Effect of Ethrel as a Flower Induction Agent on the Growth and Quality of Fresh Golden Pineapple (MD2) in Malaysia

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Abstract

Ethrel was proposed as a good flowering agent to induce the flowering of various fresh pineapples. However, very limited research studies have been carried out on the effect of this inducing agent on the growth of the golden pineapple or Millie Dillard (MD2) in Malaysia, with none in Sarawak. To address this research gap, this study aims to investigate the effect of ethrel on the growth and fruit quality of MD2 pineapples growth in Miri, Sarawak. In this study, ethrel acts as an induction agent that was applied to induce the pineapples at maturity around 11 months after planting (MAP). Moreover, these induced pineapples were harvested 15 MAPs, whereas no pineapples were available for harvesting from the control group that was induced by natural flowering. These results showed that ethrel provided a higher yield in the number of pineapples compared to natural flowering, classifying them as Grade B pineapples. For the growth and fruit quality of the MD2 pineapples, it was found that the average values for the total soluble solids (TSS), total titratable acidity (TTA), pH, diameter, height with a crown, and whole fruit fresh weights with the crown of the pineapples were 16.48 Brix, 0.54 %, pH 3.89, 11.7 cm, 40.3 cm, and 1.4 kg, respectively. Furthermore, the average TSS to TTA ratio was 32.52, which was within the range of 5.5 to 66.4, indicating that the pineapples were sweet with prospects for commercial selling. Hence, it can be concluded that using ethrel as an induction agent is significant in Malaysia.

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Keywords: *Pineapple, MD2, Flowering induction agent, Ethrel, Fruit quality.*

1. Introduction

Pineapples (Ananas comosus [L.] Merr.) are one of the highest-produced tropical fruits worldwide [1]. As of 2021, the total pineapple exports increased by about 39.5% since 2017, totalling a massive US$ 2.7 billion [2]. Malaysia aims to be among the top countries exporting pineapples at US$ 5.3 million, accounting for 0.2% of the world's total exports. Nine main varieties of pineapples

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are currently grown in Malaysia, mostly Moris, N36, Sarawak, Moris Gajah, Gandul, Yankee, Josaphine, Masapine, and Millie Dillard (MD2) [3]. The cultivars N36 and Josapine are only grown for the local market and are not sold out of the country [4]. With different types of pineapples, the MD2 pineapple has explicitly been chosen in Malaysia to be promoted for industrial planting, and it has been identified as a key fruit by the Malaysian Pineapple Industry Board (MPIB) [4]. The MD2 pineapple was created using hybrid selectivity to single out seedlings to cater to the demand in the early 1980s. It is known by various names such as "Gold" or "Golden Ripe" pineapples or more so as MD2. It has a much sweeter taste, of a brighter golden colour, and with higher vitamin C content, amongst various other qualities. It is specifically grown for its uniformity in size as well as consistency in its ripeness [4].

To maintain the qualities of the MD2 pineapples, pineapple plants require numerous nutrients to grow healthily, provided in specific quantities, with each nutrient impacting the growth in its unique way [5]. Nitrogen, Phosphorus, and Potassium (NPK) play a significant role in sustaining a healthy life for pineapples, and they are the three main elements used by the plants that are usually supplied from NPK fertilisers [6]. Plants use nitrogen (N) during the process of photosynthesis, while Phosphorus (P) is used in the root's development as well as the DNA of the plant [7]. Meanwhile, potassium (K) is usually used by plants to help activate their enzymes [8]. Higher nutrient contents are usually found in peat soils, mostly consisting of organic matter. Additionally, the peat soils in Sarawak tend to be acidic, with low amounts of N in the shallow layers of the soil [5].

On the other hand, the pineapple plants undergo flowering either artificially, with flowering agents, or naturally. The use of flowering agents has been deemed more economical. These flowering agents can vary in terms of the uniformity of induction and the fruit quality of the pineapples produced. Furthermore, pineapples contain sugars and acid, while the balance between the sugar and acid ratio helps determine the fruit's maturity and quality [9]. The acid content and sweetness are measured using the total titratable acidity (TTA) and the total soluble solids (TSS), respectively, where a lower acidity gives a higher sweetness.

Minimal research has been conducted on the effect of the flower-inducing agent ethrel on the growth of pineapples in Miri, Sarawak, while there are also very limited studies done in Malaysia and around the world. Therefore, there is limited data on MD2 pineapple in Malaysia, the inducing agent, and the effect of the inducing agent on these pineapples. To address this research gap, the current study helps to address the lack of data on ethrel with the aim of investigating the effect of the inducing agent on the growth and fruit quality of the MD2 pineapples. The major significance is that the research work on the induction of the pineapples assists in further analysing the type of inducing agent suitable for the soils in Miri, Malaysia, along with their effect on the MD2 pineapples. Agriculturally, this research contributes to improving the growth and yields of MD2 pineapples, which are larger in size and sweeter in taste, creating a better financial structure and economic understanding with higher and better produce.

