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Optimization of operating parameters under laboratory conditions for a sensor-based tractor drawn ginger rhizome planter

T Mahesh Babu and Preman PS

Abstract
The functionality of the seed metering mechanism for sensor-based tractor drawn ginger planter occurred in a laboratory setting, aiming to enhance the design and operational factors for ginger rhizome planting. The impact of operating forward speed, cell sizes and speed of chain were evaluated by examining the mean seed spacing, missing index, multiple index, quality of feed index and cell fill efficiency. For picking the single seed based on different cell sizes are 40, 50, 60 mm, forward speed 1, 1.5, 2 km h^{-1} and peripheral speed is 1:7 (127 rpm), 1:8 (138 rpm) and 1:9 (149 rpm). The seeding mechanism of the planter was configured to deposit the seeds at 15-20 cm spacing. Observations revealed that the forward speed 1.5 km h^{-1}, 50 mm cell size and peripheral speed is 1:8 rpm, this combination gave the superior performance compare to other speeds are 1, 2 km h^{-1} and 40, 60 mm cell sizes. Lower misses were observed by using 40 mm cell size at lowest forward speed, lowest peripheral speed and higher multiples were observed by using 60 mm cell size at higher peripheral speed and forward speed. The metering system with a forward speed of 1.5 km h^{-1}, 5 mm cell size and peripheral speed is 1:8 (138 rpm) was produced superior results with a quality feed index was 91.56% and recording mean seed spacing of 15-20 cm.

Keywords: Missing index, multiple index, cell sizes, quality of feed index and cell fill efficiency

1. Introduction

Planting is the act of positioning individual seeds in the soil with specified intervals. For this accuracy, plant scientists frequently utilize hand dibbling to attain this level of precision (Khadatkar *et al.*, 2018) [6]. Precision planters are characterized by inclusion of single seed metering mechanisms in their sowing apparatus.

While horizontal seed metering was popular and widely utilized. (Datta, 1974) [3] developed the first precision planter, featured horizontal plate designs with peripheral cells. But challenges are arisen with higher seed damage, missing and multiple drops will be more. In order to minimize these losses by using cup feed type metering mechanism were developed and used (Shafii & Holmes, 1990; Guarella *et al.*, 1996) [8, 4]. This system offers the benefit of accurately metering seeds with irregular seeds, in addition to spherical seeds. The most widely used planters have vertical type metering mechanism that allow them to distribute the single seeds in furrows according to the desired plant spacing.

The average dimension of ginger, obtained by cutting with two budded rhizomes, is 50 mm. In this context, it is crucial to explore various cell sizes are 40 mm, 50 mm and 60 mm to optimize the overall cell size for minimizing issues such as missing, multiple instances, and ensuring high-quality feed. Additionally, this optimization aims to enhance cell fill efficiency for improved productivity and performance.

The mechanism either selects or drops numerous seeds, causing little space between seeds, fails to select or drops a single seed resulting in a huge spacing between seeds. In order to achieve precise seed spacing, it is essential to optimize various parameters that influence the seed placement, tailored to the specific size of the seed such as: i) Shape of the seed and size of cup ii) Speed of chain, forward speed to regulate the seed spacing and revealed that forward speed is 1.5 km h^{-1} was consistently produced superior performance than 1 km h^{-1}, 2 km h^{-1} and peripheral speed is 1:8 (139 rpm) for the precision of sowing of ginger rhizomes.

The performance metrics of a planter, multiple index, miss index, quality of feed index and cell fill efficiency, were computed using the measured spacing between the deposited rhizomes as a reference point (Kachman and smith 1995) [5], (AI-Gaadi, 2011) [1] were calculated by the following calculations.

2. Materials and Methods

An experimental laboratory set up has been devised to investigate the performance of the single cell by using cup feed type metering mechanism. Forward speed (S), Peripheral speed (V) and Cell size (C) were selected to finding picking efficiency as well as evaluate the missing index, multiple index, quality of feed index and cell fill efficiency. Sand witch nylon type grease coated belt test setup was comprises of a mainframe, seed hopper, conveying chain with cups and 6-meter length of sticky belt, AC motor (1hp), DC motor (350 W) and variable frequency drive (VFD).

