

Effects of Forward Speed and Fruit Density on Picking and Collection Efficiency of a Neem Fruit Collector in Test Rig

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Manual neem fruit collection is labor-intensive, consuming 30% of harvesting time. This study assessed the impact of operational variables on picking efficiency, conveying efficiency, and the missing index in a mechanical neem fruit picker collector test rig. Findings showed that raising the forward speed from 1.5 km·h⁻¹ (S₁) to 2.0 km·h⁻¹ (S₃) led to a reduction in picking efficiency by 11.29, 11.97, and 12.64% for all the selected levels of fruit densities respectively. The picking efficiency was increased by 17.49, 20.14, and 16.49% with an increase in fruit density from F₁ to F₃. The elevation in forward speed from S₁ to S₃ resulted in 7.26, 3.28, and 4.37% reduction in collection efficiency. An increase in fruit density from F₁ to F₃ increases the collection efficiency by 8.24, 8.35, and 10.72%. It was also observed that 16.5, 23.6, and 25.6% increments in the missing index with an elevation in the forward speed from S₁ to S₃ at all the selected levels of fruit density. It was also noted that an increase in fruit density from F₁ to F₃ resulted in a gradual reduction in the missing index by 60.32, 44.56, and 42.85% at all levels of forward speed. Optimal performance was attained at a forward speed of 1.5 km·h⁻¹ (S₁) with a fruit density of 125 fruits per 0.1 m² (F₃), yielding 74.8% picking efficiency, 98.5% collection efficiency, and a 26.32% missing index. These optimal conditions are recommended for efficient and cost-effective neem fruit collection.

Keywords: Bristle, Fruit ejector, Ground picking and collection, Missing index, Neem harvesting

Introduction

Neem (*Azadirachta indica* A. Juss) is an evergreen tree native to the Indian subcontinent, exhibiting deciduous characteristics in drier areas and thriving in tropical regions.^{1,2} This tree has a lifespan of more than 200 years and demonstrates resilience by thriving in various soil types and adverse climatic conditions, excluding prolonged exposure to cold and freezing temperatures.^{3,4} Neem is predominantly propagated from seeds⁵ and seedlings that are four to six months old are ready for planting into the field.⁶ India stands as the foremost global producer of Neem having 14 million neem trees across the country, primarily from Tamil Nadu, Uttar Pradesh, and Karnataka^{7,8} contributing to an annual production of 4.4 lakh tonnes of neem, yielding 88,440 tonnes of oil and 3.5 lakh tonnes of cake.^{9,10} In Tamil Nadu, Virudhunagar and Thoothukudi districts claim the top two positions in neem plantation with 643 ha and 427 ha of

cultivation areas, respectively.¹¹ Neem serves multifaceted purposes such as soil conservation, ornamental use, providing shade, windbreaks, acting as an insecticide, producing oil and soap, serving as forage, and supplying fuel wood¹²⁻¹⁶ and it is also utilized in traditional Indian medicine as a household remedy for various ailments.¹⁷ Neem leaves are commonly used as dry-season fodder throughout India and in diverse areas within Asia.¹⁸ Additionally, neem seeds are a crucial source of non-edible vegetable oil and bio-pesticide compounds, housing various limonoids like Azadirachtin, Nimbin, Salanin, and Meliantriol.¹⁹⁻²¹ Structure of the Azadirachtin is similar to an insect hormone called ecdysones and it acts as a repellent.²² Azadirachtin offer a substantial volume of raw material for the pesticide industries.²³ The yield of neem oil extracted from seeds is approximately 20 to 25 percent, while the yield from kernels ranges from 40 to 50 percent.¹⁰ The flowering period of the neem varies depending on the location, typically occurring from January to May, with fruits ripening from May to August. Neem trees typically

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begin to bear fruit after 3 to 5 years and achieve peak productivity in about ten years.²⁴ By this time, they can produce up to 50 kg of fruits annually.²⁵ It is necessary to remove the pulp upon maturity to preserve the germination capacity of neem seeds.²⁶