2. Material and Method

This study's methodology first includes applying an induction agent in a randomised complete block design (RCBD). Secondly, identification and application of the flowering induction agent [10; 11]. In this study, the flowering agent, ethrel was selected, implemented, and compared to evaluate the effect on the growth and fruit quality of the MD2 pineapples. Moreover, a control group of pineapple plants induced by natural flowering was kept. The physical properties of the pineapples, such as weight and size, were measured, evaluated, and compared. Additionally, the acidity in the induced pineapples was identified by analysing the acid in the pineapples via titration. The acid percentages were compared to deduce the sweetness of the pineapples under different conditions, and a Brix refractometer was used to ascertain the sweetness.

2.1. Geographical location of the experiment

The location chosen for the growth and induction of the pineapples in Miri, Malaysia, was based on the companies, which are Botanium Agro-Tech (M) Sdn. Bhd and Koperasi Pembangunan Pertanian Bersatu Timur Bhd, who already had their pineapple fields (as shown in Figure 1). The absolute location was at a reading of 4°30’58.8 “N, 114°01’45.5 “E, and the soil type contained both sandy loom soil and clay soil. Moreover, the average weather conditions in this location were 31°C with sunlight coverage of approximately 12 hours daily.

Figure 1. Local pineapple plantation research site in Kuala Baram, Miri, Sarawak, Malaysia.

2.2 Field preparation and planting

Prior to planting, pineapple seedlings were grown and nurtured in a nursery before being planted. A new field was cleared, and a tractor-based plough created raised beds of approximately 20 to 30 cm in height. The ground suckers of about 35 cm were planted in the ground in a double row planting system in Mid-March 2019. A double-row planting system was implemented to maximise land use, help prevent the plants from sunburn as they provided shadings to the pineapple plants, and reduce weed infestations [12]. Black plastic mulch, shown in Figure 2, was used to cover the plants at the beginning as it helped to conserve soil moisture. Moreover, it enhanced rooting by directing moisture toward the root zones and helped control weeds [13].

Figure 2. Double row plantation and black plastic mulch application for the specified pineapple plantation.

2.3. Randomised complete block design (RCBD)

The flower induction agent was applied via RCBD to enhance the variability in the results and ensure no bias was formed. RCBD allows the elimination of systematic errors and an equal chance of receiving treatment. It further helps strengthen that the observations are due to randomness and allows for testing of differences seen [14]. In this experiment, 2 blocks for RCBD were selected from the area where the pineapple seedlings were planted. Within each block, 2 rows were allocated to the first treatment (ethrel as the flower induction agent), and the remaining 3 rows were used for the second treatment (control with no inducing agent). The pineapples in each block received the same treatment and RCBD was performed to decide the allocation of the treatment used for the rows. The inducing agent with five replications was carried out to increase the precision of the experiment. Furthermore, for the control group, five rows of pineapples for natural flowering were left with only the fertiliser composition and no inducing agent. There were 10 experiment units where rows A055 to A059 acted as a control with no induction agent, and rows A060 to A064 had ethrel applied.

2.4. Fertilisers

This experiment used two fertilisers for the pineapple plants for nutrient supply. The first kind was a base fertiliser consisting of 5-5-5 NPK sprayed on all pineapple plants. The application method for this base fertiliser was foliar spray carried out at the beginning of the pineapple plantation. The other fertiliser used was a commercial fertiliser with an NPK ratio of 12-5-35, and it was also applied to all pineapple plants. N plays an important role in the growth of the pineapple leaves, especially the D leaf, which is the most recently matured leaf with maximum physiological activity. Similar to N, K is also essential in the growth of the pineapple. Plant growth can be linked to the soil's amount of K and nutrient uptake. It was found that P showed a lesser effect on the plants as compared to N and K [15].

2.5. Flowering induction

The pineapples were left to grow tentatively until the end of January 2020, after which the flowers were induced with ethrel and compared. Ethrel is considered to be one of the better-inducing agents based on studies by Valleser [16], Valleser [17], and Van de Poel et al. [10], which were conducted outside Miri, Sarawak. The exact formulation of this agent was 30 mL of ethrel, 180 g of urea, and 18 litres of water. The reason for the dilution into solution form was for ease of absorption by the pineapple plants. Each pineapple plant was treated with 40 to 50 mL concentration poured on the centre of each pineapple plant. Natural flowering was left to act as a control group during this experiment. The pineapple plant was left for 120 to 150 days, and the pineapples were harvested once they were at least 75% ripe.

2.6. Data analysis

The methods described in this section were carried out to analyse the effect of the ethrel on plant and fruit growth. The physical data recorded included the pineapple's length, D leaf length, the number of leaves, the pineapple's diameter, pineapple's weight, and they were measured for pineapples in each row. For chemical data, TSS, pH, TTA, and TSS/TTA ratio were analysed on five randomly selected pineapples labelled as A to E. The pineapples selected for these experiments were between 75% to 90% ripe at the time of harvesting as this is the period pineapples for fresh fruit markets are generally harvested [18].