The mainframe was a rectangular section of 3000 x 850 mm made of a 40x40x3mm gi square pipe. The rectangular section was fixed at a height of 900 mm from ground surface and is supported by a 50 x 50 x 5 mm mild steel angle iron and the same angle iron was fixed at each corner of the four sides for supporting. The planter seed metering unit was mounted on the sticky belt experimental set-up with the power transmitting unit. An endless sand witch nylon type conveyor belt 3000 x 400 x 2 mm, length, width and thickness respectively. It was rotated through a pair of rollers of 80 mm diameter. Self-aligning bearings were utilized at both ends of the rectangular section to support rollers with an 80 mm diameter, which were mounted on 20 mm diameter shafts. The conveyor belt was powered by 1 hp AC motor, which is connected to an 80 mm diameter roller connected through chain and sprockets. A rotary encoder was fixed at the ground wheel shaft to count the number of revolutions and the output signals sends to dc motor through citron 30 Amp dc motor driver. USB cable was connected between the laptop and Arduino nano, then the spacing between rhizomes continuously displayed on LCD. To control the linear speed of the belt, AC motor speed was linked to a variable frequency drive (VFD) unit. A speed controller was employed to manage the speed of the DC motor and its speed was monitored using a non-contact type tachometer with the range of 0-1000 rpm. Grease was uniformly applied across the entire length of the belt to adhere the seeds, facilitating the measurement of seed spacing and other performance parameters.