Harvesting of neem fruits can be done either by ground picking, shaking off the tree or directly stripping from the branches. The conventional method of harvesting neem fruits includes collection of ground fallen fruits by hand and put into bucket, plastic bag or gunny bag normally by female labourers.²³ In some areas, farmers lay a polythene sheet or tarpaulin sheet under the tree canopy. When the wind blows, the ripened fruits along with leaves and twigs fall on the sheet and the fruits were separated and collected in gunny bags.²⁷ Manual collection of neem fruit from the ground is a time-consuming and arduous process and it takes almost 30% of harvesting time. A woman labour can collect up to 10 to 15 kg neem fruits per day at the wages of Rs. 250 per day.²⁸ The cost of collection of neem fruits from the ground (Rs. 30 kg⁻¹) surpasses the selling price of neem fruits (Rs. 25 kg⁻¹). Hence, it becomes unprofitable to collect the neem fruits by manual method. An attempt was made with engine operated pneumatic ground collection system using suction pressure to collect the neem fruit from ground¹¹ but, the collection capacity, performance and cost economics were not met as the area of collection was small. The curved teeth attached with the picking reel was used to collect the ground fallen blueberries.²⁹ As of now, there is no mechanical system available for collecting neem fruits from the ground. The performance and effectiveness of the collection of neem fruits from the ground are determined by both picking efficiency and collection efficiency. Hence, an investigation was conducted to study the influence of pertinent operational variables on picking efficiency, collection efficiency and missing index in an experimental test rig and to optimize these variables for the development of prototype mechanical neem fruit picker collector.

Materials and Methods

Laboratory evaluation was carried out at Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, Tiruchirappalli, India, during the year 2023–24 to examine the impacts of pertinent operational variables *viz.* forward speed and fruit

density that affect the picking and collection efficiencies and to optimize the variables for developing the prototype of mechanical type neem fruit picker collector.

Experimental Test Rig for Laboratory Evaluation

The experimental test rig with conveyor is commonly used for conducting seed uniformity test for testing the seed metering mechanism used in the seed drill.^{30–33} An experimental test rig^{34,35} (Fig. 1) used for investigating the effect of machine and operational variable on picking and collection efficiency was adopted and modified for investigating the influence of the selected levels of variables *viz.* Forward speed (S) and Fruit density (F) on the picking and collection of neem fruits and described below.

Conveyor Belt

The endless conveyor belt resembles a moving ground to the picker roller so that the fruits are made to move towards the picker assembly. A 2 mm thick polyurethane conveyor belt of length 8 m and breadth 0.3 m was fixed on the cylindrical rollers using the aluminium rivets. Speed of the conveyor belt was controlled by variable speed drive through 'V' belt drive.

Power Transmission

A 1 hp three – phase induction motor mounted on the right end of the main frame was powered by variable speed drive. The power was transmitted to the conveyor belt through the drive pulley of 3-inch (76 mm) diameter and the driven pulley of 12-inch (305 mm) diameter with a speed ratio of 4:1.



Fig. 1 — Developed experimental test rig

Variable Speed Drive

A Variable Speed Drive (VSD) is an electronic device that regulates the torque, speed, and direction of rotation of an induction motor. In this test rig, a variable speed drive was connected to a 1 hp three – phase induction motor. Speed and torque are the two major elements that are controlled by VSD. The speed and torque of the induction motor were controlled by adjusting the frequency and voltage of the power supply. In this experiment, selected levels of forward speed were achieved by this variable speed drive.

Picker Assembly

Picker assembly consisted of a picker roller made of Poly Vinyl Chloride (PVC) pipe as it is highly machinable and less expensive^{36,37} with nylon bristles for its flexibility³⁸ attached around its periphery. The picker roller of diameter 10 inch (250 mm) attached with 780 number of bristles was mounted on a frame using the cylindrical shaft with an operating width of 10 cm. The mechanical properties of the PVC pipe and nylon bristles are furnished in the Table 1.

Collector Assembly

Collector assembly consisted of a fruit ejector for removing the fruits from the picker roller and a collection box for collecting the neem fruits.

Fruit Ejector

Fruit ejector consists of an array of Mild Steel (MS) square rod and the same way mounted on the rear side of collection box. It consists of 9 numbers of 4 mm polished MS square rods of length 200 mm which were welded on a MS “L” angle with a dimension of 19 mm × 3 mm. These square rods were inclined at an angle of 50° to the horizontal plane and

were mounted in between each row of bristles so that the picked fruits were removed during the rotating motion of picker roller. The free end of the rods was bent inwards with a radius of curvature of 100 mm and sharpened, so that it can easily eject the fruits picked in between the bristle of the roller as well as for the smooth rotation of the roller.