Pineapple's height: The length of the pineapple was measured from the bottom to the topmost part of the crown using a measuring tape. Furthermore, the crown was removed, and the length of the pineapple was measured to give the height. The crown length of the pineapple was calculated by subtracting the two values. All measurements of the height of the pineapple were repeated three times from three different sides, and an average of the measured values was taken. The average height of the pineapples was given, as shown in Equation 1 [15]:

$$\text{Pineapple plant height} = \frac{\sum \text{Plant height}}{\text{Total number of plants used}} \quad (1)$$

D leaf length: The 'D' leaf is given as the longest leaf of the pineapple plant [20]. Therefore, the longest three leaves of the pineapple plant were selected and measured, with the longest measurement selected as the D leaf. This leaf was re-measured three times, and an average value of the measured values was taken. A tape measure was placed at the base of the pineapple's D leaf, and the leaf's apex was used as the final value.

The number of leaves of the pineapple plant: The number of leaves produced by the pineapple plant was recorded by individually counting the number of leaves 3 different times, and the average number of leaves was recorded.

Pineapple's diameter: The pineapple's diameter was measured by obtaining a measurement of the circumference of the pineapple in the middle section using a measuring tape. This measurement was recorded 3 times, and the average circumference of the pineapples was then used. The diameter of the pineapple was calculated using the following formula (Equation 2):

$$\text{Diameter} = \frac{\text{Circumference}}{\pi} \quad (2)$$

Pineapple's weight: The weight of the pineapples was measured using a Sartorius Quintix 1102-1S weighing scale, and they were recorded in kilograms. The pineapples were weighed with and without the crown to get the weight of the pineapple itself. The exterior of the pineapple was left on when the weight was measured.

TSS: To determine the sugar content in the pineapple, an Automatic Temperature Compensation Brix refractometer was used to measure the TSS. The pineapple was cut into 3 sections, mainly the top section of the pineapple below the crown, the middle section, and the basal section. Each section was then blended into pulp in a Panasonic blender (model: MX-GM1011 H). The pulp was then filtered in sieves and cloth to extract the juice with minimal pulp. Next, the Brix refractometer was calibrated using distilled water. A drop of water was placed on the prism face of the refractometer and adjusted until it gave a value of 0. Droplets of the pineapple juice were then placed on the prism face. While positioned towards the direction of light, the eyepiece was focused until a clear value was obtained. The value was recorded at the position where the demarcation line between the light and dark regions crossed the vertical scale. This measurement gave the percentage of soluble solids reading [20].

pH: The pH of the pineapple was tested from the 3 different sections of the pineapple, including the top, the middle, and the basal of the pineapple. The procedure for extracting the pineapple juice for each section was similar to that of the sugar content. The pH of the pineapple juice for each section was then measured using a Mettler Toledo Seven Compact S220 pH meter. Firstly, the electrode of the pH meter was removed and left out to dry. The pH meter was then placed in each solution whilst continuously stirring until a final value was read. This measurement was repeated 3 times for each section of the pineapple, and the average for each section was obtained [20].

TTA: The TTA was measured for the middle section of the pineapple, and it was recorded in percentage. This measuring procedure was similar to that of the TSS and pH for extracting the pineapple juice. To begin with, the middle section of the pineapple was peeled and blended. The extracted mixture was filtered with a sieve and muslin cloth, and the remaining juice was collected. A pipette was used to transfer 10 mL of this pineapple juice into a beaker. As an indicator, 3 to 5 drops of phenolphthalein were added to this beaker. 50 mL of distilled water was further added to this mixture. The mixture was then slowly titrated against 0.1 M Sodium Hydroxide (NaOH) whilst swirling to ensure the mixture was fully neutralised. Colour change was used to determine the neutralisation point when the mixture turned from yellowish to light pink. A rough titre was first carried out to approximate the titration point, after which 3 more accurate titrations were carried out with the average value used as the amount of NaOH needed. The details of this titration method can be found in the Organisation for Economic Co-operation and Development [20] and Pithava and Pandey [21]. After that, the following formula (Equation 3) was used to get the percentage of TTA [15]:

$$\text{TTA (\%)} = \frac{\text{Average volume (ml) of NaOH added} \times 0.1 \text{ (NaOH concentration)} \times 0.064 \times 100}{\text{10ml (Volume of pineapple juice used)}} \quad (3)$$

The average values of the TSS and TTA were used for the middle section of the pineapple to get the TSS to TTA ratio. Equation 4 is used for this ratio calculation is given as [15]:

$$\frac{\text{TSS}}{\text{TTA}} = \frac{\text{Average TSS value}}{\text{Average TTA Value}} \quad (4)$$

2.7. Statistical analysis of data

The data obtained was subjected to the analysis of variance (ANOVA), and thereafter, Duncan's Multiple Range Test was carried out using Microsoft Excel as a post hoc comparison between the means at a 5% level. Besides the means, the standard deviation of the data was also included.

3. Results and discussion

The following section details the results and discussions of the analysis of the pineapple's growth and fruit quality, which were carried out on the pineapple samples collected from the pineapple field. Various discussions and results for these findings are explained in the following sections, including the results of the Brix test and titration.