Fig 1: DC geared motor

Fig 2: Rotary shaft encoder

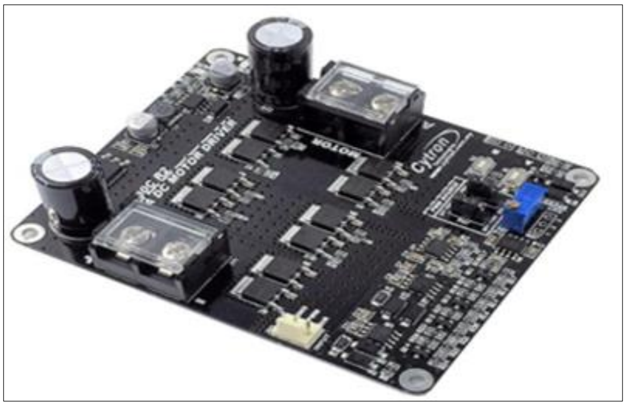


Fig 3: Cytron 30 Amp Dc motor driver

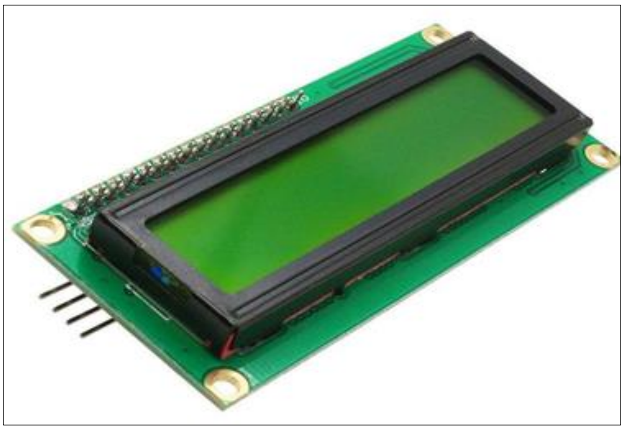


Fig 4: LCD display

Fig 5: Different cell sizes

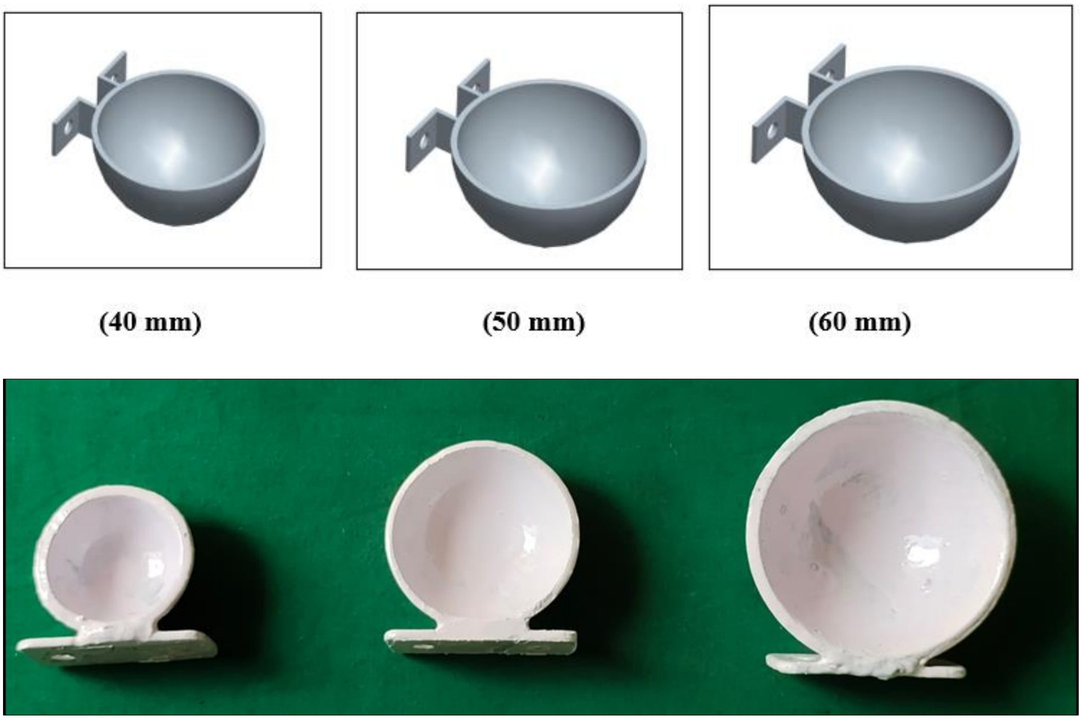


Fig 5: Different cell sizes

(a)

```
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,20,4);

// Motor encoder output pulse per rotation (change as required)
#define ENC_COUNT_REV 400

// Encoder output to Arduino Interrupt pin
#define ENC_IN 3

// MD10C PWM connected to pin 10
#define PWM 10
// MD10C DIR connected to pin 12
#define DIR 7

// Analog pin for potentiometer
int speedcontrol = 0;

// Pulse count from encoder
volatile long encoderValue = 0;

// One-second interval for measurements
int interval = 500;

// Counters for milliseconds during interval
long previousMillis = 0;
long currentMillis = 0;
```

(b)

```
// Variable for RPM measuerment
float rpm = 0;

// Variable for PWM motor speed output
int motorPwm = 0;
int motorPwm1 =6;
int motorPwm2 =9;
int motorPwm3 = 13;
int motorPwm4 =14;
int motorPwm5 =19;
int motorPwm6 =20;
int motorPwm7=26;
int motorPwm8=29;
int motorPwm9 =32;
int motorPwm10 =34;
int motorPwm11 =39;
int motorPwm12=42;
int motorPwm13 =46;
int motorPwm14 =49;
int motorPwm15 =52;
int motorPwm16 =55;
int motorPwm17=59;
int motorPwm18=62;
```

(c)

```
int motorPwm19 =65;
int motorPwm20 =68;
int motorPwm21 =70;
int motorPwm22=74;
int motorPwm23 =77;
int motorPwm24 =80;
int motorPwm25 =85;
int motorPwm26 =87;
int motorPwm27=88;
int motorPwm28=94;
int motorPwm29 =97;
int motorPwm30 =101;
int motorPwm31 =104;
int motorPwm32=107;
int motorPwm33 =111;
```

(d)

```
void setup()
{
 // Setup Serial Monitor
 Serial.begin(9600);
 lcd.clear();
 lcd.init();
 lcd.backlight();
 lcd.setCursor(3,0);
  lcd.print("A SENSOR BASED");
  lcd.setCursor(3,1);
  lcd.print(" TRACTOR DRAWN ");
  lcd.setCursor(3,2);
  lcd.print("GINGER PLANTER");
  delay(1000);
  lcd.clear();
 // Set encoder as input with internal pullup
 pinMode(ENC_IN, INPUT_PULLUP);

 // Set PWM and DIR connections as outputs
 pinMode(PWM, OUTPUT);
 pinMode(DIR, OUTPUT);

 // Attach interrupt
 attachInterrupt(digitalPinToInterrupt(ENC_IN), updateEncoder, RISING);

 // Setup initial values for timer
 previousMillis = millis();
}
void loop()
{
 digitalWrite(DIR,LOW);
```

(e)

```
currentMillis = millis();
if (currentMillis - previousMillis > interval) {
 previousMillis = currentMillis;
 rpm = (float)(encoderValue *120 / ENC_COUNT_REV);
if (rpm > 0) {

  Serial.print("PWM VALUE: ");
  Serial.print(motorPwm);
  Serial.print('\t');
  Serial.print(" PULSES: ");
  Serial.print(encoderValue);
  Serial.print('\t');
  Serial.print(" SPEED: ");
  Serial.print(rpm);
  Serial.println(" RPM");
 }
```

(f)

```
 encoderValue = 0;
}

if (rpm >=1)
{
 analogWrite(PWM,motorPwm1);
}
else
{
 analogWrite(PWM,motorPwm);
}
if(rpm>=2)
{
 analogWrite(PWM,motorPwm2);
}
else
{
 analogWrite(PWM,motorPwm);
}
```

```
if(rpm>=3)
{
analogWrite(PWM,motorPwm3);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=4)
{
analogWrite(PWM,motorPwm4);
}
else
{
analogWrite(PWM,motorPwm);
```

(g)

```
if(rpm>=5)
{
analogWrite(PWM,motorPwm5);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=6)
{
analogWrite(PWM,motorPwm6);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=7)
{
analogWrite(PWM,motorPwm7);
}
else
{
```

(h)

```
analogWrite(PWM,motorPwm);
}
if(rpm>=8)
{
analogWrite(PWM,motorPwm8);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=9)
{
analogWrite(PWM,motorPwm9);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=10)
{
analogWrite(PWM,motorPwm10);
}
else
{
analogWrite(PWM,motorPwm);
```

