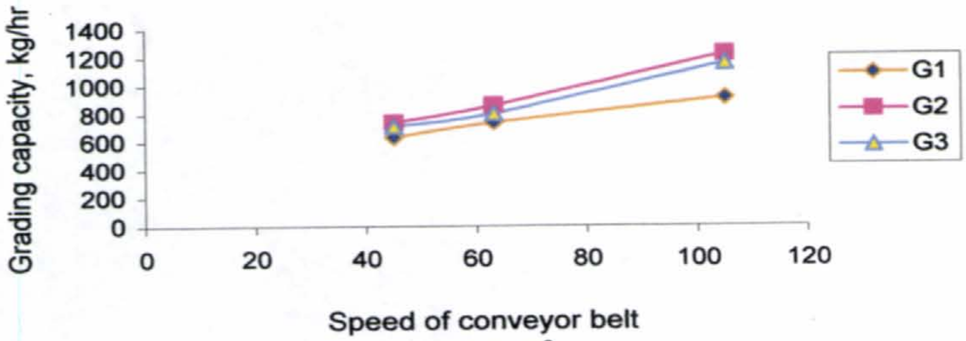

**Fig. 4.1 Effect of inclination and gap between conveyor belt and idler on capacity at various speeds**




(a) $I_1 = 10^0$

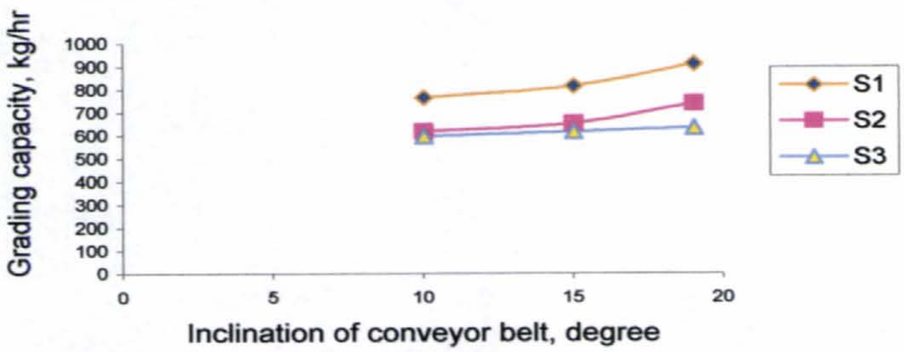



(b) $I_2 = 15^0$

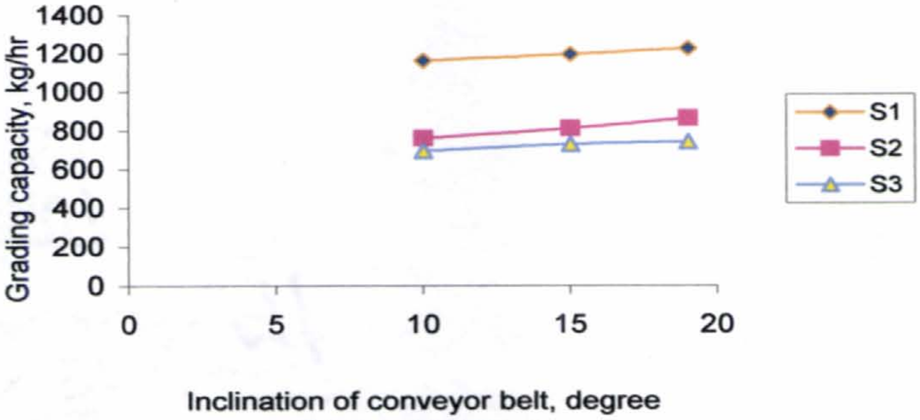



(c) $I_3 = 19^0$

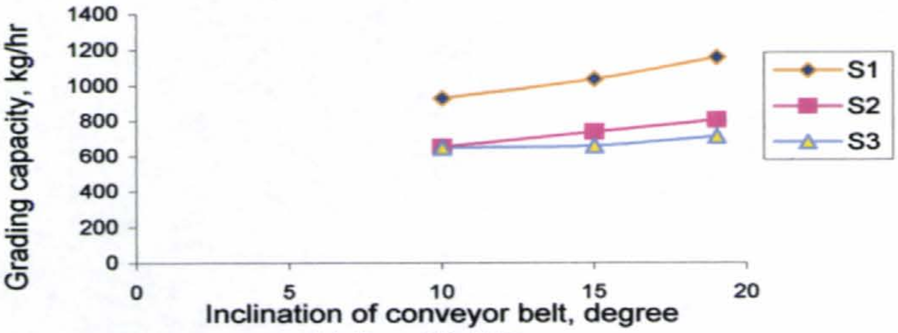
**Fig. 4.2 Effect of speed and gap between conveyor belt and idler on capacity at various inclinations.**




(a) $G_1$ = 53-95 mm




(b) $G_2$ = 57-99 mm




(c) $G_3$ = 61-103 mm

**Fig. 4.3 Effect of inclination and speed of conveyor belt and capacity a various gaps**

## 4.4 Effect of Machine Parameters on Efficiency

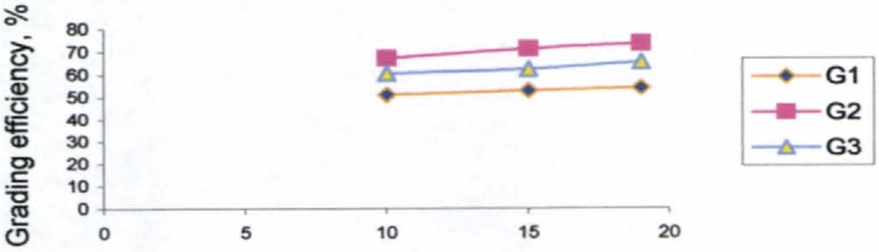
The data on the effect of machine parameters on the efficiency of grader is tabulated and given in Table 4.2. The data shows that the efficiency varies with respect to the speed of conveyor belt, inclinations of conveyor belt with roller frame assembly and gap between the conveyor belt and idler. For the machine parameters statistical analysis was done at 5% level of significance (Table 4.4). The efficiency varied between 51.02 to 77.00 % for all machine parameter combinations. The maximum efficiency was found in case of $S_3I_3G_2$ ($S_3$ = 45 rpm, $I_3$ = 19° and $G_2$ = 57 to 99 mm) and the minimum efficiency was found in case of $S_1I_1G_1$ ($S_1$ = 105 rpm, $I_1$ = 10° and $G_1$ = 53 to 95 mm). The data on inclination and gap between the conveyor belt and idler on efficiency at various speeds is plotted and shown in Fig. 4.4 (a) to Fig. 4.4 (c). The Fig. 4. 4, shows that the efficiency increased with increase the inclination and gap between the conveyor belt and idler for all speeds. The efficiency increased upto 19°inclination and 45 rpm speed of conveyor belt and gap $G_2$. Efficiency increases with decrease in speed of conveyor belt. The maximum efficiency was found in case of speed 45 rpm, whereas the minimum efficiency was obtained for speed 105 rpm.

The efficiency increased with respect to speed and gap between the conveyor belt and idler for all inclinations [Fig. 4.5 (a) through Fig. 4.5 (c)]. Efficiency increased with increasing the inclination of conveyor belt with roller frame assembly upto 19°. The maximum efficiency observed at inclination $I_3$ (19°) whereas the minimum efficiency was obtained at inclination $I_1$ (10°). Figure 4.6 shows that the efficiency increases with increase in the inclination and decrease in speed of conveyor belt for all gaps. The maximum efficiency was found at gap $G_2$ ( 57 to 99 mm) where as the minimum efficiency was found at gap $G_1$ ( 53 to 95 mm) the results of efficiency were found in agreement with Nevkar (1990) and Patil and Patil (2002).

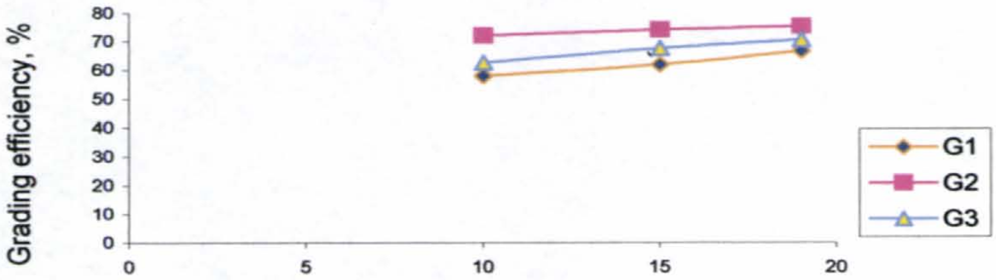
**Table 4.4** ANOVA for efficiency of grader

| Source | D. F. | S. S. | M. S. S. | $F_{cal}$ | $F_{tab}$ | Result |
|---|---|---|---|---|---|---|
| Speed (A) | 2 | 667.6 | 338.3 | 14.814 | 3.17 | Significant |
| Inclination (B) | 2 | 304.5 | 152.3 | 6.668 | 3.17 | Significant |
| Interaction (A X B) | 4 | 29.47 | 7.367 | 0.323 | 2.54 | N. S. |
| Gap (C) | 2 | 2323 | 1162 | 50.873 | 3.17 | Significant |
| Interaction (A X C) | 4 | 218.6 | 54.65 | 2.393 | 2.54 | N. S. |
| Interaction (B X C) | 4 | 159.7 | 3.992 | 0.175 | 2.54 | N. S. |
| Interaction (A X B X C) | 8 | 63.56 | 7.945 | 0.348 | 2.11 | N. S. |
| Error | 54 | 1233 | 22.84 | | | |
| Total | 80 | 4865 | | | | |