Collection Box

The dimension of collection box of size 300 mm × 230 mm × 230 mm made of 19 mm × 3 mm MS “L” angle covered by MS sheets with 20-gauge thickness was mounted on a frame made of 10 mm square rod for adjusting in vertical and horizontal direction according to the size of the picker roller.

Experimental Design

Forward Speed (*S*)

The collection of the fruits from the ground depends on the forward speed the operation¹⁹, as time frame to complete one revolution of the picking surface varies with forward speed. The ground speeds *viz.* 1.2, 1.6 and 2.0 km·h⁻¹ were used for assessing the effect of the forward speed on picking efficiency for the collection of commercial wild blueberry.²⁹ The operating speed of 1.82 km·h⁻¹ and 1.84 km·h⁻¹ were found to be the average operating speed of manually operated seeder for cotton and castor seeds respectively.³⁹ Three different levels of operating speeds *viz.* 1.0 – 1.5, 1.5 – 2.0 and 2.0 – 2.5 km·h⁻¹ were selected for investigating the effect of forward speed on solar operated walking type power weeder.⁴⁰ In a laboratory study of evaluating the performance of manually operated cowpea precision planter, an operating speed of 2.1 km·h⁻¹ was used for determining the uniformity of seed spacing.⁴¹ Hence, to investigate the effect of forward speed on the selected parameters, three levels of forward speed *viz.* 1.5 km·h⁻¹, 1.75 km·h⁻¹, and 2 km·h⁻¹ were selected for the investigation. The forward speed levels were chosen based on the operating speed of manually operated machinery, as speeds below 1.5 km·h⁻¹ would reduce collection capacity.

Fruit Density (*F*)

The fruit density significantly influences the number of fruits picked per revolution thereby picking efficiency. More number of fruits could be picked when a greater number of fruits available per unit area. The density of ground fallen fruits per square meter per day increases gradually during the starting of the harvesting season and gradually reduces during

Table 1 — Mechanical properties PVC pipe and nylon bristles

Property	Values	
	PVC pipes	Nylon bristles
Ultimate tensile strength	52 MPa	38.6 – 170 MPa
Elongation at break	50 – 80%	2.30 – 450%
Short term creep rupture	44 MPa	—
Long term creep rupture	28 MPa	—
Elastic tensile modulus	3.0 – 3.3 GPa	0.210 – 4.10 GPa
Elastic flexural modulus	2.7 – 3.0 GPa	0.230 – 9.50 GPa
Long term creep modulus	0.9 – 1.2 GPa	—
Shear modulus	1.0 GPa	—
Bulk modulus	4.7 GPa	—
Poisson's ratio	0.4	0.380 – 0.450

Source: <https://www.vinidex.com.au/technical-resources/material-properties/pvc-properties/and>

https://www.matweb.com/search/datasheet_print.aspx?matguid=26386631ec1b49eeba62c80a49730dc4 (Accessed on 27 July 2024)

the end of the harvesting season. Hence, to minimize the number of operations during the season *i.e.* operation interval, three levels of fruit density (Fig. 2) *viz.* 75 fruits per 0.1 m², 100 fruits per 0.1 m² and 125 fruits per 0.1 m² were selected for the laboratory evaluation. Fruit density levels were determined by the maximum and minimum average densities of fallen fruits during peak harvest.

Levels of Variables

The levels of variables that were selected for the investigation are as follows.

- i. Forward speed (S) - 3 levels
 1. 1.5 km·h⁻¹ - S₁
 2. 1.75 km·h⁻¹ - S₂
 3. 2.0 km·h⁻¹ - S₃
- ii. Fruit density (F) - 3 levels
 1. 75 fruits per 0.1m² - F₁
 2. 100 fruits per 0.1m² - F₂
 3. 125 fruits per 0.1m² - F₃

Replications (R) = 3

Total number of treatments = S × F × R
 = 3 × 3 × 3
 = 27 treatments

Functioning of Experimental Test Rig

A rectangular mark of dimension of cm (0.1 m²) was drawn on the conveyor belt (Fig. 2). The neem fruits were uniformly laid on the rectangular mark with selected levels of fruit density (F₁). The optimized levels of Picker roller of the diameter 250 mm (10") with 30 mm length of bristles was mounted on the conveyor belt and the position of collector assembly was adjusted both vertically and horizontally in order to place the fruit ejector in between the bristles of the roller. The conveyor belt