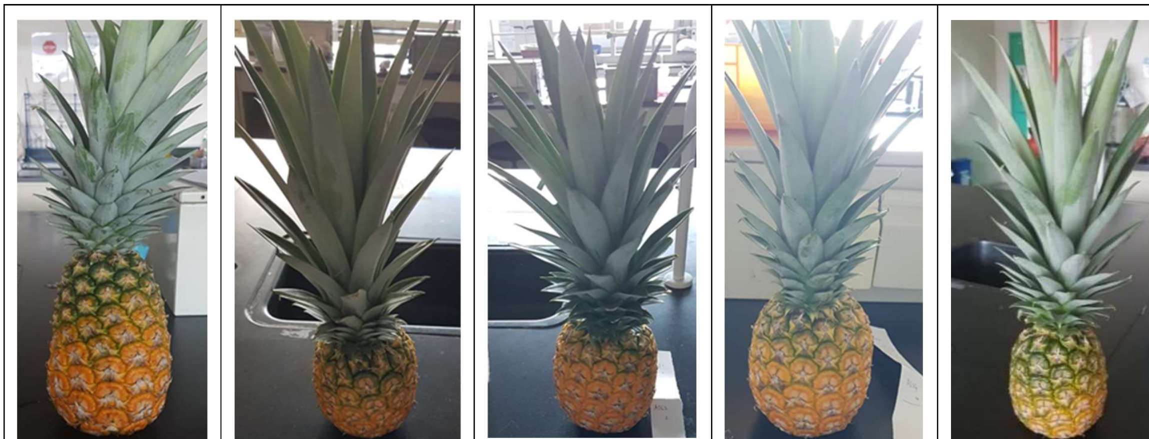
3.1. Yield results

In terms of inducing the pineapples from the plants, it was visible from the results that ethrel was more effective in producing the pineapples as compared to natural flowering. The yield results are presented in Table 1, showing the number of pineapples produced in each row. From Table 1, no pineapples were induced naturally in rows A055 to A059, where no chemical-inducing factors were applied.

The pineapples were harvested between 75% and 90% ripeness, as viewed in Figure 3. The pineapples were harvested on 14th July 2020, Tuesday, noon, around 15 months after planting (MAP) in the middle of March 2019. The physical data on these pineapples are presented in Table 2. Table 2 shows that the pineapples ranged in weight between 1.2 kg to 1.8 kg, with the average weight with crown as 1.4 kg. The average pineapple length without the crown measured 12.8 cm, and the diameter of the pineapples varied between 11.4 cm and 12.1 cm.

Table 1. Yield results for each row in terms of pineapples induced.

Row numbers	Variable	Number of pineapples produced after induction
A055	Control with no inducing agent	0
A056	Control with no inducing agent	0
A057	Control with no inducing agent	0
A058	Control with no inducing agent	0
A059	Control with no inducing agent	0
A060	Ethrel	78
A061	Ethrel	43
A062	Ethrel	9
A063	Ethrel	7
A064	Ethrel	2



Pineapple A from Row A060	Pineapple B from Row A061	Pineapple C from Row A062	Pineapple D from Row A064	Pineapple E from Row A061

Figure 3. Pineapples A, B, C, D, and E were harvested.

Table 2. Physical data on the pineapples harvested.

Pineapple	A	B	C	D	E	Average
Row number	A060	A061	A062	A064	A061	
Pineapples weight with a crown (kg)	1.8	1.3	1.4	1.2	1.3	1.4
Crown weight (kg)	0.4	0.3	0.3	0.2	0.4	0.3
Fresh fruit weight without crown (kg)	1.4	1.0	1.1	1.0	0.9	1.1
Pineapple length with a crown (cm)	44.3	39.0	42.1	34.3	41.6	40.3
Pineapple length crown (cm)	28.0	29.3	28.7	22.4	28.7	27.4
Pineapple length without crown (cm)	16.3	9.7	13.4	11.9	12.9	12.8
Pineapple Diameter (cm)	12.1	11.6	11.9	11.6	11.4	11.7

The pineapples had an average weight similar to the heavier pineapples studied by Valleser [15], which weighed between 1.42 kg and 1.44 kg. The resulting heavier fruits could be hypothesised to be due to the correct nutrient ratios received. Other research conducted by Leon and Kellon [22] reported that the MD2 pineapples ranged between 1.5 kg and 2 kg in Costa Rica. This may have differed from the results in this paper possibly due to the different climatic conditions, fertiliser ratios used, and other factors. Increasing the size of the pineapples is possible, noting that the maximum fruit size is usually dependent on plant weight at the time of forcing [22].

From this physical data, the pineapples are labelled as Grade B MD2 pineapples based solely on their size, i.e., they weighed between 1.3 kg and 1.6 kg [4]. This was in line with research by the Malaysian Pineapple Industry Board, MPIB, which classified the Grade A pineapples as weighing larger than 1.7 kg. Some of the pineapples cultivated were within this range, therefore suggesting that the pineapples could still grow larger without compromising the sweetness that makes MD2 pineapples unique. However, in Ghana, pineapples that were labelled Grade B weighed a maximum of 1 kg and were affected by sunburn. This meant that the pineapples grown in this research were classified as Grade A [23]. These two different grades meant that the pineapples grown varied from location in terms of grade; however, it still meant the pineapples had a chance to grow larger.