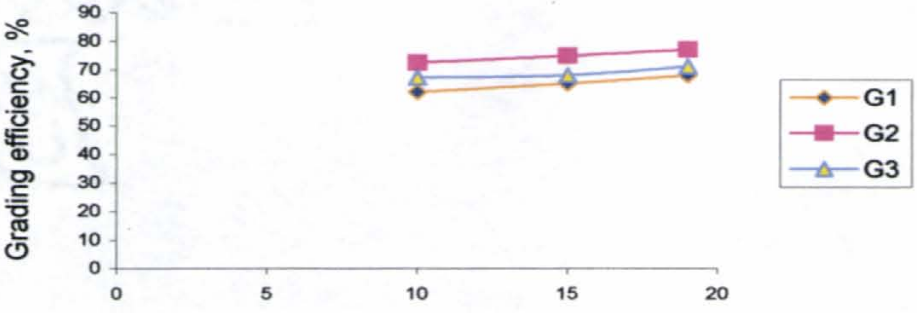
| Source | S. E.(±) | C. D. at 5 % |
|---|---|---|
| Speed (A) | 0.920 | 2.614 |
| Inclination (B) | 0.920 | 2.614 |
| Gap (C) | 0.920 | 2.614 |
| Interaction (A X B) | 1.593 | 4.528 |
| Interaction (A X C) | 1.593 | 4.528 |
| Interaction (B X C) | 1.593 | 4.528 |
| Interaction (A X B X C) | 2.760 | 7.842 |




Inclination of conveyor belt, degree
(a) $S_1$=105 rpm

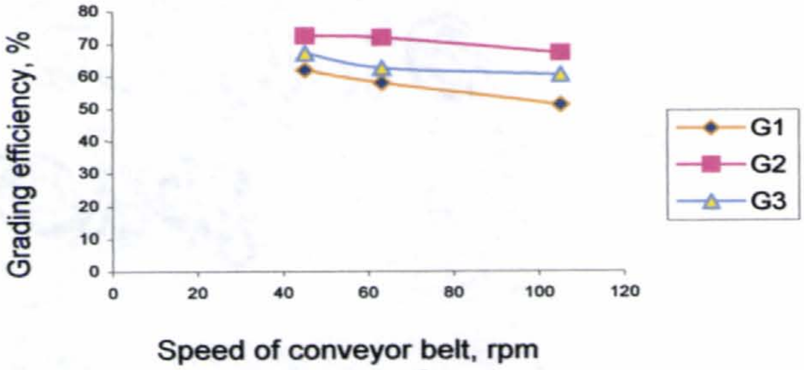



Inclination of conveyor belt, degree
(b) $S_2$ = 63 rpm

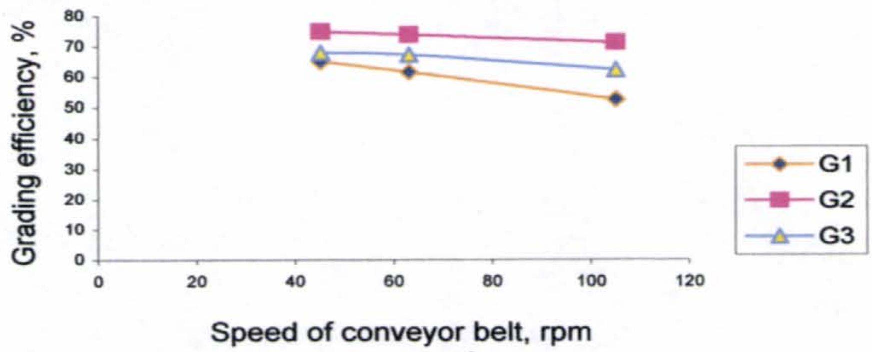



Inclination of conveyor belt, degree
(c) $S_3$ = 45 rpm

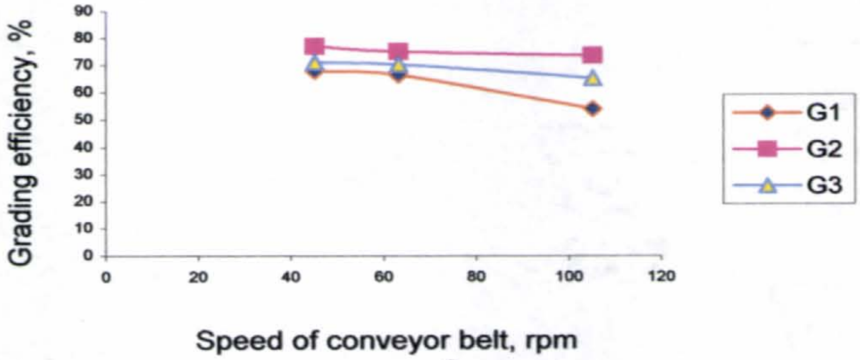
**Fig. 4.4 Effect of inclination and gap between conveyor belt and idler on efficiency at various speeds**




(a) $I_1 = 10^0$

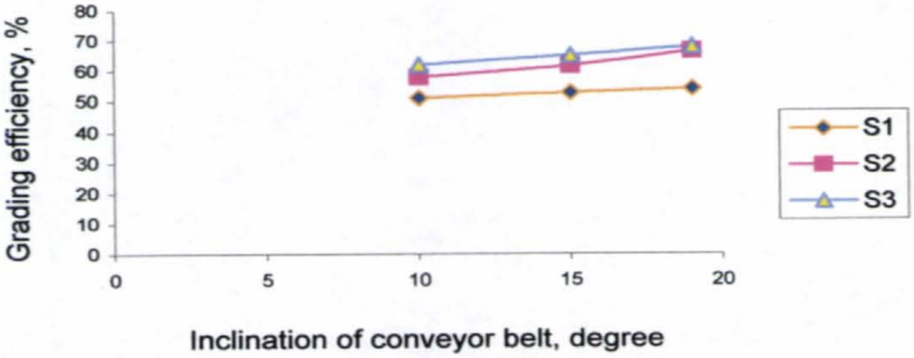



(b) $I_2 = 15^0$

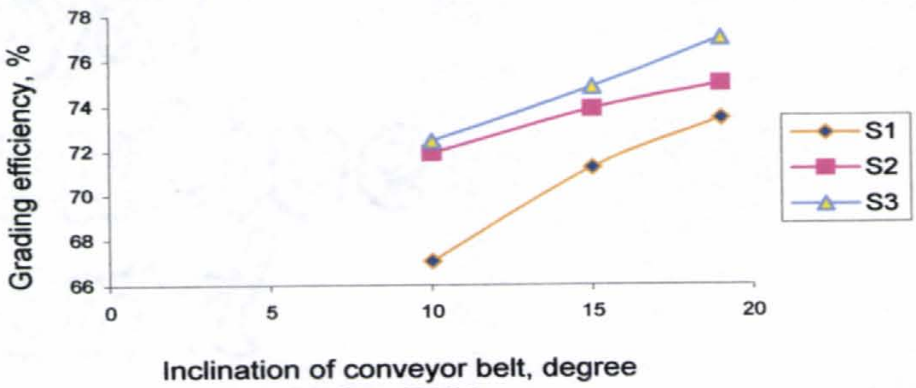



(c) $I_3 = 19^0$

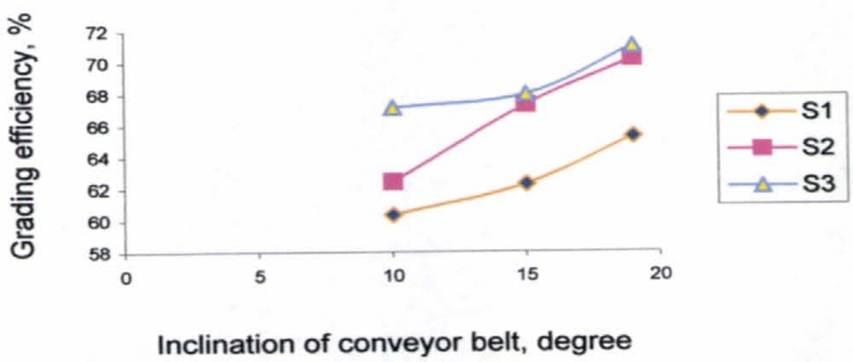
**Fig. 4.5 Effect of speed and gap between conveyor belt and idler on efficiency at various inclinations**




(a) $G_1$ = 53-95 mm




(b) $G_2$ = 57-99 mm




(c) $G_3$ = 61-103 mm

**Fig. 4.6 Effect of inclination and speed of conveyor belt on efficiency a various gaps**

## 4.5 Performance Evaluation of Mango Fruit Grader

The data on effect of speed of conveyor belt, inclination of conveyor belt with roller frame assembly and gap between the conveyor belt and idler on quantities of mango collected into three grades outlet is tabulated and given in Table C.1 (Appendix C). In the feed the ratio of Grade I : Grade II : Grade III was taken as 1:2:1 The sample taken for grading was 8 kg in which 2 kg of Grade I, 4 kg of Grade II and 2 kg of Grade III. On the basis of the quantities of fruit collected and using the Eqn. 3.1 the efficiency was calculated. The performance index was calculated by using the Eq. 3.2. The ANOVA is given in Table C.2 (Grade I), Table C.3 (Grade II) and Table C.4 (Grade III) (Appendix C). This shows that for all the machine parameters (speed, inclination and gap between the conveyor belt and idler), statistical analysis was done at 5% level of significance.

The data on effect of machine parameters on the performance index is tabulated and given in Table 4.5. The data shows that the performance index varies with respect to the speed of conveyor belt, inclination of conveyor belt with roller frame assembly and gap between the conveyor belt and idler. The performance index varied between 1.69 to 4.25. The maximum performance index was found at $S_1I_3$ $G_2$ ($S_1$ = 105 rpm, $I_3$ = 19° and $G_2$ = 57 to 99 mm) and the minimum performance index was found in case of $S_2$ $I_1$ $G_1$ ($S_2$ = 63 rpm, $I_1$ = 10° and $G_1$ = 53 to 95 mm).