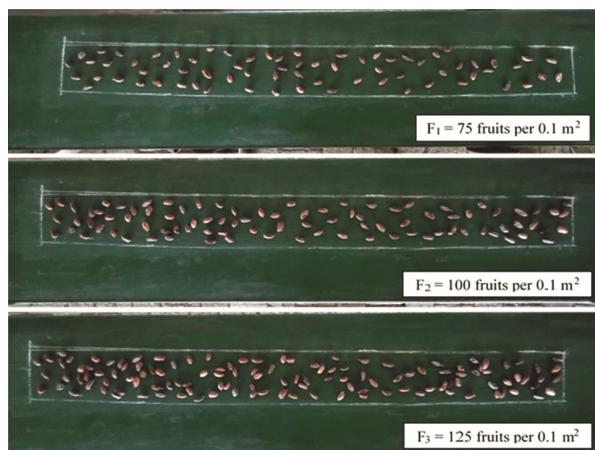


Fig. 2 — Three levels of the fruit density (F₁, F₂, F₃)

was driven in three selected levels of forward speed using variable speed drive. As the conveyor belt moves, picker roller rotate in opposite direction thereby fruits were picked up by the roller. The picked fruits were conveyed to the fruit ejector in which the fruits were removed from the roller and collected in the collection box. The collected fruits were counted and recorded. The uncollected fruits remain in the fruit ejector and unpicked fruits left on the conveyor were also counted and recorded. The same procedure was repeated for all the treatments.

Evaluational Parameters

The effectiveness of the picking and collection of neem fruit was evaluated by the parameters such as the picking efficiency, collection efficiency and missing index.

Picking Efficiency (η_p)

Picking efficiency (η_p) can be defined as the number of fruits picked up to the total number of fruit laid on the conveyor belt. Picking efficiency can be calculated using the following Eq. (1).⁽³⁴⁾

$$\text{Picking efficiency } (\eta_p), \% = \frac{N_p}{N_T} \times 100 \quad \dots (1)$$

where, N_T = Total number of fruits laid on the conveyor; N_p = Number of fruits picked by the picker roller.

Collection Efficiency (η_c)

Collection efficiency (η_c) can be defined as the number of fruits collected in the collection box to the number of fruits picked by the picker roller. Collection efficiency can be determined using the following Eq. (2)⁽³⁴⁾

$$\text{Collection efficiency } (\eta_c), \% = \frac{N_c}{N_p} \times 100 \quad \dots (2)$$

where, N_c = Number of fruits collected in the collection box; N_p = Number of fruits picked by the picker roller; N_T = Total number of fruits laid on the conveyor.

Missing Index (Mi)

Missing index (M_i) can be defined as the sum of unpicked fruits (N_{up}) and uncollected fruits (N_{uc}) to the total number of fruits laid on the conveyor (N_T). Missing index can be calculated using the following Eq. (3)⁽⁴²⁾

$$\text{Missing index } (M_i), \% = \frac{N_{up} + N_{uc}}{N_T} \times 100 \quad \dots (3)$$

where, N_{up} = Number of unpicked fruits; N_{uc} = Number of uncollected fruits; N_T = Total number of fruits laid on the conveyor.

A total number of 27 experiments were carried out using the experimental test rig with the selected levels of variables. The picking efficiency and collection efficiency for picking and collection of neem fruit were recorded for all the treatments of investigation. The data were analysed using a statistical package called ‘Minitab’ to obtain the much-needed analysis of variance of mean and interaction of the selected independent variables such as forward speed (S) and fruit density (F) over the selected dependent variables. In order to achieve maximum picking efficiency and collection efficiency, the levels of variables were optimized.

Results and Discussion

Effect of Forward Speed (S) and Fruit Density (F) on Picking Efficiency

The recorded values of picking efficiency for the selected levels of forward speed (S) at selected levels of fruit density (F) are furnished in Table 2 and depicted in Fig. 3.