Based on the pineapples harvested, as seen in Figure 3, the shell colour was orange, reflecting the pineapple's ripeness. The pineapples did not have sunburn, which alters the cuticle and damages the epidermal and sub-epidermal tissues [24]. Furthermore, this result was in line with research studied by Ding and Syazwani [25], which demonstrated that the shell of the pineapples should have this bright orange colour at 75% ripeness. Additionally, their research showed that pineapples at 50% and 75% ripe held the most nutrients in the pineapple, therefore proposing that the pineapples at this stage had the same effect. The results reflect that the inducing agent plays a significant role in the growth of MD2 pineapples. Other external factors also affect the size of the pineapples, showing that larger plants had a better nutrient uptake and, therefore, produced heavier pineapples, as shown by Cunha et al. [26].

3.2. Effect of inducing agent on the growth of pineapples

Several reasons affect the natural induction of pineapples, which occurs in its own time. Natural flowering occurs in pineapple plants under various environmental conditions, such as low night temperatures and geographic simulation, among many others [27]. These conditions produce inductive stress conditions in the pineapple plants, which leads to triggering Acetyl-CoA carboxylase production and, hence, ethylene biosynthesis [28]. Based on these factors, it is suggested that no pineapples were naturally induced due to the lack of stress factors affecting the pineapple plant. Given that the plants were approximately the same size as those that were artificially induced, the maturity levels of the plants could be identified based on the length of the D leaves [10]. Therefore, it can be concluded that the lack of naturally induced pineapples resulted from the lack of stress factors.

The other group of pineapples was induced by ethrel that was mixed with water and urea. These pineapples were induced by pouring the mixture down to the centre of the rosette. Table 1 shows that 139 pineapples were induced using this method and were more than the 0 pineapples via natural induction. The liquid version of ethrel allowed for easier absorption by the plants as it was poured down to the centre of the cup, allowing the active ingredient ethrel to be taken up instantly by the apical meristem [10]. This resulted in a greater amount of pineapple plants induced as the plants' probability of absorbing the liquid was greater. The ethrel seemed to be more effective in inducing the pineapple, and this has reported by other researchers such as Butrat and Wangmuang [29], whereby the ethephon treatment (100 mg per litre combination with urea) produced nearly a 100% flowering of pineapple plants and showed a higher flowering.

Plants often use Ethrel to produce ethylene, which causes the inducing of the plants. The plants absorb any inducing agents in the meristematic zone where, due to more intense cellular activity, the stem apex reacts much more sensitively to the effects of endogenous auxin. Hence, ethylene needs to be synthesised by the plant [30; 31]. Ethrel is converted directly into ethylene [32]. Ethrel induces more pineapples as it is converted to ethylene, the primary factor that begins to induce them. Another factor that makes ethrel a good flowering agent is the addition of urea to increase the number of pineapples induced. The addition of urea helps to increase the efficiency of the flowering agents, specifically ethrel, as it promotes its absorption and thus increases ethylene availability to the plant tissues [33]. A similar statement was reported in the research conducted by Dass et al. [33] and Valleser [34] that ethrel mixed with urea had the highest and fastest flowering when compared with ethrel alone.

Moreover, the inducing agent was placed between 3 and 5 p.m., when the stomata began opening. This factor is crucial and required for absorption when applying inducing agents. According to Glennie [35] and Turnbull et al. [36], the application of inducing agents is preferred in the evening as it may result in large concentrations of ethylene in the tissue, which can enhance the absorption of the agent. The stomata are also primarily opened for about 5 to 6 hours during the evenings to allow absorption.

According to Dass et al. [33] and Van de Poel et al. [10], the ethrel and urea treatments seemed to show higher flowing rates, usually between 80% and 100%, whereas, in the research that was carried out, the ethrel gave a flowering percentage of 31%. This lack of homogeneity could be potentially explained by the ethrel application having 3 repetitions. These repetitions increase the effect and chances of flowering. Furthermore, ethrel applications should be reapplied if there is rain within 6 hours of the initial application, which was the case for this research, however, no repetitions were made [32]. Therefore, this could have led to a lower percentage rate of success and the explanation for the 31% flowering.

Another factor that could have affected the ethrel treatment was the rain in Miri, Sarawak, Malaysia, during the application of ethrel. There was heavy rainfall in Miri, Sarawak, Malaysia, during the application of the flowering agent, and this could have caused an insufficient amount of time to allow the ethrel to be absorbed, resulting in a lack of pineapples induced. This scenario is reported by Py and Guyot [37], and the authors suggested that the rain can dilute or drag the solution from the leaves, thereby affecting the concentration and amount of the ethrel absorbed by the plant. Table 3 shows the precipitation for the day that the pineapple induction was carried out, noting that there was rainfall between 3 and 9 p.m. This period reflects the same time the induction was carried out, showing that the rainfall may have played a factor in flushing out the ethrel from the pineapple stems.

Table 3. Weather conditions were found on the website when the flowering agent was applied on 14th February 2020 [38].