**Table 4.5** Effect of machine parameters on performance index

| Roller speed (s ) rpm | Inclination (I) degree | Gap between conveyor belt (G), cm | Performance Index |
|---|---|---|---|
| $S_1$ | $I_1$ | $G_1$ | 1.85 |
| $S_1$ | $I_1$ | $G_2$ | 3.69 |
| $S_1$ | $I_1$ | $G_3$ | 2.66 |
| $S_1$ | $I_2$ | $G_1$ | 2.04 |
| $S_1$ | $I_2$ | $G_2$ | 4.03 |
| $S_1$ | $I_2$ | $G_3$ | 3.06 |
| $S_1$ | $I_3$ | $G_1$ | 2.33 |
| $S_1$ | $I_3$ | $G_2$ | 4.25 |
| $S_1$ | $I_3$ | $G_3$ | 3.58 |
| $S_2$ | $I_1$ | $G_1$ | 1.69 |
| $S_2$ | $I_1$ | $G_2$ | 2.59 |
| $S_2$ | $I_1$ | $G_3$ | 1.93 |
| $S_2$ | $I_2$ | $G_1$ | 1.90 |
| $S_2$ | $I_2$ | $G_2$ | 2.83 |
| $S_2$ | $I_2$ | $G_3$ | 2.44 |
| $S_2$ | $I_3$ | $G_1$ | 2.32 |
| $S_2$ | $I_3$ | $G_2$ | 3.06 |
| $S_2$ | $I_3$ | $G_3$ | 2.68 |
| $S_3$ | $I_1$ | $G_1$ | 1.75 |
| $S_3$ | $I_1$ | $G_2$ | 2.38 |
| $S_3$ | $I_1$ | $G_3$ | 2.06 |
| $S_3$ | $I_2$ | $G_1$ | 1.90 |
| $S_3$ | $I_2$ | $G_2$ | 2.58 |
| $S_3$ | $I_2$ | $G_3$ | 2.11 |
| $S_3$ | $I_3$ | $G_1$ | 2.03 |
| $S_3$ | $I_3$ | $G_2$ | 2.70 |
| $S_3$ | $I_3$ | $G_3$ | 2.39 |

Table 4.6 shows the ANOVA for average grades. For all the machine parameters statistical analysis was done at 5% level of significance.

## 4.6 Cost Economics of Mango Grading

The cost economics of mango grading was determined and shown in Table 4.7. The cost for manual grading was found Rs. 200/- per tonne. Whereas the cost for machines grading was Rs. 21.11 per tonne. The ratio of cost for manual to mechanical grading obtained was 9.47:1.

**Table 4.6** ANOVA for average grades

| Source | D. F. | S. S. | M. S. S. | $F_{cal}$ | $F_{tab}$ | Result |
|---|---|---|---|---|---|---|
| Speed (A) | 2 | 6.276 | 3.138 | 27.203 | 3.17 | Significant |
| Inclination (B) | 2 | 1.348 | 0.674 | 5.842 | 3.17 | Significant |
| Interaction (A X B) | 4 | 0.205 | 0.051 | 0.443 | 2.54 | N. S. |
| Gap (C) | 2 | 21.29 | 10.64 | 92.282 | 3.17 | Significant |
| Interaction (A X C) | 4 | 3.653 | 0.913 | 7.918 | 2.54 | Significant |
| Interaction (B X C) | 4 | 0.648 | 0.162 | 1.405 | 2.54 | N. S. |
| Interaction (A X B X C) | 8 | 0.621 | 0.078 | 0.673 | 2.11 | N. S. |
| Error | 54 | 6.229 | 0.115 | | | |
| Total | 80 | | | | | |

| Source | S. E.(±) | C. D. at 5 % |
|---|---|---|
| Speed (A) | 0.065 | 0.186 |
| Inclination (B) | 0.065 | 0.186 |
| Gap (C) | 0.065 | 0.186 |
| Interaction (A X B) | 0.113 | 0.322 |
| Interaction (A X C) | 0.113 | 0.322 |
| Interaction (B X C) | 0.113 | 0.322 |
| Interaction (A X B X C) | 0.196 | 0.557 |

**Table 4.7** Cost economics of mango grading

| Method/Cost | Details | Cost (Rs) |
|---|---|---|
| **I) Manual Grading** | | |
| a) Fixed charges | Nil | Rs.: 40/- per day |
| b) Variable charges | 1 labour @ Rs.: 40/- per day | Rs. 200/- per tonne |
| Total cost of labour grading | capacity 2 quintal per day | |
| **II) Mechanical Grading** | | |
| A) Fixed cost | | |
| 1) Depreciation | @10 % ,life 10 year<br>Salvage value 10 % | 1543/- |
| 2) Intrest on investment | 12 % | 1852/-<br>-------------- |
| | | **3392/- per year** |
| Total fixed cost | Working days in year 90 days. Capacity of machine 7.40 quintal/hr i.e 59.2 quintal per day (one day is of eight hour). | a) Rs. 38/- per day |
| | @ 2% = Rs. 308 | 03/- per day |
| B)Variable cost | 2 labour @ Rs. 40 per day | 80/- |
| 1) Repair & Maint. | 1 KWH X Rs.4 per unit | 04/- |
| 2) Labour charges | | -------------- |
| Electricity | | b) Rs. 87/-day |
| Total cost of machine grading | (a + b) | = Rs. 125/- per day<br>= **Rs. 21.11/- per tonne** |