(i)

```
if(rpm>=11)
{
analogWrite(PWM,motorPwm11);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=12)
{
analogWrite(PWM,motorPwm12);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=13)
{
analogWrite(PWM,motorPwm13);
}
else
{
analogWrite(PWM,motorPwm);
}
```

(j)

```
if(rpm>=14)
{
analogWrite(PWM,motorPwm14);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=15)
{
analogWrite(PWM,motorPwm15);
}
else
{
analogWrite(PWM,motorPwm);
}

if(rpm>=16)
{
analogWrite(PWM,motorPwm16);
}
else
```

(k)

```
{
analogWrite(PWM,motorPwm);
}
if(rpm>=17)
{
analogWrite(PWM,motorPwm17);
}
else
{
analogWrite(PWM,motorPwm);
}
if (rpm >=18)
{
analogWrite(PWM,motorPwm18);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=19)
{
analogWrite(PWM,motorPwm19);
}
else
{
analogWrite(PWM,motorPwm);
}
```

(l)

```
if(rpm>=20)
{
analogWrite(PWM,motorPwm20);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=21)
{
analogWrite(PWM,motorPwm21);
}
else
{
analogWrite(PWM,motorPwm);
}

if(rpm>=22)
{
analogWrite(PWM,motorPwm22);
}
else
```

(m)

```
{
analogWrite(PWM,motorPwm);
}

if(rpm>=23)
{
analogWrite(PWM,motorPwm23);
}
else
{
analogWrite(PWM,motorPwm);
}
if(rpm>=24)
{
analogWrite(PWM,motorPwm24);
}
else
{
analogWrite(PWM,motorPwm);
}
```

(n)

```
if(rpm>=25)
{
analogWrite(PWM,motorPwm25);
}
else
{
analogWrite(PWM,motorPwm);
}

if(rpm>=26)
{
analogWrite(PWM,motorPwm26);
}
else
{
analogWrite(PWM,motorPwm);
}
}

void updateEncoder()
{
// Increment value for each pulse from encoder
encoderValue++;
}
```

(o)

Fig 6: Arduino Nano program for a sensor based tractor drawn ginger planter

Electronic programs for measuring rhizome spacing in planting are invaluable tools in modern agriculture. They enable precise and consistent spacing between rhizomes, optimizing resource utilization and promoting uniform crop growth. By automating measurements, these programs save time and reduce labour costs while also facilitating early problem detection. They provide data for analysis and decision-making, helping farmers refine their planting techniques and enhance overall crop management. Whether on small or large scales, electronic programs for rhizome spacing improve efficiency, yield, and profitability, making them essential for precision agriculture and sustainable farming practices.

(A) (B)

(40 mm) (50 mm) (60 mm)