An increase in forward speed from 1.5 km·h⁻¹ (S₁) to 2 km·h⁻¹ (S₃) was observed to reduce the picking efficiency by 11.29, 11.97 and 12.64% for the selected levels of fruit density of 75 fruits per 0.1 m² (F₁), 100 fruits per 0.1 m² (F₂) and 125 fruits per 0.1 m² (F₃) respectively. This may be due to the fact that increase in forward speed reduces the time to pick the fruits from the conveyor which in turn reduces the picking efficiency. It was also noticed that picking

efficiency was increased by 17.49, 20.14 and 16.49% with increase in fruit density from 75 fruits per 0.1 m² (F₁) to 125 fruits per 0.1 m² (F₃) at all selected levels of forward speed. It was obvious that increased number of fruits per 0.1 m² increases the picking of neem fruits from the conveyor. The lowest picking efficiency of 54.96% was observed at a forward speed of 2 km·h⁻¹ (S₃) with fruit density of 75 fruits per 0.1 m² (F₁), while the highest picking efficiency of 74.13 % occurred at a forward speed of 1.5 km·h⁻¹ (S₁) with a fruit density of 125 fruits per 0.1 m² (F₃). However, 94.73% of picking efficiency was noticed with the suction type pneumatic ground collection system.¹⁸ The reason for the higher picking efficiency with the suction system may be due to the narrow area the picking duct besides engine power.

Effect of Forward Speed (S) and Fruit Density (F) on Collection Efficiency

The recorded values of collection efficiency for the selected levels of forward speed (S) at selected levels

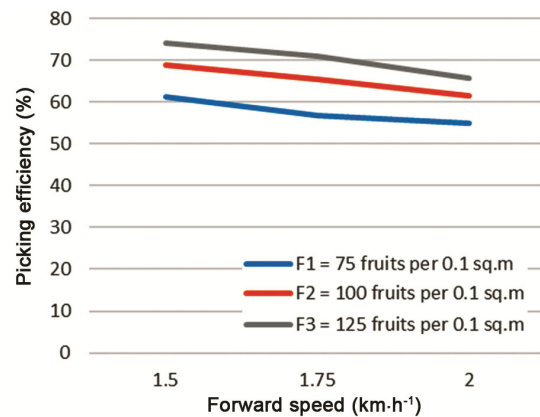


Fig. 3 — Effect of forward speed and fruit density on picking efficiency

Table 2 — Effect of forward speed and fruit density on picking efficiency

S.No	Fruit density (No. of fruits in 0.1 m ²)	Picking efficiency (%)			Mean
		R ₁	R ₂	R ₃	
S ₁ = 1.5 km·h ⁻¹					
1	75	62.00	61.50	60.00	61.17
2	100	71.20	69.00	66.50	68.90
3	125	73.60	74.80	74.00	74.13
S ₂ = 1.75 km·h ⁻¹					
1	75	55.61	57.00	57.33	56.65
2	100	65.00	65.00	66.00	65.33
3	125	69.80	70.00	73.00	70.93
S ₃ = 2.0 km·h ⁻¹					
1	75	53.89	56.50	54.50	54.96
2	100	60.00	62.60	62.00	61.53
3	125	66.60	65.85	65.00	65.82

Table 3 — Effect of forward speed and fruit density on collection efficiency

S.No	Fruit density (No. of fruits in 0.1 m ²)	Collection efficiency (%)			Mean
		R ₁	R ₂	R ₃	
S ₁ = 1.5 km.h ⁻¹					
1	75	88.00	86.75	95.00	89.92
2	100	93.00	95.06	97.25	95.10
3	125	97.50	98.50	98.00	98.00
S ₂ = 1.75 km.h ⁻¹					
1	75	87.85	88.30	85.50	87.22
2	100	94.50	92.00	90.75	92.42
3	125	95.50	95.00	95.00	95.17
S ₃ = 2.0 km.h ⁻¹					
1	75	84.50	83.00	84.00	83.83
2	100	92.25	92.00	92.00	92.08
3	125	94.50	93.20	94.00	93.90

of the fruit density (F) are furnished in Table 3 and depicted in Fig. 4.