**Ratio of cost for manual to mechanical grading :** 200 : 21.11 = 9.47 : 1

Plate 4.1 Grading Machine

Plate 4.2 Trial of Mango Grading

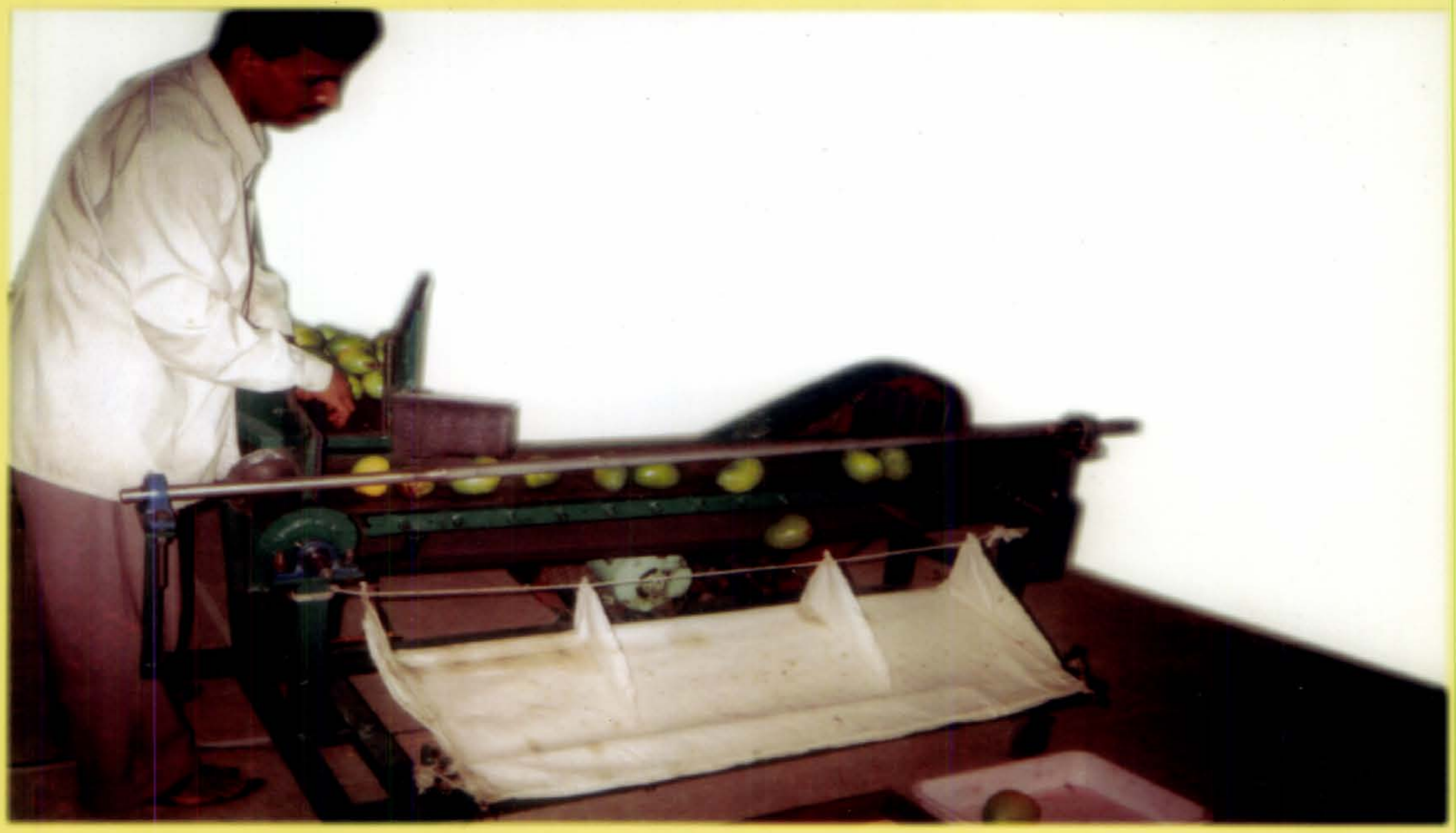


**Plate 4.3 Grading Unit**

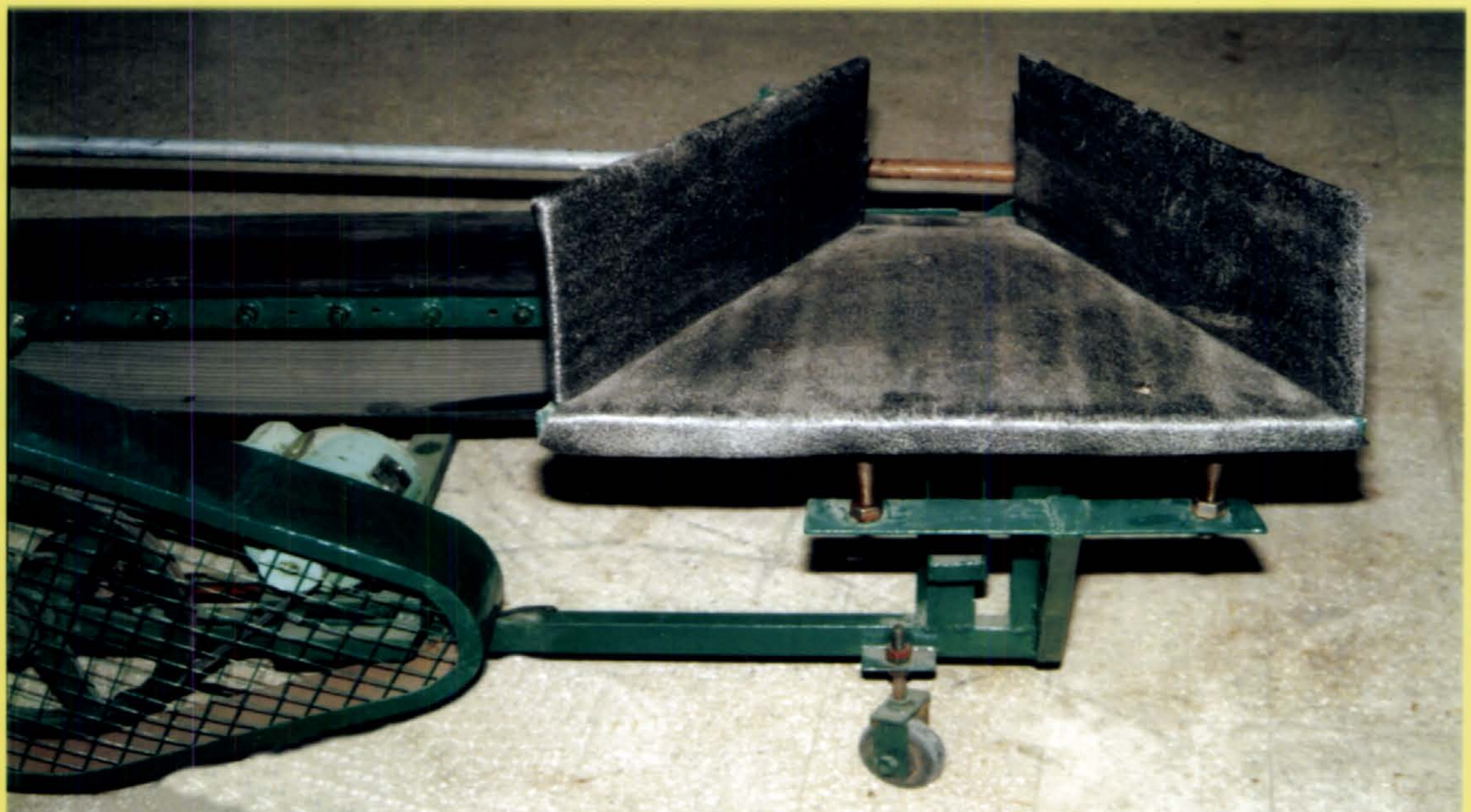


**Plate 4.4 Feeding Unit**

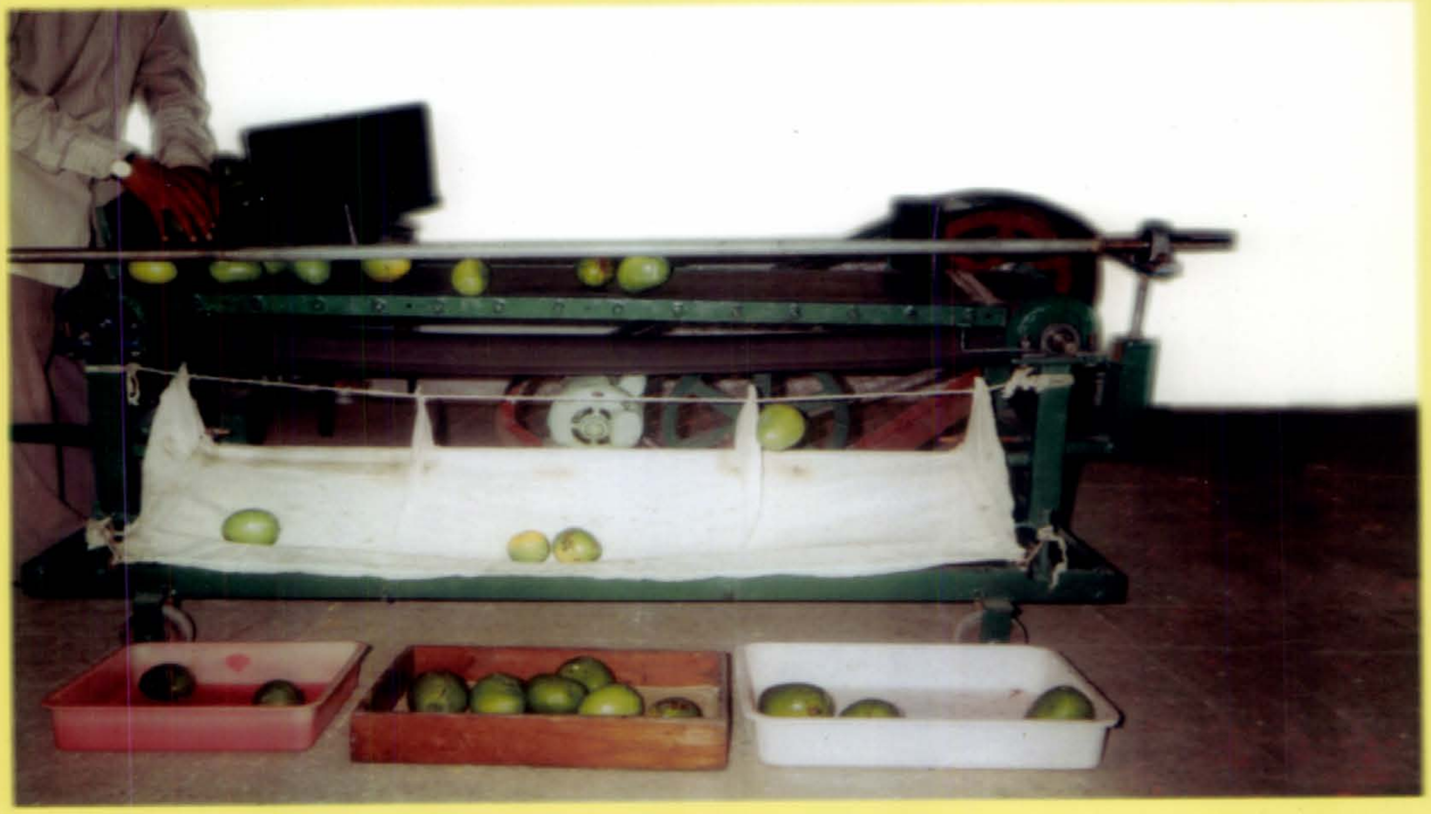


Plate 4.5 Collection Unit

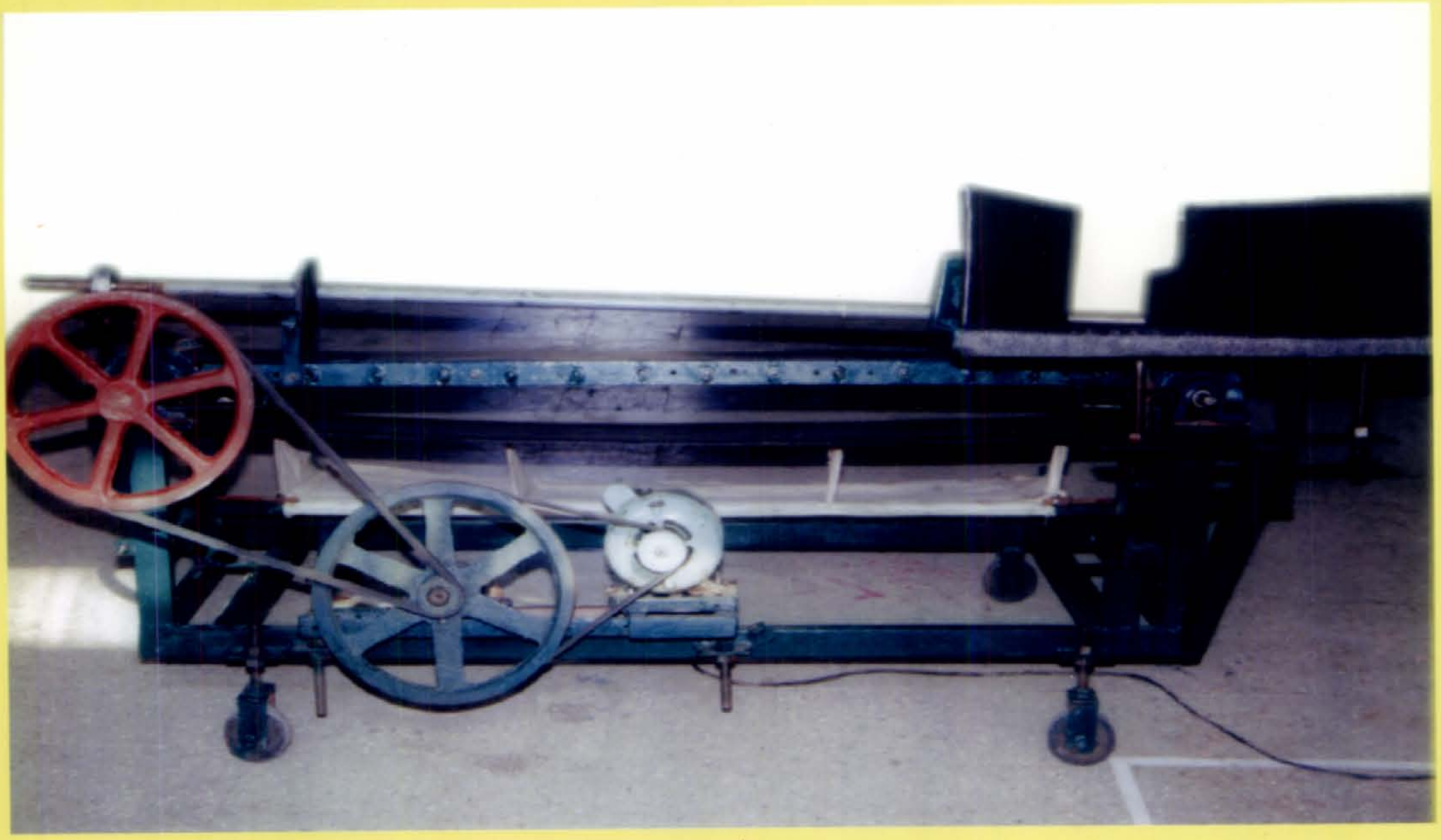


Plate 4.6 Power Transmission Unit

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# Summary and Conclusions

# 5. SUMMARY AND CONCLUSIONS

Grading is one of the most important unit operations involving separation of material according to size and quality that affect its acceptance as food and as working substance for the processor. The comparative value of the graded fruits depends on their grade factor. In order to grade the mango fruits, it was felt necessary to develop a good grader which meets the requirements of various categories of fruit growing farmers. Comparatively little work has been done on a low cost on farm grading system using mechanical grader. On the other hand, the grading cost (rate) should be reasonable. In view of this, the work was initiated and undertaken in the Department of Agricultural Process Engineering, MPKV, Rahuri.

Based on the results, the following conclusions could be drawn :

1. The mango fruits of cv. Alphonso were graded into three grades based on size and weight. The average size and specific weight found were 85.93 mm and 300 g, 76.73 mm and 216.40 g, 62.02 mm and 124.86 g, respectively for Grade I, Grade II and Grade III. The average sphericity of mango fruits ranged between 89.9 ± 2.29 %.

2. A prototype mango fruit grader was developed using conveyor belt principle. The machine consisted of grading, feeding, collection and power transmission units. The overall dimensions of machine are

1600 mm x 610 mm x 440 mm and the cost of machine is Rs. 15430/- (including an electric motor).

3. The capacity, efficiency and performance index of the machine varied with respect to speed inclination and gap. For all machine parameters statistical analysis done at 5 % level of significance. The capacity of the machine varied between 597 to 1222 kg/hr. The maximum capacity of 1222 kg/hr was found for the combination $S_1I_3G_2$ ($S_1$ = 105 rpm, $I_3$ = 19°, $G_2$ = 57-99 mm).

4. The efficiency of the machine varied between 51.02 to 77.00 %. The maximum efficiency of 77.00 % was found for the combination $S_3I_3G_2$ ($S_3$ = 45 rpm, $I_3$ = 19°, $G_2$ = 57-99 mm).

5. The performance index of the machine varied between 1.69 to 4.25. The maximum performance index of 4.25 was found for the combination of $S_1$ $I_3$ $G_2$ ($S_1$ = 105 rpm, $I_3$ = 19°, $G_2$ = 57-99 mm).