Fig 8: Different cell sizes with ginger rhizomes

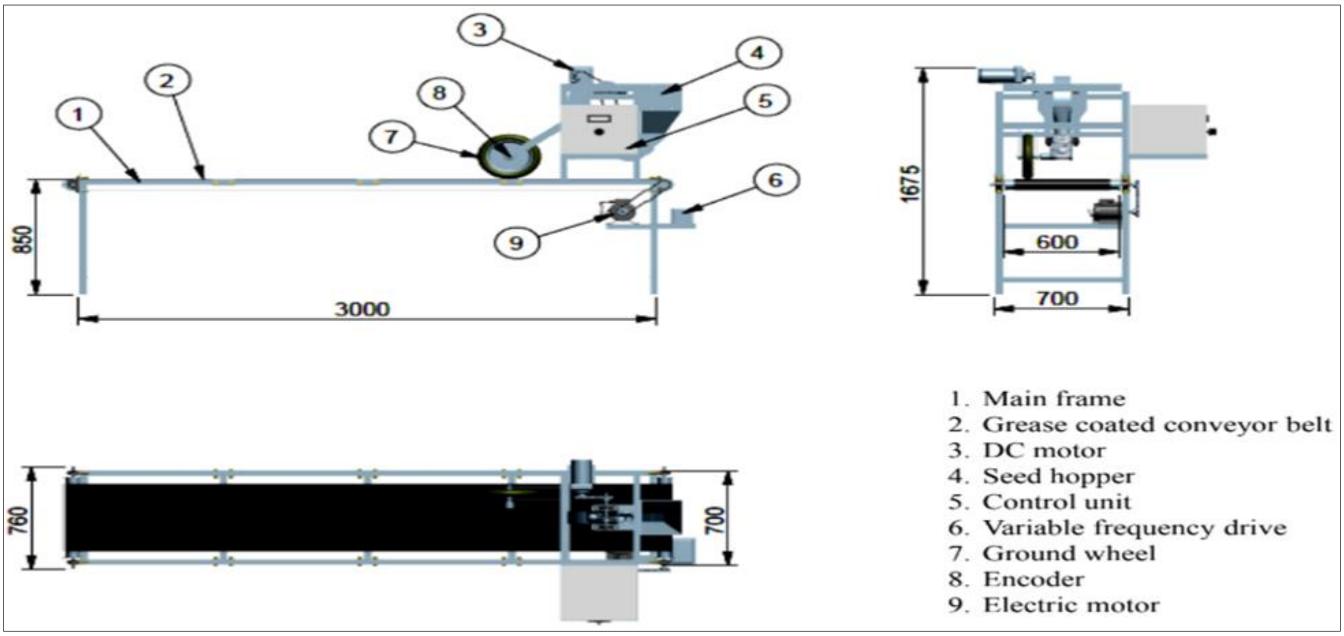


Fig 9: Schematic view of the laboratory set up for the sensor-based tractor drawn ginger planter

Fig 10: Developed laboratory set up for the sensor-based tractor drawn ginger planter

2.1.1 Missing index

Miss index (I_{miss}) skips are created when seed cells are fails to pick-up the seed and deliver the seeds into delivery tubes. This refers to the percentage of spacing exceeding 1.5 times the standard value, the theoretical spacing S in mm. (Singh, *et al.* 2005 [9]; Bakhtiari and Loghavi, 2009 [2] and Madhu Kumar, 2017) [7].

$$I_{miss} = \frac{n_1}{N} \times 100$$

Where,
n_1 = Number of spacing in the region > 1.5 S
N = Total number of observations

2.1.2. Multiple index

Multiple index (I_{mult}) serves as an indicator for instances where more than one seed is deposited within the desired spacing. It is calculated as the percentage of spacing intervals that are equal to or less than half of the theoretical spacing S in mm. (Singh, *et al.* 2005 [9]; Bakhtiari and Loghavi, 2009 [2] and Madhu Kumar, 2017) [7].

$$I_{miss} = \frac{n_2}{N} \times 100$$

Where,
n_1 = Number of spacing in the region ≥ 0.5 S
N = Total number of observations

2.1.3 Quality of feed index

Quality of feed index (I_{fq}) quantifies the frequency with which spacing closely matches the theoretical spacing. It represents the percentage of spacing intervals that fall within the range of more than half but not exceeding 1.5 times the theoretical spacing S in mm. The mathematical expression for the quality of feed index is as follows: (Kachman and Smith, 1995) [5].

$I_{fq} = 100 - (I_{miss} + I_{mult})$
Where,
Imiss – Missing index
Imult – Multiple index

2.1.4 Cell fill efficiency

Per cent cell fill for a given planter is influenced by such factors as the diameter of the cell, speed of the metering mechanism and size of seeds are picked. The shape and size uniformity of seed cells, the duration of cell is exposed to seeds within the picking chamber of rhizome box and the peripheral speed of the cell. Per cent cell fill is determined by dividing the total number of discharged seeds by the total number of cells that pass the discharge point. The most consistent rhizome distribution is achieved when using rhizomes are uniform size that are appropriate for the cell dimensions, resulting in nearly 100% cell fill.

Generally, experience has indicated, it has been observed that the cell diameter or length should be about 10% larger than the maximum seed dimension and cell depth should be roughly equivalent to the average seed minor diameter or thickness.

3. Results and Discussion

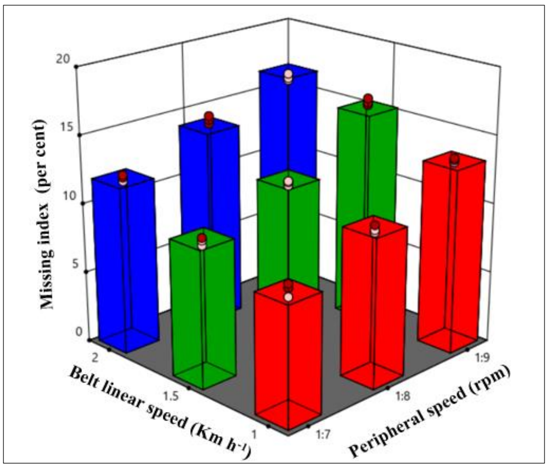
3.1 Missing index

Effect of forward speed and peripheral speed on missing index was investigated using different cell sizes of 40 mm, 50 cm and 60 mm. This study observed that increasing the forward speed from 1 km h^{-1}, 1.5 km h^{-1} and 2 km h^{-1} along with increasing the peripheral speed is 1:7(127 rpm) to 1:8 (138 rpm) and then 1:9 (149 rpm) led to a rise in missing index.