Time	3 p.m.	6 p.m.	9 p.m.
Temperature (°C)	28	27	26
Rainfall (mm)	0.8	0.5	0.3
Cloud cover (%)	82	57	41

While the ethrel induced more pineapples, an inconsistency was noticed between the rows in terms of those induced, as seen in Table 1. The size of the plants in the rows may explain this result. Therefore, the D leaves size and the number of leaves for each row were compared and shown in Table 4. The results show a general correlation between the number of leaves and pineapples, whereby rows A060 to A062 had more leaves and pineapples induced compared to those seen in rows A063. These similarities could suggest why there was a lack of pineapples induced for the given rows. The results of the experiments involving the D leaf and the number of leaves are summarised in Table 4.

Table 4. The average D leaf length and the number of leaves of the pineapple plants for rows induced by ethrel.

Row	A064	A063	A062	A061	A060	Average
D leaf average length (cm)	72.27 ± 0.91^{b}	72.90 ± 7.71^{b}	78.75 ± 6.69^{a}	79.23 ± 5.48^{a}	70.03 ± 4.80^{b}	74.64
Number of leaves average	35 ± 1^{a}	25 ± 3^{d}	29 ± 2^{c}	34 ± 2^{ab}	33 ± 4^{b}	31

Note: Mean ± standard deviation, values in the same row followed by the same letter are not significantly different at $p<0.05$.

The plants had reached maturity based on the number of leaves and the D leaf lengths. Larger plants seemed more responsive to the treatments, as seen in research by Valleser [16], which showed that the larger plants could induce larger and more fruits. In addition, it demonstrated that these factors could be used to identify the right time to induce the plants, leading to better fruit yields. Therefore, the results are seemingly within these explanations as the larger plants were more susceptible to the inducing agent ethrel. On the other hand, the plants were planted simultaneously; however, the sizes varied considerably within the rows. Nutrient losses in the soil account for this, leading to slower growth in some plants. As the D leaf reflects the current nutrient status, it is suggested that as they were smaller, they could not receive enough nutrients to reach the correct size and, thus, were less susceptible to the inducing agent [15]. Therefore, the different rows induced different flowers based on these results.

3.3. Fruit quality

Once the ethrel induced pineapples matured and ripened, 5 random pineapples were selected and tested for quality. The obtained chemical analysis results of the pineapples, shown in Figure 3, can be seen in Table 5. As shown in Table 5 and Figure 4, the pH was analysed to check for the pineapple's acidity levels, ranging from pH 3 to pH 4. This pH range is typical for pineapples, given the acidic nature of the fruits. Meanwhile, Lasekan and Hussein [39] showed that MD2 pineapples should have a pH of between 3 and 4; the results agreed with this. Moreover, the less acidic the pineapple, the better, as they contain less hydrogen plus ions, which trigger the sour taste buds of a person. The pineapples grown were on the upper end of the pH, suggesting that the sourness was reduced and better for consumption.

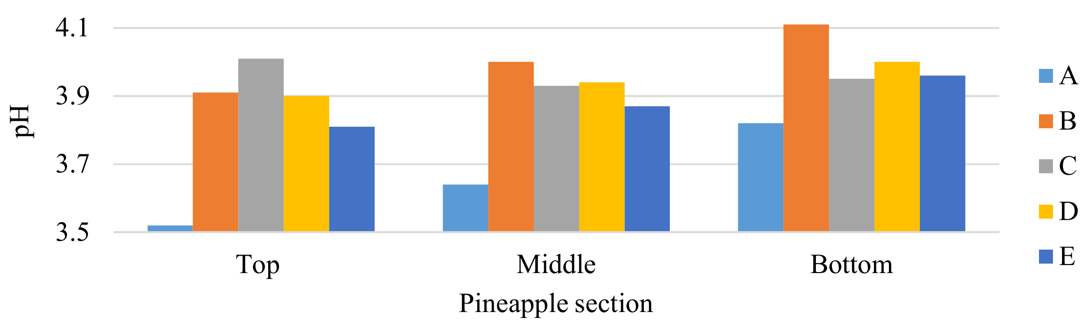


Figure 4. pH across the pineapples harvested.

Except for Pineapple B, it was noticed that the pH values of the pineapples A and C to E in Table 5 were the lowest on the top section of the pineapple, followed by the middle, and lastly, the basal. This result shows that the pineapples ripen from the bottom upwards, showing that the pH differs in the different sections. Ramsaroop and Saulo [40] presented similar trends in terms of the pH across the Smooth Cayenne pineapples, with higher pH values found at the bottom of the pineapple. The anomaly of Pineapple B during the fruit ripening could be due to the rapid utilisation of acids as a substrate during respiration, as found in the Mauritius pineapple, whereby it was converted to sugars Sarananda and Wijesinghe [41]. The obtained results in Table 5 and Figure 4 showed that the remaining pineapples had no abnormality and were within the required range of their chemical characteristics.

Table 5. Fruit quality of pineapples harvested.