6. The minimum capacity, efficiency and performance index of the machine were found 597 kg/hr, 51.02 % and 1.69, respectively, for $S_3$ $I_1$ $G_1$, $S_1$ $I_1$ $G_1$ and $S_2$ $I_1$ $G_1$ combinations.

7. The cost of manual grading was worked out to Rs. 200.00 per tonne. Whereas the cost for mechanical grading was Rs. 21.11 per tonne. The ratio of cost for manual to mechanical grading obtained was 9.47:1.

## Suggestions for future work

1. Proper feeding system to feed the fruits without clogging should be developed.

2. The length of the outlet chutes should be made adjustable with the fruit lot to be graded.

3. For better performance of the grader idler rotating mechanism should be provided.

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# Appendices

# APPENDIX - A

**Table A.1** Some engineering properties of mango fruits

| Sr. No. | Dimensions (mm) | | | Sphericity | Size (mm) | Weight (gm) |
|---|---|---|---|---|---|---|
| | a | b | c | | | |
| 1 | 95.1 | 92.3 | 73.3 | 0.90 | 86.3 | 284 |
| 2 | 75.0 | 72.3 | 61.7 | 0.92 | 69.4 | 172 |
| 3 | 75.3 | 72.5 | 50.3 | 0.86 | 65.0 | 140 |
| 4 | 91.2 | 88.2 | 77.1 | 0.93 | 85.2 | 308 |
| 5 | 70.3 | 66.6 | 55.0 | 0.90 | 63.7 | 118 |
| 6 | 85.3 | 84.4 | 70.2 | 0.93 | 76.7 | 224 |
| 7 | 71.9 | 68.5 | 51.4 | 0.88 | 63.2 | 114 |
| 8 | 72.5 | 71.3 | 64.4 | 0.95 | 69.3 | 158 |
| 9 | 86.3 | 83.5 | 74.2 | 0.94 | 81.1 | 242 |
| 10 | 59.3 | 57.0 | 49.5 | 0.93 | 55.1 | 110 |
| 11 | 87.0 | 82.5 | 69.5 | 0.91 | 79.3 | 242 |
| 12 | 77.0 | 66.7 | 61.1 | 0.88 | 68.0 | 172 |
| 13 | 56.4 | 51.6 | 41.9 | 0.88 | 49.6 | 66 |
| 14 | 101.4 | 99.3 | 71.5 | 0.88 | 89.7 | 316 |
| 15 | 67.0 | 60.5 | 58.8 | 0.92 | 62.0 | 138 |
| 16 | 68.0 | 62.1 | 51.1 | 0.88 | 60.0 | 124 |
| 17 | 92.3 | 89.4 | 75.7 | 0.92 | 85.4 | 302 |
| 18 | 95.5 | 84.5 | 67.6 | 0.84 | 81.8 | 276 |
| 19 | 89.4 | 85.0 | 69.6 | 0.90 | 80.9 | 260 |
| 20 | 59.2 | 52.1 | 44.3 | 0.87 | 51.5 | 64.0 |
| 21 | 85.6 | 81.2 | 68.4 | 0.91 | 78.0 | 224 |
| 22 | 72.2 | 72.0 | 56.4 | 0.92 | 66.4 | 142 |
| 23 | 72.5 | 70.5 | 54.0 | 0.90 | 65.1 | 140 |
| 24 | 77.6 | 75.4 | 60.4 | 0.91 | 70.7 | 178 |
| 25 | 85.0 | 83.5 | 65.1 | 0.91 | 77.3 | 198 |
| 26 | 92.5 | 89.2 | 75.0 | 0.92 | 85.2 | 294 |
| 27 | 61.4 | 58.5 | 50.5 | 0.92 | 56.6 | 108 |
| 28 | 84.2 | 82.7 | 68.1 | 0.93 | 78.0 | 231 |
| 29 | 86.0 | 82.5 | 67.5 | 0.91 | 78.7 | 240 |
| 30 | 64.1 | 61.7 | 54.3 | 0.93 | 59.9 | 112.0 |
| 31 | 71.5 | 67.0 | 52.5 | 0.88 | 63.1 | 120 |
| 32 | 81.6 | 69.1 | 63.5 | 0.87 | 71.0 | 214 |
| 33 | 79.0 | 75.1 | 62.3 | 0.91 | 71.8 | 116 |
| 34 | 87.7 | 84.0 | 64.5 | 0.89 | 78.0 | 216 |
| 35 | 85.0 | 75.2 | 66.7 | 0.88 | 75.2 | 212 |
| 36 | 93.2 | 86.1 | 77.0 | 0.91 | 85.1 | 316 |