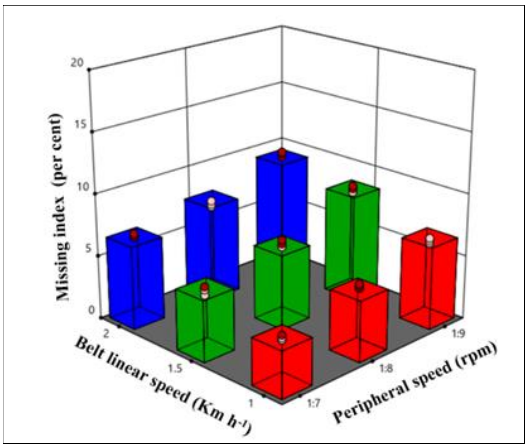
The results, indicate that using the 50 mm cell size offers superior performance when compared to both 40 mm and 60 mm cell size. By reducing the missing index and increasing the multiples, the accuracy and efficiency of data collection have been improved especially in capturing data related to ginger rhizomes. These findings suggest that adopting 50 mm cell size configuration is a viable option for obtaining satisfactory results while optimizing data collection efforts during the study of ginger rhizomes.

However, it was found that a favourable spacing between rhizomes was achieved when maintaining a forward speed is 1.5 km h^{-1} and peripheral speed is 1:8 (138 rpm), using a cell size of 50 mm. At these specific conditions, the spacing between rhizomes was suitable for this combination.

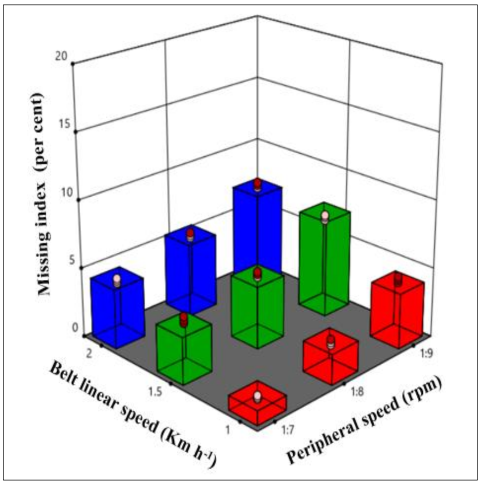
In summary, higher forward speeds and faster peripheral speeds are generally resulted in increased missing index. But specific combinations, such as forward speed is 1.5 km h^{-1} and peripheral speed is 1:8 (138) rpm with a 50 mm cell size were able to maintain an appropriate spacing between rhizomes. The result on the missing index as shown in below Fig. 3.1.



(a) 40 mm



(b) 50 mm

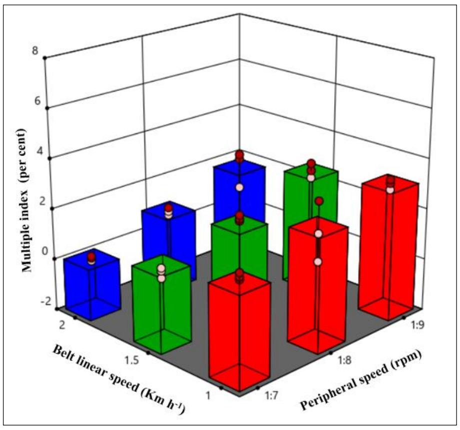


(c) 60 mm

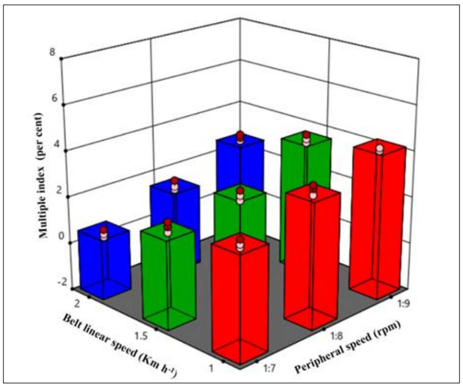
Fig 3.1: Effect of forward speed and speed of the chain on missing index for different size of cells (a) 40 mm (b) 50 mm and (c) 60 mm

3.2 Multiple index

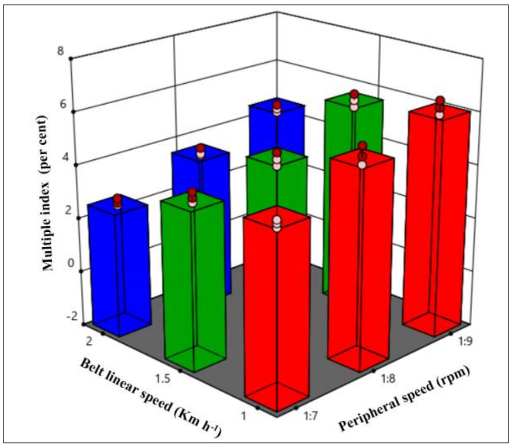
The influence of forward speed, cell size, peripheral speed on multiple index was examined in the study. When using 50 mm cell size, it was observed that decreasing the missing index and maintaining multiple rhizomes was achievable with a forward speed is 1.5 km h^{-1} and peripheral speed is 1:8 (138 rpm). On the other hand, when using a 60 mm cell size, the missing index decreased, but the number of multiples increased. Interestingly, the performance of the 50 mm cell size was found to be acceptable, when compared to both the 40 mm and 60 mm cell sizes. Fig. 3.2. displays the results of the multiple indices on ginger rhizome obtained from the study.