Pineapple Row	A A060	B A061	C A062	D A064	E A061	Average
Pineapple number in a row	3	4	2	4	3	3.2
Juice pH - Top	3.52 ± 0.00[d]	3.91 ± 0.01[b]	4.01 ± 0.02[a]	3.90 ± 0.00[b]	3.81 ± 0.01[c]	3.83
Juice pH - Middle	3.64 ± 0.00[d]	4.00 ± 0.01[a]	3.93 ± 0.01[b]	3.94 ± 0.01[b]	3.87 ± 0.01[c]	3.88
Juice pH - Bottom	3.82 ± 0.01[d]	4.11 ± 0.00[a]	3.95 ± 0.02[c]	4.00 ± 0.02[b]	3.96 ± 0.02[c]	3.97
Average pH	3.66	4.01	3.96	3.95	3.88	3.89
TSS (°Brix or %) - Top	13.00 ± 0.26[c]	16.10 ± 0.00[a]	16.23 ± 0.06[a]	16.10 ± 0.00[a]	13.67 ± 0.06[b]	15.02
TSS (°Brix or %) - Middle	15.10 ± 0.00[d]	18.37 ± 0.06[a]	16.63 ± 0.06[b]	16.57 ± 0.06[b]	16.40 ± 0.00[c]	16.61
TSS (°Brix or %) - Bottom	17.30 ± 0.00[d]	18.47 ± 0.06[a]	17.03 ± 0.06[e]	17.90 ± 0.00[c]	18.30 ± 0.00[b]	17.80
Average TSS (°Brix or %)	15.13	17.65	16.63	16.86	16.12	16.48
Titratable acidity, (mg/100 mL or % Citric acid) of the middle section	0.76 ± 0.03[a]	0.44 ± 0.01[c]	0.51 ± 0.01[b]	0.43 ± 0.00[c]	0.54 ± 0.01[b]	0.54
TSS/TTA-middle section	19.81	40.54	32.62	39.51	30.12	32.52

Note: Mean ± standard deviation, values in the same row followed by the same letter are not significantly different at $p<0.05$.

The TSS was tested for the different sections of the pineapples, shown in Figure 5, and the results showed that the Brix increases from the top to the basal sections of the pineapple. This result showed a correlation between the sections and the TSS, with the basal section giving the highest Brix readings and, therefore, the highest TSS. This result indicated that it could be due to the ripening process from the bottom to the top, showing the basal sections are much sweeter [42]. Montero-Calderón et al. [42] reported a TSS reading of 13% in the middle and 12.6% at the top section, with a similar trend of results also found in this study, proving that the top section has a lower TSS value than the bottom sections. There was no decrease in TSS; however, any reduction may have resulted from excessive ripening and rotting when stored [43].

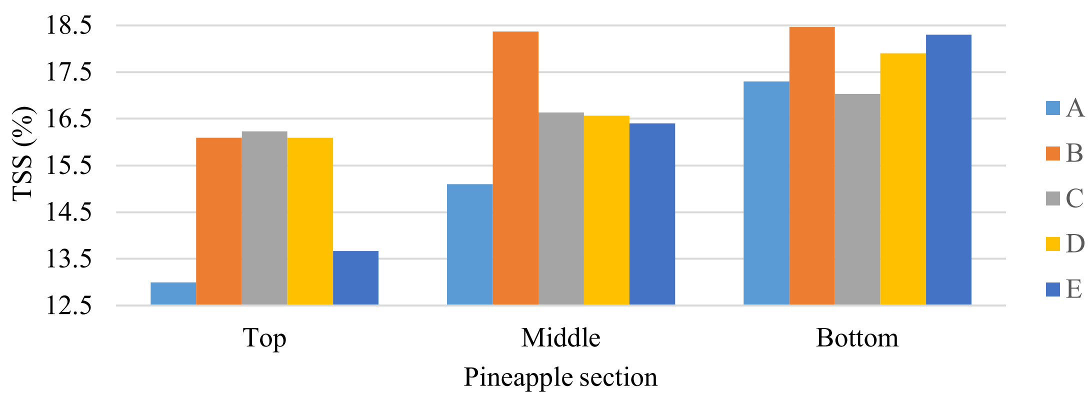


Figure 5. TSS across the pineapples harvested.

Also, the findings showed that the pH and Brix have a correlation where a lower pH has a lower Brix reading when compared to a higher pH. The TSS results, which ranged between 13% to 18.5% (seen in Figure 5), were compared with the MD2 pineapples in the study carried out by Siti Rashima et al. [11] whereby their results showed a TSS reading within the range of 6.6% and 18%. Additional studies done by Ding and Syazwani [26] showed that MD2 pineapples grown in Malaysia and harvested at about 75% ripeness had a TSS of about 18%, whereas the pineapples in Ghana had a TSS of 14.5%. The results concurred with the study by Siti Rashima et al. [11], suggesting that the pineapples grown in this research were sweet. They were also sweeter than those pineapples in Ghana due to the growing location and agronomic practices. Therefore, the pineapples grown in the Miri plantation in Malaysia were in line with other research and showed a high TSS, which was a direct result of increased sweetness.