*Table contd...*

| | | | | | | |
|---|---|---|---|---|---|---|
| 37 | 84.2 | 72.0 | 68.7 | 0.89 | 74.7 | 228 |
| 38 | 88.6 | 85.9 | 69.3 | 0.91 | 80.8 | 232 |
| 39 | 80.0 | 74.6 | 63.5 | 0.90 | 72.3 | 190 |
| 40 | 75.4 | 7.30 | 59.5 | 0.85 | 64.6 | 162 |
| 41 | 104.1 | 103.4 | 78.0 | 0.90 | 94.7 | 392 |
| 42 | 82.5 | 77.7 | 63.0 | 0.89 | 74.0 | 188 |
| 43 | 59.4 | 53.2 | 51.0 | 0.92 | 54.6 | 98 |
| 44 | 83.2 | 74.1 | 65.2 | 0.89 | 73.8 | 192 |
| 45 | 74.6 | 69.7 | 60.0 | 0.91 | 67.9 | 154 |
| 46 | 88.5 | 85.7 | 66.8 | 0.90 | 79.8 | 246 |
| 47 | 62.5 | 50.5 | 43.6 | 0.83 | 51.7 | 74 |
| 48 | 106.3 | 102.4 | 77.6 | 0.88 | 94.6 | 394 |
| 49 | 85.6 | 77.7 | 65.0 | 0.88 | 75.7 | 214 |
| 50 | 93.4 | 85.5 | 72.0 | 0.88 | 83.4 | 298 |
| 51 | 85.3 | 81.5 | 66.4 | 0.91 | 77.2 | 230 |
| 52 | 87.8 | 85.4 | 69.5 | 0.92 | 80.4 | 240 |
| 53 | 87.3 | 83.0 | 69.2 | 0.91 | 79.4 | 238 |
| 54 | 82.3 | 79.5 | 62.0 | 0.90 | 74.0 | 176 |
| 55 | 71.9 | 64.5 | 53.2 | 0.87 | 62.7 | 134 |
| 56 | 92.5 | 90.9 | 73.1 | 0.91 | 85.0 | 268 |
| 57 | 83.4 | 80.0 | 67.3 | 0.92 | 76.6 | 218 |
| 58 | 94.0 | 92.9 | 77.3 | 0.93 | 87.8 | 314 |
| 59 | 87.6 | 81.7 | 65.0 | 0.88 | 77.4 | 226 |
| 60 | 77.3 | 61.7 | 55.5 | 0.83 | 64.0 | 154 |
| 61 | 95.0 | 93.7 | 64.2 | 0.87 | 84.3 | 264 |
| 62 | 76.3 | 74.8 | 63.2 | 0.93 | 71.1 | 182 |
| 63 | 86.5 | 78.7 | 76.6 | 0.93 | 80.4 | 236 |
| 64 | 71.2 | 65.0 | 51.4 | 0.87 | 62.0 | 110 |
| 65 | 93.4 | 86.5 | 76.8 | 0.91 | 85.3 | 310 |
| 66 | 71.7 | 69.7 | 54.2 | 0.90 | 64.7 | 130 |
| 67 | 86.3 | 82.7 | 70.3 | 0.92 | 79.5 | 242 |
| 68 | 75.6 | 75.1 | 54.6 | 0.89 | 67.7 | 146 |
| 69 | 86.0 | 84.3 | 64.5 | 0.90 | 77.7 | 216 |
| 70 | 83.5 | 79.3 | 63.5 | 0.90 | 75.0 | 182 |
| 71 | 75.0 | 74.7 | 59.3 | 0.92 | 69.2 | 164 |
| 72 | 79.2 | 78.7 | 64.2 | 0.93 | 73.7 | 176 |
| 73 | 76.4 | 71.5 | 56.2 | 0.88 | 67.4 | 154 |
| 74 | 93.3 | 88.5 | 69.5 | 0.89 | 83.1 | 280 |
| 75 | 86.6 | 85.9 | 69.7 | 0.93 | 80.3 | 234 |
| 76 | 91.7 | 89.0 | 73.5 | 0.91 | 84.3 | 260 |
| 77 | 93.0 | 91.7 | 71.7 | 0.91 | 84.9 | 264 |
| 78 | 54.5 | 51.7 | 39.8 | 0.88 | 48.2 | 52 |
| 79 | 84.2 | 79.7 | 69.3 | 0.92 | 77.5 | 218 |
| 80 | 52.8 | 49.5 | 37.8 | 0.87 | 46.2 | 48.0 |

**Table A.2** Grades of mango fruits

**For grade III**

| Sr. No. | Dimensions (mm) | | | Sphericity | Size (mm) | Weight (gm) |
|---|---|---|---|---|---|---|
| | a | b | c | | | |
| 1 | 75.0 | 72.3 | 61.7 | 0.92 | 69.4 | 172 |
| 2 | 75.3 | 72.5 | 50.3 | 0.86 | 65.0 | 140 |
| 3 | 70.3 | 66.6 | 55.0 | 0.90 | 63.7 | 118 |
| 4 | 71.9 | 68.5 | 51.4 | 0.88 | 63.2 | 114 |
| 5 | 72.5 | 71.3 | 64.4 | 0.95 | 69.3 | 158 |
| 6 | 59.3 | 57.0 | 49.5 | 0.93 | 55.1 | 110 |
| 7 | 77.0 | 66.7 | 61.1 | 0.88 | 68.0 | 172 |
| 8 | 56.4 | 51.6 | 41.9 | 0.88 | 49.6 | 66 |
| 9 | 67.0 | 60.5 | 58.8 | 0.92 | 62.0 | 138 |
| 10 | 68.0 | 62.1 | 51.1 | 0.88 | 60.0 | 124 |
| 11 | 59.2 | 52.1 | 44.3 | 0.87 | 51.5 | 64.0 |
| 12 | 72.2 | 72.0 | 56.4 | 0.92 | 66.4 | 142 |
| 13 | 72.5 | 70.5 | 54.0 | 0.90 | 65.1 | 140 |
| 14 | 61.4 | 58.5 | 50.5 | 0.92 | 56.6 | 108 |
| 15 | 64.1 | 61.7 | 54.3 | 0.93 | 59.9 | 112 |
| 16 | 71.5 | 67.0 | 52.5 | 0.88 | 63.1 | 120 |
| 17 | 79.0 | 75.1 | 62.3 | 0.91 | 71.8 | 166 |
| 18 | 75.4 | 60.3 | 59.5 | 0.85 | 64.6 | 162 |
| 19 | 59.4 | 53.5 | 51.0 | 0.92 | 54.6 | 98 |
| 20 | 74.6 | 69.7 | 60.0 | 0.91 | 67.9 | 154 |
| 21 | 62.5 | 50.5 | 43.6 | 0.83 | 51.7 | 74 |
| 22 | 71.9 | 64.5 | 53.2 | 0.87 | 62.7 | 136 |
| 23 | 77.3 | 61.7 | 55.5 | 0.83 | 64.0 | 154 |
| 24 | 71.2 | 65.0 | 51.4 | 0.87 | 62.0 | 110 |
| 25 | 71.7 | 69.7 | 54.2 | 0.90 | 64.7 | 130 |
| 26 | 75.6 | 75.1 | 54.6 | 0.89 | 67.7 | 146 |
| 27 | 75.0 | 74.7 | 59.3 | 0.92 | 69.2 | 164 |
| 28 | 76.4 | 71.5 | 56.2 | 0.88 | 67.4 | 154 |
| 29 | 54.5 | 51.7 | 39.8 | 0.88 | 48.2 | 52 |
| 30 | 52.8 | 49.5 | 37.8 | 0.87 | 46.2 | 48 |
| Mean | 69.03 | 64.11 | 53.18 | 0.89 | 62.2 | 124.86 |
| S. D. (±) | 7.37 | 7.75 | 6.56 | 0.029 | 6.82 | 35.11 |

## For grade II

| Sr. No. | Dimensions (mm) | | | Sphericity | Size (mm) | Weight (gm) |
|---|---|---|---|---|---|---|
| | a | b | c | | | |
| 1 | 77.6 | 75.4 | 60.4 | 0.91 | 70.7 | 178 |
| 2 | 85.0 | 83.5 | 65.1 | 0.91 | 77.3 | 198 |
| 3 | 84.2 | 82.7 | 68.1 | 0.93 | 78.0 | 231 |
| 4 | 86.0 | 82.5 | 67.5 | 0.91 | 78.7 | 240 |
| 5 | 81.6 | 69.1 | 63.5 | 0.87 | 71.0 | 214 |
| 6 | 87.7 | 84.0 | 64.5 | 0.89 | 78.0 | 216 |
| 7 | 85.0 | 75.2 | 66.7 | 0.88 | 75.2 | 212 |
| 8 | 84.2 | 72.0 | 68.7 | 0.89 | 74.7 | 228 |
| 9 | 88.6 | 85.9 | 69.3 | 0.91 | 80.8 | 232 |
| 10 | 80.0 | 74.6 | 63.5 | 0.90 | 72.3 | 190 |
| 11 | 82.5 | 77.7 | 63.0 | 0.89 | 74.0 | 188 |
| 12 | 83.2 | 74.1 | 65.2 | 0.89 | 73.8 | 192 |
| 13 | 88.5 | 85.7 | 66.8 | 0.90 | 79.8 | 246 |
| 14 | 85.6 | 77.7 | 65.0 | 0.88 | 75.7 | 214 |
| 15 | 85.3 | 81.5 | 66.4 | 0.91 | 77.2 | 230 |
| 16 | 87.8 | 85.4 | 69.5 | 0.92 | 80.4 | 240 |
| 17 | 87.3 | 83.0 | 69.2 | 0.91 | 79.4 | 238 |
| 18 | 82.3 | 79.5 | 62.0 | 0.90 | 74.0 | 176 |
| 19 | 83.4 | 80.0 | 67.3 | 0.92 | 76.6 | 218 |
| 20 | 67.6 | 81.7 | 65.0 | 0.88 | 77.4 | 226 |
| 21 | 76.3 | 74.8 | 63.2 | 0.93 | 71.1 | 182 |
| 22 | 85.3 | 84.4 | 70.2 | 0.93 | 76.7 | 224 |
| 23 | 86.5 | 78.7 | 76.6 | 0.93 | 80.4 | 236 |
| 24 | 86.3 | 83.5 | 74.2 | 0.94 | 81.1 | 242 |
| 25 | 86.0 | 84.3 | 64.5 | 0.90 | 77.7 | 216 |
| 26 | 83.5 | 79.3 | 63.5 | 0.90 | 75.0 | 182 |
| 27 | 79.2 | 78.7 | 64.2 | 0.93 | 73.7 | 176 |
| 28 | 86.6 | 85.9 | 69.7 | 0.93 | 80.3 | 234 |
| 29 | 87.0 | 82.5 | 69.5 | 0.91 | 79.3 | 242 |
| 30 | 85.6 | 81.2 | 68.4 | 0.91 | 78.0 | 224 |
| 31 | 84.2 | 79.7 | 69.3 | 0.92 | 70.5 | 218 |
| 32 | 86.3 | 82.7 | 70.3 | 0.92 | 79.5 | 242 |
| Mean | 84.57 | 80.21 | 66.88 | 0.90 | 76.73 | 216.40 |
| S. D. (±) | 2.99 | 4.27 | 3.43 | 0.017 | 2.97 | 22.13 |