It was observed that the elevation of forward speed from 1.5 km.h⁻¹ (S₁) to 2 km.h⁻¹ (S₃) caused a reduction in collection efficiency by 7.26, 3.28 and 4.37% for the selected levels of fruit density of 75 fruits per 0.1 m² (F₁), 100 fruits per 0.1 m² (F₂) and 125 fruits per 0.1 m² (F₃) respectively. It may be due to the fact that increase in forward speed reduces the collection time of neem fruits from the picker roller which reduces the collection efficiency. It was also noticed that collection efficiency was increased by 8.24, 8.35 and 10.72% with increase in fruit density from 75 fruits per 0.1 m² (F₁) to 125 fruits per 0.1 m² (F₃) at all selected levels of forward speed. This may be due to the fact that increased number of fruits increases the collection of neem fruits from the picker roller. The minimum value of collection efficiency of 83.83% was observed at a forward speed of 2 km.h⁻¹ (S₃) with fruit density of 75 fruits per 0.1 m² (F₁), whereas 98% was observed as maximum collection efficiency at a forward speed of 1.5 km.h⁻¹ (S₁) with the fruit density of 125 fruits per 0.1 m² (F₃). Collection efficiency of 77.1 % was noticed with the suction type pneumatic ground collection system.³⁴ The fruit ejector in the mechanical type ground collection of neem fruits ensures more positive collection after picking the neem fruits.

Effect of Forward Speed (S) and Fruit Density (F) on Missing Index

The recorded values of missing index for the selected levels of forward speed (S) at selected levels of fruit density (F) are furnished in Table 4 and depicted in Fig. 5.

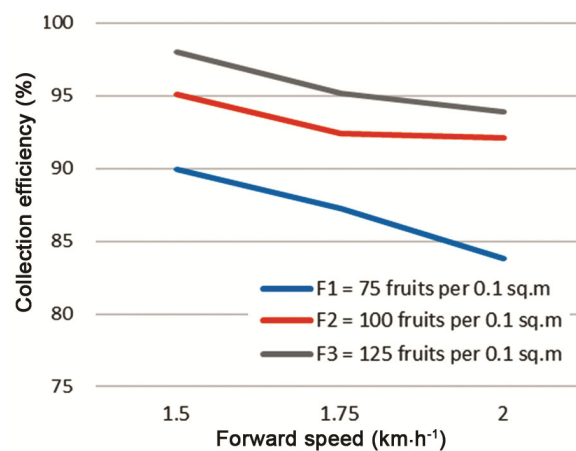


Fig. 4 — Effect of forward speed and fruit density on collection efficiency

It was observed that an increase in forward speed from 1.5 km.h⁻¹ (S₁) to 2 km.h⁻¹ (S₃) resulted in a corresponding increase in the missing index by 16.5, 23.6 and 25.6% for fruit density of 75 fruits per 0.1 m² (F₁), 100 fruits per 0.1 m² (F₂) and 125 fruits per 0.1 m² (F₃) respectively. This trend can be attributed to the elevated number of missed neem fruits at higher forward speeds. Conversely, as fruit density increased from 75 to 125 fruits per 0.1 m² (F₁ to F₃), the missing index gradually decreased by 60.32, 44.56 and 42.85% across all the tested forward speeds. This reduction is linked to an increased number of picked fruits and consequently, few missed fruits at higher fruit density. The minimum missing index of 28.09% was observed at a forward speed of 1.5 km.h⁻¹ (S₁) and a fruit density of 125 fruits per 0.1 m² (F₃), while the maximum of 53.93% missing index was occurred at a forward speed of 2 km.h⁻¹ (S₃) and a fruit density of 75 fruits per 0.1 m² (F₁).

Table 4 — Effect of forward speed and fruit density on missing index

S.No.	Fruit density (No. of fruits in 0.1 m ²)	Missing index (%)			Mean
		R ₁	R ₂	R ₃	
S ₁ = 1.5 km·h ⁻¹					
1	75	45.44	46.65	43.00	45.03
2	100	33.78	34.41	35.33	34.51
3	125	28.24	26.32	29.70	28.09
S ₂ = 1.75 km·h ⁻¹					
1	75	51.15	49.67	50.98	50.60
2	100	38.58	40.20	40.11	39.63
3	125	37.88	34.66	32.48	35.00
S ₃ = 2.0 km·h ⁻¹					
1	75	54.46	53.11	54.22	53.93
2	100	46.30	44.91	44.29	45.17
3	125	40.06	36.20	37.00	37.75

Table 5 — ANOVA for selected levels of variables

S.No	Variables	DoF	Picking efficiency		Collection efficiency		Missing index	
			MS	F - value	MS	F - value	MS	F - value
1.	Forward speed (S)	2	119.79	64.88**	44.45	13.43**	216.55	93.96**
2.	Fruit density (F)	2	368.19	199.42**	180.70	54.57**	604.85	262.45**
	Error	22	—	—	—	—	—	—
	Total	26	—	—	—	—	—	—