(A)



(B)

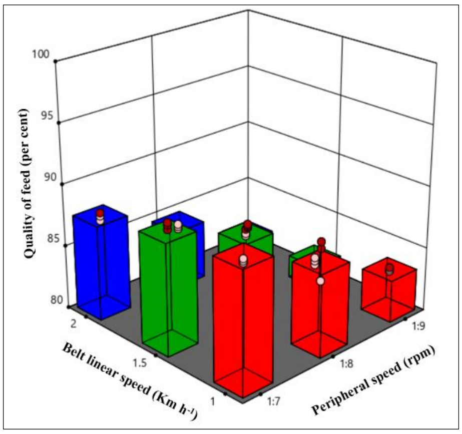


(C)

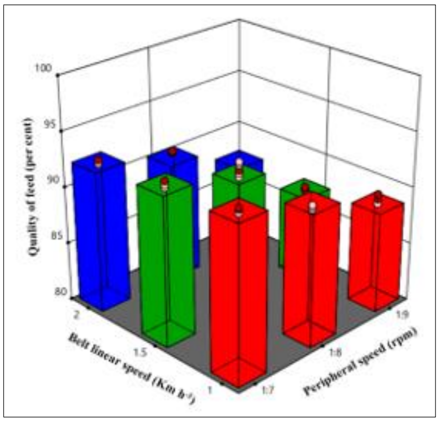
Fig 3.2: Effect of forward speed and speed of the chain on multiple index for different size of cells (a) 40 mm (b) 50 mm and (c) 60 mm

3.3 Quality of feed index

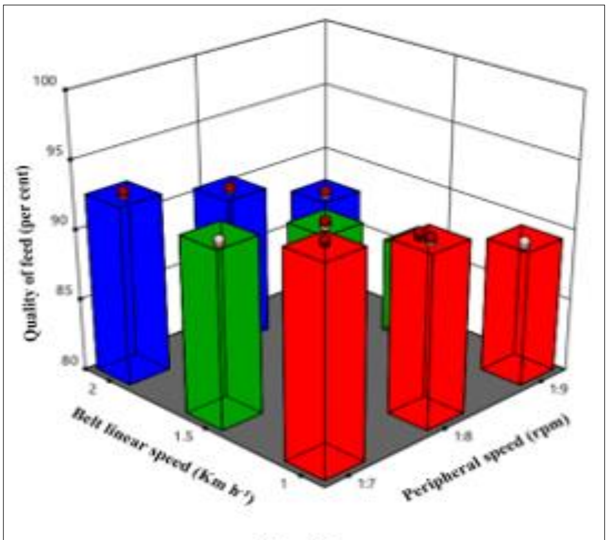
The impact of forward speed, cell size and peripheral speed on the quality of feed index was investigated and the results are depicted in Fig. 3.3. It was evident from the findings that the highest quality of feed index reaching 91.56% was achieved when using a 50 mm cell size with a forward speed is 1.5 km h-1 and a peripheral speed is 1:8 (138 rpm). In comparison, both the 40 mm and 60 mm cell sizes led to an increase in missing and multiple rhizomes, indicating inferior performance. Based on the laboratory study, the optimized parameters were determined to be a cell size of 50 mm, forward speed is 1.5 km h-1 and peripheral speed is 1:8 (138 rpm).



(a) 40 mm



(b) 50 mm



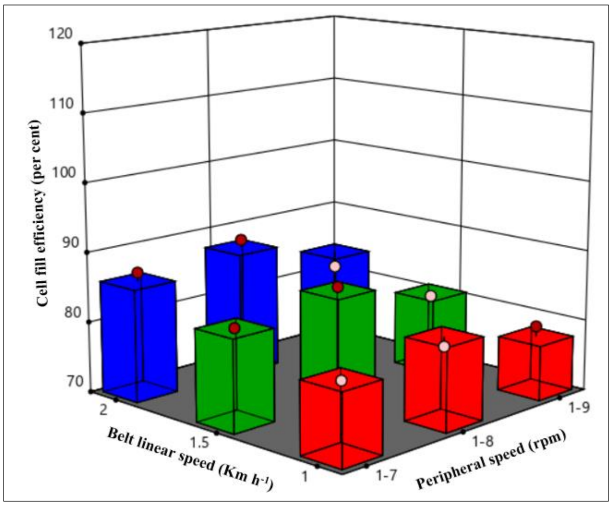
(c) 60 mm

Fig 3.3: Effect of forward speed and speed of chain on quality of feed index for different size of cells (a) 40 mm (b) 50 mm and (c) 60 mm