# For grade I

| Sr. No. | Dimensions (mm) | | | Sphericity | Size (mm) | Weight (gm) |
|---|---|---|---|---|---|---|
| | a | b | c | | | |
| 1 | 95.1 | 92.3 | 73.3 | 0.90 | 86.3 | 284 |
| 2 | 91.2 | 88.2 | 77.1 | 0.93 | 85.2 | 308 |
| 3 | 94.3 | 85.5 | 72.0 | 0.88 | 83.4 | 298 |
| 4 | 101.4 | 99.3 | 71.5 | 0.88 | 89.7 | 316 |
| 5 | 92.3 | 89.4 | 75.7 | 0.92 | 85.4 | 302 |
| 6 | 95.5 | 84.5 | 67.6 | 0.84 | 81.8 | 276 |
| 7 | 89.4 | 85.0 | 69.6 | 0.90 | 80.9 | 260 |
| 8 | 92.5 | 89.2 | 75.0 | 0.92 | 85.2 | 294 |
| 9 | 93.2 | 86.1 | 77.0 | 0.91 | 85.1 | 316 |
| 10 | 104.1 | 103.4 | 78.0 | 0.90 | 94.7 | 392 |
| 11 | 106.3 | 102.4 | 77.6 | 0.88 | 94.6 | 394 |
| 12 | 92.5 | 90.9 | 73.1 | 0.91 | 85.0 | 268 |
| 13 | 94.0 | 92.9 | 77.3 | 0.93 | 87.8 | 314 |
| 14 | 95.0 | 93.7 | 64.2 | 0.87 | 84.3 | 264 |
| 15 | 93.3 | 88.5 | 69.5 | 0.89 | 83.1 | 280 |
| 16 | 91.7 | 89.0 | 73.5 | 0.89 | 84.3 | 260 |
| 17 | 93.0 | 91.7 | 71.7 | 0.91 | 84.9 | 264 |
| 18 | 93.4 | 86.5 | 76.8 | 0.91 | 85.2 | 310 |
| Mean | 94.9 | 91.02 | 73.36 | 0.90 | 85.93 | 300 |
| S. D. (±) | 4.36 | 5.49 | 3.77 | 0.022 | 3.62 | 38.19 |

# APPENDIX-B

**Table B.1** Schedule of quantities and rates of materials

| Item | Specification | Quantity (Kg) | Rate/Kg | Amount (Rs.) |
|---|---|---|---|---|
| I) Main Frame | | | | |
| a) Square pipe | 2 x 1 inch | 16 | 28.0 | 448 |
| b) M.S. Flat | 50 x 5 mm | 2 | 18.50 | 37.0 |
| c) M.S. Flat | 25 x 5 mm | 2 | 18.50 | 37 |
| d) Rubber wheel | - | 4 | 80 | 320 |
| e) Nut bolt | - | 3 | 50 | 150 |
| f) Paint & thinner | - | 2 | 110 | 220 |
| g) Brush | - | 1 | 25 | 25 |
| h) Welding rod | 3.15 | 1 | 100 | 100 |
| i) Redoxer | - | 1 | 35 | 35.0 |
| Total | | | | 1372/- |
| II) Feeding, Grading and Collection Unit | | | | |
| a) M.S. Angle | 25 x 25 x 3 mm | 4 | 18.50 | 74/- |
| b) G. I. Sheet | 20 gauge | 2 | 400 | 800 |
| c) Hot lone Sheet | 3 x 6 sq. ft | - | 10 | 180 |
| d) G. I. Pipe | 25 mm | 10 | 20 | 200 |
| e) G. I. Pipe | 4 inch | 2 ft. | 40 | 80 |
| f) M. S. flat | 40 x 5 mm | 8 | 18.50 | 148 |
| g) White drawn bar | 25 mm | 15 | 28 | 420 |
| h) Belt and belt clip | - | - | 1000 | 1000 |
| i) Bush (gun metal) | 20 mm | 28 | - | 560 |
| j) cloth | 2 meter | - | 50 | 100 |
| k) M. S. pipe | - | 8 | 20 | 160 |
| | | | Total | 3722 |
| III) Transmission Unit | | | | |
| a) M. S Flat | 25 x 3 mm | 1 | 18.50 | 18.50 |
| b) Pedestal bearing and bearing block | 20 mm (P204) | 4 | 250 | 1000 |
| c) Pedestal bearing and bearing block | 25mm (P205) | 4 | 300 | 1200 |
| d) Net | 4 x 2 ft. | - | 10 | 80 |
| e) M. S. angle | 20 x 20 x 3 mm | 2 | 18.50 | 37.0 |
| f) White drawn bar | 25 mm | 1.5 | 28 | 28.0 |
| g) Pulley | 12 inch | 2 | 150 | 300 |
| h) Pulley | 2.5 inch | 2 | 60 | 120 |
| i) V-belt | B<br>B | 2 | 150 | 300 |
| | | | Total | 3083.50 |

Total cost of material : Rs.8177.5
30 % Fabrication : Rs.2453.25
Total cost : Rs.10,630
Electric Motor (Single phase, 1 HP) : Rs.4800
Total cost of m/c including motor : Rs.15,430/-

# APPENDIX- C

**Table C.1** Effect of machine parameters on fruit collected into three grades

| peed (s) pm | Inclin-ation (I) degree | Gap (G) cm | Quantities of mango collected (kg) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R1 | | | R2 | | | R3 | | |
| | | | Gr 1 | Gr2 | Gr3 | Gr 1 | Gr2 | Gr3 | Gr 1 | Gr2 | Gr3 |
| | $I_1$ | $G_1$ | 1.210 | 1.704 | 0.822 | 1.126 | 2.174 | 1.064 | 1.170 | 1.630 | 1.040 |
| | | $G_2$ | 1.106 | 3.094 | 1.310 | 1.124 | 3.322 | 1.410 | 1.208 | 3.279 | 1.127 |
| | | $G_3$ | 1.720 | 2.394 | 1.164 | 1.132 | 3.172 | 0.818 | 1.170 | 2.386 | 1.176 |
| | $I_2$ | $G_1$ | 1.736 | 0.880 | 0.714 | 1.364 | 1.894 | 1.142 | 1.298 | 1.770 | 0.982 |
| | | $G_2$ | 0.810 | 3.102 | 1.48 | 1.130 | 3.348 | 1.586 | 1.104 | 3.344 | 1.618 |
| | | $G_3$ | 1.462 | 2.218 | 1.038 | 1.716 | 2.870 | 0.860 | 1.670 | 2.577 | 0.840 |
| | $I_3$ | $G_1$ | 1.120 | 1.852 | 1.110 | 1.436 | 1.732 | 0.928 | 1.098 | 1.810 | 1.388 |
| | | $G_2$ | 1.108 | 2.826 | 1.812 | 1.210 | 3.350 | 1.744 | 1.146 | 2.693 | 1.768 |
| | | $G_3$ | 1.170 | 3.264 | 0.964 | 1.132 | 3.296 | 1.408 | 1.110 | 3.360 | 1.010 |
| 2 | $I_1$ | $G_1$ | 0.860 | 2.352 | 1.708 | 1.082 | 2.576 | 1.294 | 0.890 | 2.570 | 1.416 |
| | | $G_2$ | 1.410 | 3.76 | 1.114 | 1.536 | 3.746 | 1.112 | 1.273 | 3.410 | 1.040 |
| | | $G_3$ | 1.178 | 2.388 | 1.292 | 1.718 | 3.098 | 0.848 | 1.152 | 2.854 | 0.890 |
| | $I_2$ | $G_1$ | 1.468 | 2.206 | 1.004 | 1.278 | 2.188 | 1.368 | 1.527 | 2.280 | 1.118 |
| | | $G_2$ | 1.493 | 3.310 | 1.260 | 1.150 | 3.758 | 1.350 | 1.414 | 3.332 | 1.431 |
| | | $G_3$ | 1.118 | 3.244 | 1.302 | 1.692 | 3.088 | 0.750 | 1.322 | 3.371 | 1.082 |
| | $I_3$ | $G_1$ | 1.180 | 2.574 | 1.054 | 1.110 | 3.04 | 1.684 | 1.230 | 2.870 | 1.462 |
| | | $G_2$ | 1.420 | 3.514 | 1.160 | 1.576 | 3.320 | 1.730 | 1.246 | 3.470 | 1.220 |
| | | $G_3$ | 0.822 | 3.526 | 1.147 | 1.873 | 3.042 | 1.112 | 1.582 | 3.320 | 1.240 |
| 3 | $I_1$ | $G_1$ | 0.770 | 2.846 | 1.656 | 0.788 | 3.240 | 1.120 | 1.110 | 3.110 | 1.121 |
| | | $G_2$ | 2.00 | 2.796 | 1.04 | 1.090 | 3.780 | 1.676 | 1.204 | 3.247 | 1.120 |
| | | $G_3$ | 1.110 | 3.556 | 1.258 | 1.704 | 2.776 | 0.924 | 1.440 | 3.280 | 0.847 |
| | $I_2$ | $G_1$ | 1.177 | 3.266 | 1.143 | 1.327 | 3.348 | 0.802 | 1.280 | 3.116 | 1.108 |
| | | $G_2$ | 1.430 | 3.334 | 1.473 | 1.414 | 3.318 | 1.392 | 1.460 | 3.261 | 1.350 |
| | | $G_3$ | 1.460 | 2.610 | 1.180 | 1.273 | 3.352 | 1.172 | 1.371 | 3.182 | 1.215 |
| | $I_3$ | $G_1$ | 1.470 | 2.636 | 1.326 | 0.776 | 3.330 | 1.112 | 1.423 | 3.090 | 1.182 |
| | | $G_2$ | 1.390 | 3.312 | 1.456 | 1.606 | 3.034 | 1.504 | 1.471 | 3.337 | 1.593 |
| | | $G_3$ | 1.578 | 3.566 | 1.045 | 1.477 | 3.586 | 0.850 | 0.392 | 3.214 | 1.264 |