***' p < 0.01 '**'p < 0.05 'ns' not significant ; MS – Mean Square ; DoF – Degree of Freedpm

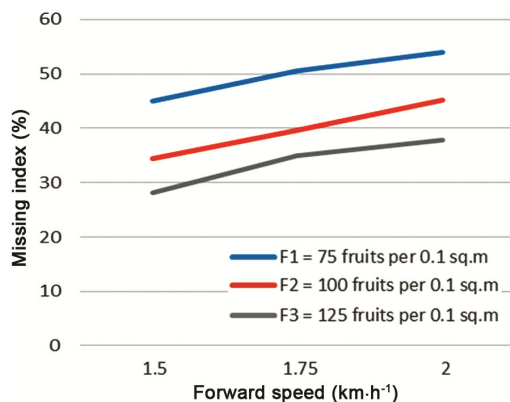


Fig. 5 — Effect of forward speed and fruit density on missing index

The Analysis of Variance (ANOVA) obtained using “Minitab” software is furnished in Table 5.

The operational parameters such as Forward speed (S), Fruit density (F) were significantly affecting the evaluational parameters viz., picking efficiency, collection efficiency and missing index. The individual effects of the selected variables were highly significant at 1% level of probability for all the evaluational parameters.

Linear Regression Model

The multiple linear regression equation for the impact of forward speed and fruit density over

picking efficiency (Eq. 4), collection efficiency (Eq. 5) and missing index (Eq. 6) are as follows and also depicted graphically in Fig. 6.

$$Y_1 = 34.514 + 25.404(X_1) - 0.145(X_2) \quad \dots (4)$$

$$R^2 = 0.949**$$

$$R^2(\text{adjusted for } DF) = 0.945**$$

(** Significant at 1 %level)

$$Y_2 = 70.31 + 17.40(X_1) - 0.080(X_2) \quad \dots (5)$$

$$R^2 = 0.817*$$

$$R^2(\text{adjusted for } DF) = 0.802*$$

(* Significant at 5 % level)

$$Y_3 = 78.426 + 32.475(X_1) - 0.194(X_2) \quad \dots (6)$$

$$R^2 = 0.952*$$

$$R^2(\text{adjusted for } DF) = 0.948*$$

(*Significant at 5 %level)

where, Y₁ = Picking efficiency (%); Y₂= Collection efficiency (%); Y₃ = Missing index (%); X₁= Forward speed (km·h⁻¹); X₂=Fruit density (No. of fruits in 0.1 m²).

It was noticed that the R-square value of 0.949 (Eq. 4) was significant at 1% level of probability on picking efficiency and the R-square value of 0.817 (Eq. 5) and 0.952 (Eq. 6) were significant at 5% level of probability on collection efficiency and missing index respectively.

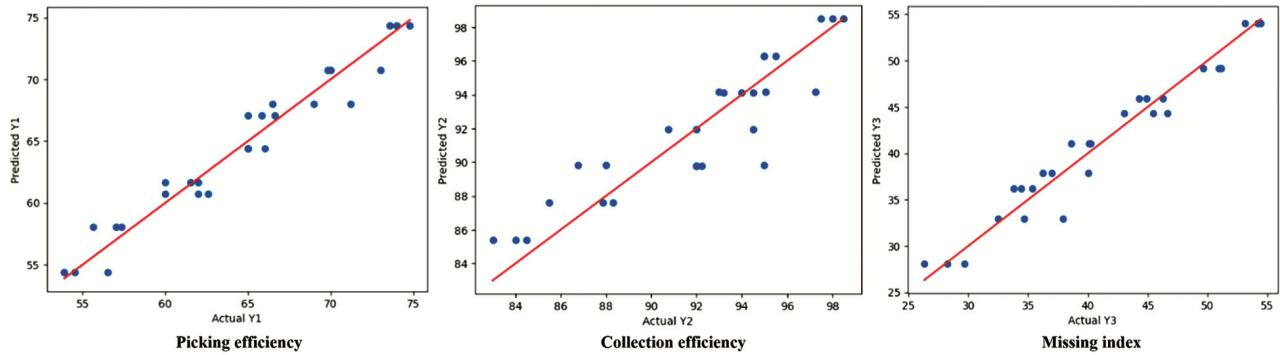


Fig. 6 — Linear regression model for the effect of forward speed and fruit density