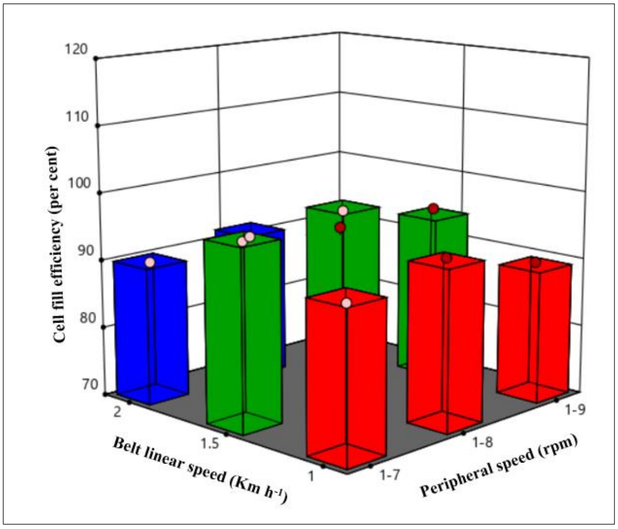
3.4 Cell fill efficiency

The impact of forward speed, cell size and peripheral speed on cell fill efficiency was investigated. The experiment involved varying the forward speed between 1 km h^{-1} and 2 km h^{-1}, the cell sizes at 40 mm and 60 mm and the peripheral speed at 1:7 (127 rpm) and 1:9 (149 rpm). Surprisingly, the lowest forward speed is 1 km h^{-1}, the highest forward speed is 2 km h^{-1} and the cell sizes are 40 mm and 60 mm exhibited poor picking efficiency by using 40 mm cell size and increasing cell fill efficiency more than required by using 60 mm cell size. Similarly, the chain speed is 1:7 (127 rpm) and 1:9 (149 rpm) also resulted in subpar performance.

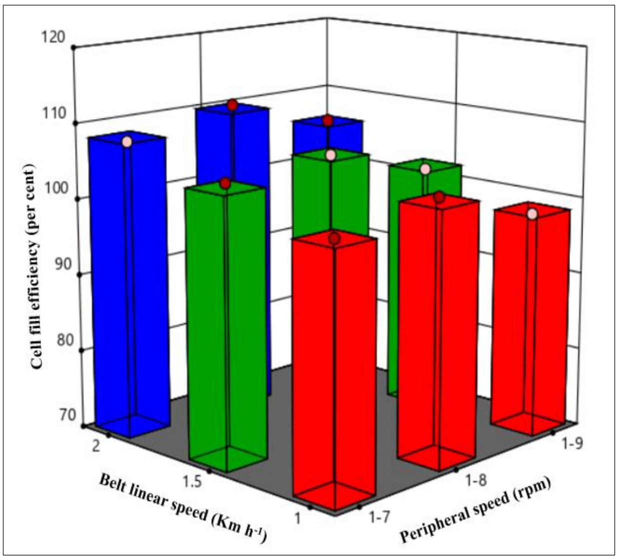
In contrast, the best cell fill efficiency was observed at a forward speed of 1.5 km h^{-1}, a cell size of 50 mm and a peripheral speed is 1:8 (138 rpm). These parameters outperformed the other configurations and showed better results, particularly when picking rhizomes, as illustrated in Fig.3.4. This suggests that a combination of moderately higher forward speed, smaller cell size and optimal peripheral speed is essential for achieving superior cell fill efficiency in this particular context.



(a) 40 mm



(b) 50 mm



(c) 60 mm

4. Conclusion

Statistical analysis focused on evaluating the performance of a seed metering mechanism for planting ginger rhizomes and Various operational variables were tested, including different cell sizes (40 mm, 50 mm & 60 mm) and peripheral speed to determine their impact on the mean spacing between ginger rhizomes. The results showed that at these settings, the mean miss index was 6.24% and multiple index was 2.2%. Additionally, the quality feed index reached an impressive 91.56%, indicating the efficiency of the optimized design and operational parameters.

Moreover, the planter's performance was further examined under laboratory conditions and the observed performance indices were found to be significantly different at a 5% level of significance. In the laboratory, 92% of the seeds were effectively distributed within the desired seed spacing range of 15-20 cm. These findings highlighted the importance of accurate seed metering and placement methods to achieve optimal plant spacing distribution.

In conclusion, the study emphasized the crucial role of the seed metering mechanism in achieving precise and consistent plant spacing for ginger rhizome. The optimized design and operational parameters proved to be effective leading to an impressive 91.56% quality feed index. The variations are noticed in the performance indicators under laboratory conditions underscored the significance of poor seed metering and placement techniques for successful ginger cultivation.

5. References

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