**Table C.2** ANOVA for grade I

| Source | D. F. | S. S. | M. S. S. | $F_{cal}$ | $F_{tab}$ | Result |
|---|---|---|---|---|---|---|
| Speed (A) | 2 | 0.103 | 0.051 | 0.983 | 3.17 | N. S. |
| Inclination (B) | 2 | 0.249 | 0.124 | 2.383 | 3.17 | N. S. |
| Interaction (A X B) | 4 | 0.157 | 0.04 | 0.750 | 2.54 | N. S. |
| Gap (C) | 2 | 0.518 | 0.259 | 4.961 | 3.17 | Significant |
| Interaction (A X C) | 4 | 0.648 | 0.162 | 3.104 | 2.54 | Significant |
| Interaction (B X C) | 4 | 0.504 | 0.126 | 2.416 | 2.54 | N. S. |
| Interaction (A X B X C) | 8 | 0.266 | 0.033 | 0.637 | 2.11 | |
| Error | 54 | 2.817 | 0.052 | | | |
| Total | 80 | 5.259 | | | | |

| Source | S. E.(±) | C. D. at 5 % |
|---|---|---|
| Speed (A) | 0.044 | 0.125 |
| Inclination (B) | 0.044 | 0.125 |
| Gap (C) | 0.044 | 0.125 |
| Interaction (A X B) | 0.076 | 0.216 |
| Interaction (A X C) | 0.076 | 0.216 |
| Interaction (B X C) | 0.076 | 0.216 |
| Interaction (A X B X C) | 0.132 | 0.375 |

**Table C.3** ANOVA for grade II

| Source | D. F. | S. S. | M. S. S. | Fcal | Ftab | Result |
|---|---|---|---|---|---|---|
| Speed (A) | 2 | 5.625 | 2.813 | 35.315 | 3.17 | Significant |
| Inclination (B) | 2 | 0.346 | 0.173 | 2.171 | 3.17 | N. S. |
| Interaction (A X B) | 4 | 0.115 | 0.029 | 0.361 | 2.54 | N. S. |
| Gap (C) | 2 | 10.95 | 5.473 | 68.723 | 3.17 | Significant |
| Interaction (A X C) | 4 | 4.411 | 1.103 | 13.846 | 2.54 | Significant |
| Interaction (B X C) | 4 | 1.257 | 0.314 | 3.947 | 2.54 | Significant |
| Interaction (A X B X C) | 8 | 1.213 | 0.152 | 1.903 | 2.11 | N. S. |
| Error | 54 | 4.301 | 0.08 | | | |
| Total | 80 | 28.21 | | | | |

| Source | S. E. (±) | C. D. at 5 % |
|---|---|---|
| Speed (A) | 0.054 | 0.154 |
| Inclination (B) | 0.054 | 0.154 |
| Gap (C) | 0.054 | 0.154 |
| Interaction (A X B) | 0.094 | 0.267 |
| Interaction (A X C) | 0.094 | 0.267 |
| Interaction (B X C) | 0.094 | 0.267 |
| Interaction (A X B X C) | 0.163 | 0.463 |

**Table C.4** ANOVA for grade III

| Source | D. F. | S. S. | M. S. S. | Fcal | Ftab | Result |
|---|---|---|---|---|---|---|
| Speed (A) | 2 | 0.015 | 0.007 | 0.188 | 3.17 | N. S. |
| Inclination (B) | 2 | 0.338 | 0.169 | 4.345 | 3.17 | Significant |
| Interaction (A X B) | 4 | 0.09 | 0.022 | 0.572 | 2.54 | N. S. |
| Gap (C) | 2 | 1.610 | 0.805 | 20.673 | 3.17 | Significant |
| Interaction (A X C) | 4 | 0.803 | 0.201 | 5.157 | 2.54 | Significant |
| Interaction (B X C) | 4 | 0.448 | 0.122 | 3.133 | 2.54 | Significant |
| Interaction (A X B X C) | 8 | 0.194 | 0.024 | 0.622 | 2.11 | N. S. |
| Error | 54 | 2.103 | 0.039 | | | |
| Total | 80 | 5.641 | | | | |

| Source | S. E. (±) | C. D. at 5 % |
|---|---|---|
| Speed (A) | 0.038 | 0.108 |
| Inclination (B) | 0.038 | 0.108 |
| Gap (C) | 0.038 | 0.108 |
| Interaction (A X B) | 0.066 | 0.187 |
| Interaction (A X C) | 0.066 | 0.187 |
| Interaction (B X C) | 0.066 | 0.187 |
| Interaction (A X B X C) | 0.114 | 0.324 |

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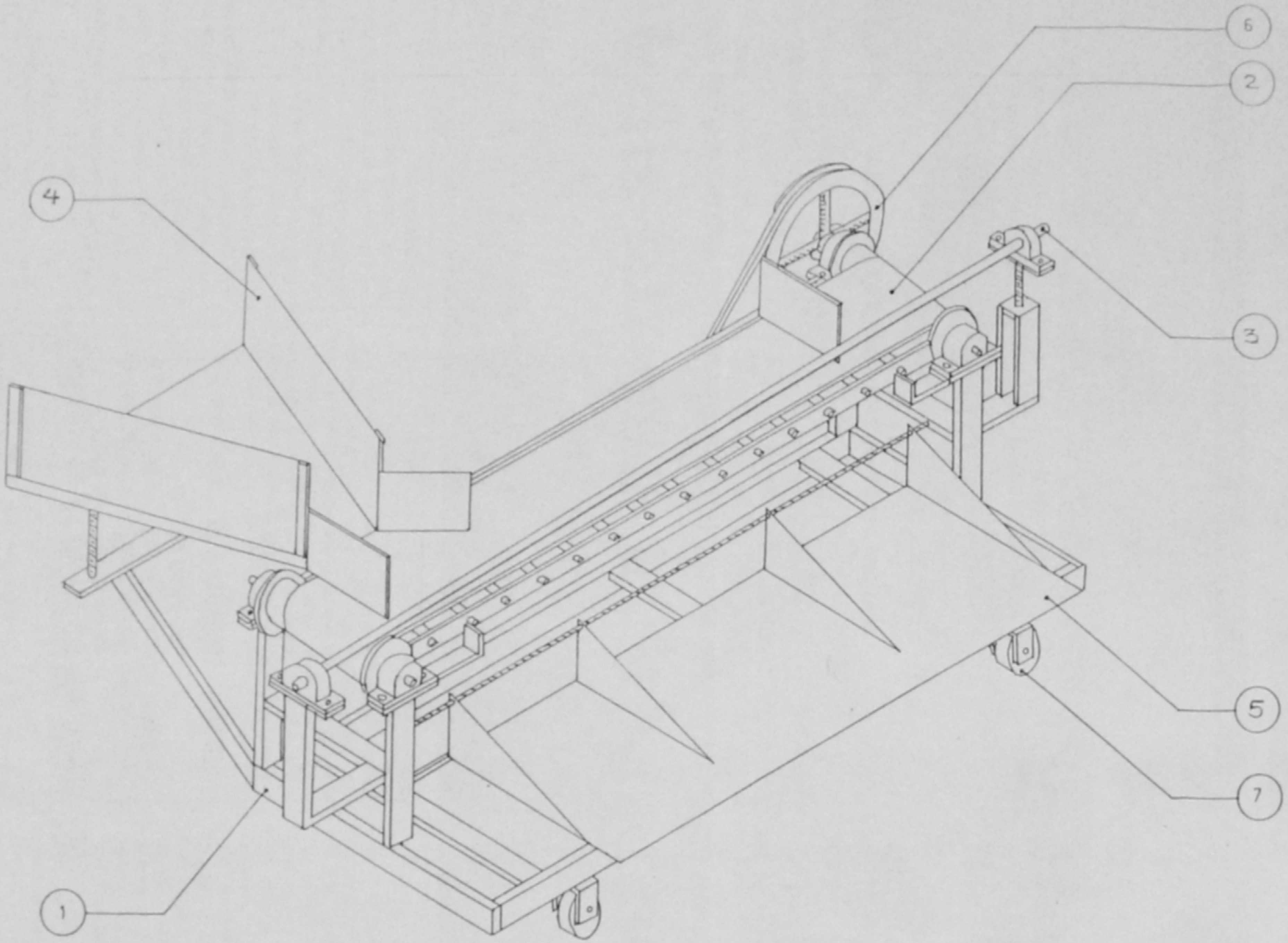


| | | | | | |
|---|---|---|---|---|---|
| 7 | 3.9 | Groundwheel | C | | |
| | | Nut | B | M. S. | 2 |
| | | Bolt | A | M. S. | 4 |
| | | Tilting adjustment device | | | |
| 6 | 3.8 | Power transmission unit | | | |
| 5 | 3.7 | Collection unit | | Cloth | 1 |
| 4 | 3.6 | Feeding hopper with guide/flap | C | GI | 1 |
| | | slope adjustment screw | B | MS | 3 |
| | | Feeding hopper | A | GI | 1 |
| | | Feeding unit | | | |
| 3 | 3.5 | Idler | | GI | 1 |
| 2 | 3.4 | Roller supporting frame | D | MS | 1 |
| | | Roller | C | MS | 14 |
| | | Drum roller | B | GI | 2 |
| | | Conveyor belt with roller frame assembly | A | | 1 |
| | | Grading conveyor belt | | | |
| 1 | 3.3 | Idler supporting main frame | B | MS | 1 |
| | | Hopper supporting main frame | A | MS | 1 |
| | 3.2 | Main frame | | MS | 1 |
| SR. No. | FIG. NO. | NAME OF FIG/PARTS | PARTS CODE | MAT. | QTY |

| | |
|---|---|
| Department of Agricultural Process Engineering, MPKV, Rahuri | |
| **Grading Machine** | |
| Scale : 1:10<br>All dimensions are in mm. | Fig. 3.1 |