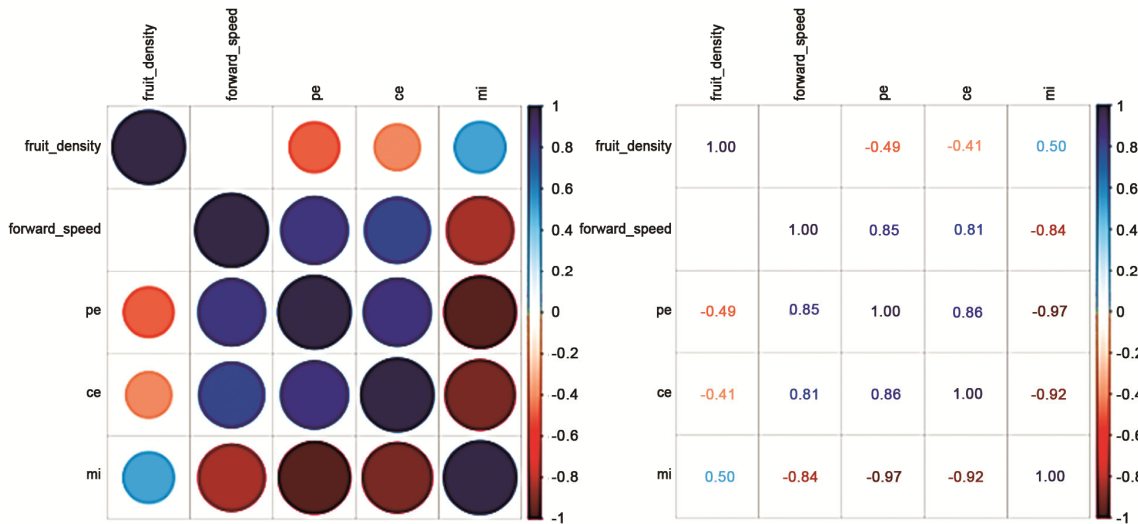


Fig. 7 — Correlation plot for the impact of fruit density and forward speed

Correlation Plot

In statistical analysis, a correlation plot (also known as a scatterplot matrix) was used to visualize the relationships between multiple variables in a data set. The following correlation plot (Fig. 7) depicts the impact of forward speed and fruit density over picking efficiency, collection efficiency, and missing index.

From the Fig. 7, it was observed that forward speed (S) was positively correlated and there was no negative correlation, so it proves that the selected levels of forward speed were significantly affecting the picking efficiency and collection efficiency whereas, for missing index, S shows a negative correlation which proves that the selected levels of forward speed were not significantly affecting the missing index.

It was observed that fruit density (F) showed a negative correlation on both picking and collection

Table 6 — Combinations of variables with optimized values

S. No	Evaluational parameters	Combination levels of variables	Value, %
i	Picking efficiency, %		74.8
ii	Collection efficiency, %	S ₁ – F ₃	98.5
iii	Missing index, %		26.32

efficiency, so it proves that the selected levels of fruit density were not significantly affecting the picking efficiency and collection efficiency whereas, for missing index, F shows a positive correlation which proves that the selected levels of fruit density were significantly affecting the missing index.

The treatment with the combination of selected variables that resulted in desired output was selected as optimized combination levels of the variables which are furnished in Table 6. The view of the developed prototype mechanical type neem picker collector based on optimized parameters is shown in Fig. 8.



Fig. 8 — Developed prototype mechanical type neem picker collector

Conclusions

The investigation assessed the influence of forward speed and fruit density on picking efficiency, conveying efficiency and missing index using an experimental test rig. The maximum picking efficiency of 74.8%, maximum collection efficiency of 98.5% and minimum missing index of 26.32% were optimized for the combination of $1.5 \text{ km}\cdot\text{h}^{-1}$ forward speed (S_1) with a fruit density of 125 fruits per 0.1 m^2 (F_3). The picking efficiency of the device could be increased by changing the bristle material with less flexibility than the nylon rope. The performance of the device could be increased by the increasing the length and diameter of the picker roller. The collection box made of MS material may be replaced with plastic to reduce the overall weight of the device. The device may be scaled up and attached to the mini tractor for the larger coverage suitable for neem plantations.

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