Malaysian Applied Biology (2022) 51(6): 85-94
https://doi.org/10.55230/mabjournal.v51i6.2350

Research Article

Physical and Chemical Properties of Pineapple Fruit of cv. Pada and cv. Sarawak in Response to Flowering Hormones

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ABSTRACT

Pineapple flowering can be stimulated through artificially induced flowering (AIF) to ensure year-round production. The post effect gains from AIF is currently not universally acknowledged by previous studies, therefore, this study aims to evaluate the physical and chemical fruit properties in response to different AIF practices on cv. Pada, and cv. Sarawak. The AIF was applied to 9-month-old plants with nine treatments being tested, consisting of calcium carbide (CaC_2), naphthaleneacetic acid (NAA), and ethephon at various concentrations. The fruit samples were collected at a maturity index of 5 in order to determine its physical (total fruit weight, fruit weight without crown, total fruit length, fruit length without crown, fruit diameter, peduncle length and peduncle diameter) and chemical properties (pH, total soluble solid and titratable acidity). The results showed that the total fruit weight as well as fruit weight without crown on cv. Pada and total fruit weight on cv. Sarawak were not affected by AIF treatments. The study showed a significantly higher fruit weight in T7 (low ethephon concentration) in comparison to T10 (high ethephon concentration) and T4 (NAA treatment) was recorded on cv. Sarawak. The trend of fruit length without crown on both cultivars decreased as the hormone concentration increased. The peduncle length exhibited significantly shorter in T3 (high CaC_2 concentration) for cv. Pada, and T10 (high ethephon concentration) for cv. Sarawak at 30%, and 15% shorter than other treatments, respectively. In fruit chemical properties, TSS and TA on cv. Pada showed a significant difference, this particular result may have been influenced by an external factor such as the environmental conditions during the fruit ripening stage due to differing harvesting periods between the treatments. Overall, the study suggests that the AIF treatments may affect some of the physical and chemical fruit properties either via the direct or indirect response toward AIF.

Key words: Artificially induced flowering, CaC_2, Ethephon, NAA

Article History
Accepted: 27 December 2022
First version online: 31 December 2022

Cite This Article:
Sam Sabtu, S.N., Saupi, N., Ramaiya, S.D., Abu Bakar, F. & Ding, P. 2022. Physical and chemical properties of pineapple fruit of cv. Pada and cv. Sarawak in response to flowering hormones. Malaysian Applied Biology, 51(6): 85-94. https://doi.org/10.55230/mabjournal.v51i6.2350

INTRODUCTION

Artificially induced flowering (AIF) is currently a regular practice on a commercial scale in the pineapple industry with the main purpose of ensuring a year round pineapple fruit production. The AIF practices use several types of hormones that purposely elevate the plant's ethylene level, especially on the apical stem region, where the transition from vegetative to reproductive was located. In Malaysia, the common hormones used for AIF are ethephon, calcium carbide (CaC_2), and naphthaleneacetic acid (NAA). The mechanisms of these hormones are varied. Ethephon is basically stable under acidic conditions (pH <3.5) but decomposes to ethylene when the acidity is reduced (Silva & Caputo, 2012). The pH of pineapple leaves tissue could reach 6.5 (Prigge & Gurierrez-Soto, 2014; RodrÍguez-Escriba *et al.*, 2015). Under such conditions, ethephon decomposes after penetration into the leaves. Additional alkaline substances were also excellent in causing rapid decomposition of ethephon, which can directly be exposed to the plant to carry out the transition process (Dass *et al.*, 1975; Malip, 2011; Liu *et al.*, 2020). The CaC_2 is liberated into acetylene which has a similar action as in ethylene response when contacted with water (Bawa *et al.*, 2020). The NAA is classified as an auxin type; however, studies have proved that not the auxin is causing transitional stage, but it works indirectly by stimulating 1-aminocyclopropane-1-carboxylic acid synthase, which is an ethylene precursor (Yu & Yang, 1979; Hansen & Grossmann, 2000).

The period from the inflorescence emergence to the harvesting of pineapple fruit depends on the cultivar used. Chan (2008) and Federal Agricultural Marketing Authority (n.d.) stated that approximately 100 to 170 days were needed to complete a cycle. A pineapple fruit is ready to be harvested at the onset of ripening. The ripening stage can be distinguished by the fruits outer shell colour turning reddish-brown or yellowish (depending on the cultivar), the colour change begins from the base and gradually reaches to the top of the fruit. The ripening stage is generally classified into seven maturity indices (Rohazrin *et al.*, 2016). The indices are mainly represented by the percentage of ripened fruitlets. As the ripening progresses, the physical and chemical properties of the fruit also undergo change (Paull & Chen, 2018). The identification of maturity indices has significant importance in consumer preference and post-harvest handling. Several authors have reported that the harvesting period of pineapple is affected by AIF practices (Shamsul Alam *et al.*, 2010), the use of fruiting hormones (Hassan *et al.*, 2011), and temperature (Julius *et al.*, 2017). Harvesting at early ripening is commonly practiced for long-distance transportation, to ensure the quality of fruit delivered to consumers.

In Sarawak, Malaysia, a number of pineapple cultivars are commonly grown, including cv. Sarawak, and cv. Pada. Currently, there is still a lack of published data on the cv. Pada. According to Federal Agricultural Marketing Authority (n.d.), the classification of fruit grades depends on the cultivars. In terms of fruit weight, which is commercially used as an indicator of fruit grade, the common division is into three categories namely: large, medium, and small. For cv. Sarawak, fruits lesser than 1.5 kg are considered small, while any fruits exceeding 2 kg are categorized as large. Other interesting attributes of cv. Sarawak includes total soluble solids (TSS) ranging from 14-17 °Brix, and titratable acidity (TA) ranging from 0.3% to 1.2% (Department of Agriculture, n.d.).