The TTA in the pineapple was analysed and used as an indicator for organic acid content. Critic acid is one of the major acids found in pineapples, and TTA was used to show the amount of citric acid in the middle section of the pineapple [44]. From Table 5, the obtained TTA was within the ranges of 0.4% to 0.8% citric acid. This result showed that some of the pineapples had a larger content of citric acid, which could be perceived as having an increased tartness in pineapples. It also showed that the pH increased as the TTA decreased due to a more palatable fruit with lower acidity. The decrease in the pH could be due to the rapid utilisation of the acids as substrates during respiration when converted to sugars. A similar result was found to be the case in Mauritius pineapples, as seen in a study conducted by Sarananda and Wijesinghe [41]. These authors found that as the TTA decreased, the hydrogen ion concentration used to measure pH was reduced in the cell saps, thereby increasing the pH.

Another study carried out by Viana et al. [45] showed that the TTA for FRF 632 pineapples was 0.85% citric acid, and these results were better than the pineapples grown in Miri, Sarawak as the acid percentage was less, indicating that these authors' pineapples were much sweeter. Additionally, a better indicator of the perceived tartness is the TSS/TTA ratio. A higher ratio shows a sweeter pineapple and vice versa. From Table 5, Pineapples B and D have larger ratios of 40.54 and 39.51, respectively. These ratios indicate that the bottom sections had a larger TSS/TTA ratio, having already established they were sweeter [40]. Furthermore, Hassan et al. [46] and Siti Rashima et al. [11] showed a TSS/TTA ratio of 5.4 to 66.4 and between 41.51 and 108.94, respectively. The results were parallel with these authors' ratios, and it can be concluded that the higher the ratio, the sweeter the pineapples and the more intense the aroma is.

3.4. External factors influencing the pineapples

One of the major factors influencing the growth and quality of the pineapples and the plant crops was the weather and rainfall during the 1.5 years of the pineapple. Rainfall plays a big part in the growth of the pineapple, and the recent rains in Malaysia seemed to play a beneficial role, with rainfall present during the vegetative phases [47]. This constant supply of rainfall was adequate in helping the crops mature; however, given the soil's nature as a mix between clay and sandy, excessive rainfall clogged the soils and might not have helped with their growth. Some crops were much smaller, especially in areas where the water was not able to drain thoroughly. Therefore, the pineapples require well-drained soils to avoid water saturation and to avoid making the soil more acidic, as was the case in this research [48].

Humidity also plays a significant role in the size of the pineapples produced. It is predicted that humidity affects the weight of the harvest from cooler subtropics by 0.5 in humid tropics. The humidity effect observed in places such as Thailand showed that larger crops produced half the size of the pineapple when compared to those in Hawaii, whereby a 2.0 kg plant produced a 2.0 kg fruit [48]. In terms of climate, sunlight also plays a big part in the growth of pineapples. Pineapples require annual sun exposure of about 2,500 to 3,000 hours of sun for growing best in temperatures of 22 to 32 ºC [48]. This factor may suggest why some plants were able to grow large leaves due to the constant sunlight and temperature provided in Malaysia. The average temperature over the year was about 27.18 ºC, and thus, it can be suggested that the climatic changes might have influenced the growth of the pineapple crops both negatively and positively in some instances [49].

More so, the maintenance of the crops is pivotal for their growth. Weeds are one of the biggest issues in pineapple cultivation as they compete with plants for the nutrients in the soil. The weeds might have hindered the growth process of the fruits and their plants whilst inhibiting photosynthesis [50]. The lack of weeding certainly affected the pineapples' sizes, as shown in a study by Eshetu et al. [51]. These authors reported that the un-weeded section had significantly smaller sizes of plants compared to those where weeding was carried out more frequently.

4. Conclusion

This research work tested the effect of ethrel as an induction agent on the growth and fruit quality of the MD2 pineapples. Various methodologies for this work have been outlined with further explanations for their implementation. Furthermore, results and discussions showed that large pineapple plants with an average D leaf and several leaves of 75.98 cm and 28 leaves were produced. This was a good indication that good-sized pineapples were grown; however, there seemed to be an area to increase the sizes based on the larger crops. The induction agent on the pineapples showed that ethrel had a better effect on inducing the pineapples, as 139 pineapples were induced compared to no pineapples produced via natural flowering, demonstrating the significance of ethrel as an induction agent in Malaysia.

The quality of the fruits induced by ethrel was tested and showed that when harvested between 75% and 85% ripe, the average pH, Brix, and TSS/TTA ratio were 3.89, 16.48%, and 32.52. These results classified the pineapples as Grade B MD2 pineapples according to the MPIB and showed that the pineapples were sweet and that the fertiliser ratios and the induction agent played a role in this. Further correlations were observed, such as an increase in Brix from the top of the pineapple to the basal, a higher pH at the basal, and a higher TTA at the top of the pineapples. Additionally, the size of the plants and the number of leaves showed a positive relationship with the weight and size of the pineapples, but it was suggested that this correlation should not be used as the results were not 100% definitive.

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Conflict of interest

The authors have no competing interests to declare that are relevant to the content of this article.

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