There are several factors that influence the physical and chemical properties of pineapple fruits; including, soil types (Chan, 1997; Jaman, 2009, as cited in Solomon George *et al.*, 2016), shading (Liu & Liu, 2012), irrigation (Dorey *et al.*, 2016), planting density (Valleser, 2018), seedling size (Siti Zubaidah *et al.*, 2018), plant age during AIF (Barker *et al.*, 2020), and fertilization (Spironello *et al.*, 2004; Cunha *et al.*, 2021). In addition to that, several authors have claimed that the AIF practices, i.e., using different hormones (Py *et al.*, 1987; Butrat & Wangmuang, 2004) or different concentrations of hormones (Bhowmick *et al.*, 2011; Liu *et al.*, 2020), can also affect the pineapple fruit properties. However, others found little or no significant effect on a number of fruit properties (Norman, 1977; Mohammed Selamat *et al.*, 2005; Shamsul Alam *et al.*, 2010; Li *et al.*, 2016; Usha Kumari *et al.*, 2020). Therefore, this study evaluates the physical and chemical properties of pineapple cv. Pada, and cv. Sarawak in response to different AIF treatments.

MATERIALS AND METHODS

Experimental background

Planting activities were carried out at Ladang TPU 2, Universiti Putra Malaysia, Bintulu, Sarawak. Suckers of cv. Pada and Sarawak at between 300-500 g were planted with soil media (Bekenu series) in polybags (16 " × 16") arranged in a double row system at a distance of 30 cm × 60 cm × 90 cm between plants, within rows and between rows, respectively. The cv. Pada was planted in January 2020 and cv. Sarawak was planted in February 2020. A completely randomized design with three replications (n=15 plants) was implemented for the present study. The planting management protocols followed the recommendations of the Malaysian Pineapple Industry Board (n.d.). The in situ meteorological data i.e. temperature and humidity during the growing cycle was recorded using a data logger (HOBO, MX2301A, Onset, Australia), and precipitation was recorded using a rain gauge (Stratus, USA) with the monthly average shown as in Figure 1. The daily rainfall was plotted during the fruit ripening stage as shown in Figure 2.

Artificially induced flowering treatments

After plants reached 9-months-old, the AIF treatments were administered to both cv. Pada and cv. Sarawak, comprising of T1-T9, and T1-T10, respectively (Table 1). These treatments were selected based on a double increment and double deduction from the standard concentration normally practiced by the farmers in Malaysia. Due to poor response of the flowering of cv. Sarawak in treatments, the physical and chemical fruit properties were evaluated based on selected treatments (T4, T7, T8, T9, and T10). Fruits that reached a maturity index of 5 (50% of fruitlets ripened) (Rohazrin *et al.*, 2016) were selected. Also, since the AIF treatments affect the flowering period and its uniformity, only fruits within the range of the majority of fruits whose maturity is uniform were selected for the fruit's physical and chemical analysis (Figure 2).

Determination of fruit's physical and chemical properties

The selected physical properties of pineapple

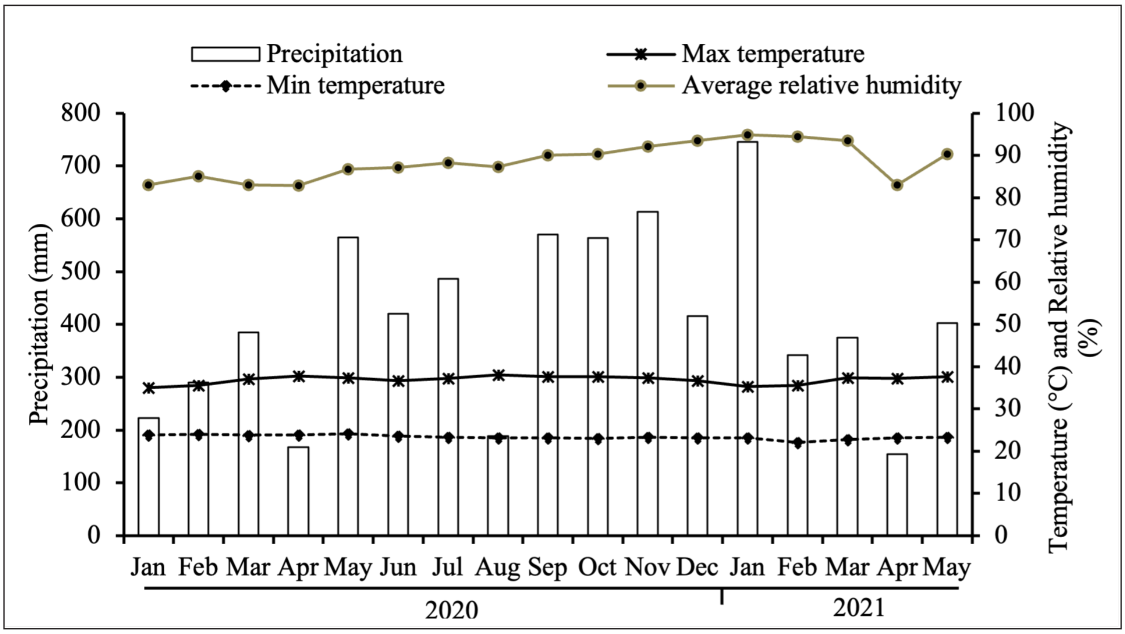

Fig. 1. In situ total precipitation, average relative humidity, and maximum and minimum temperature during the growing cycle.

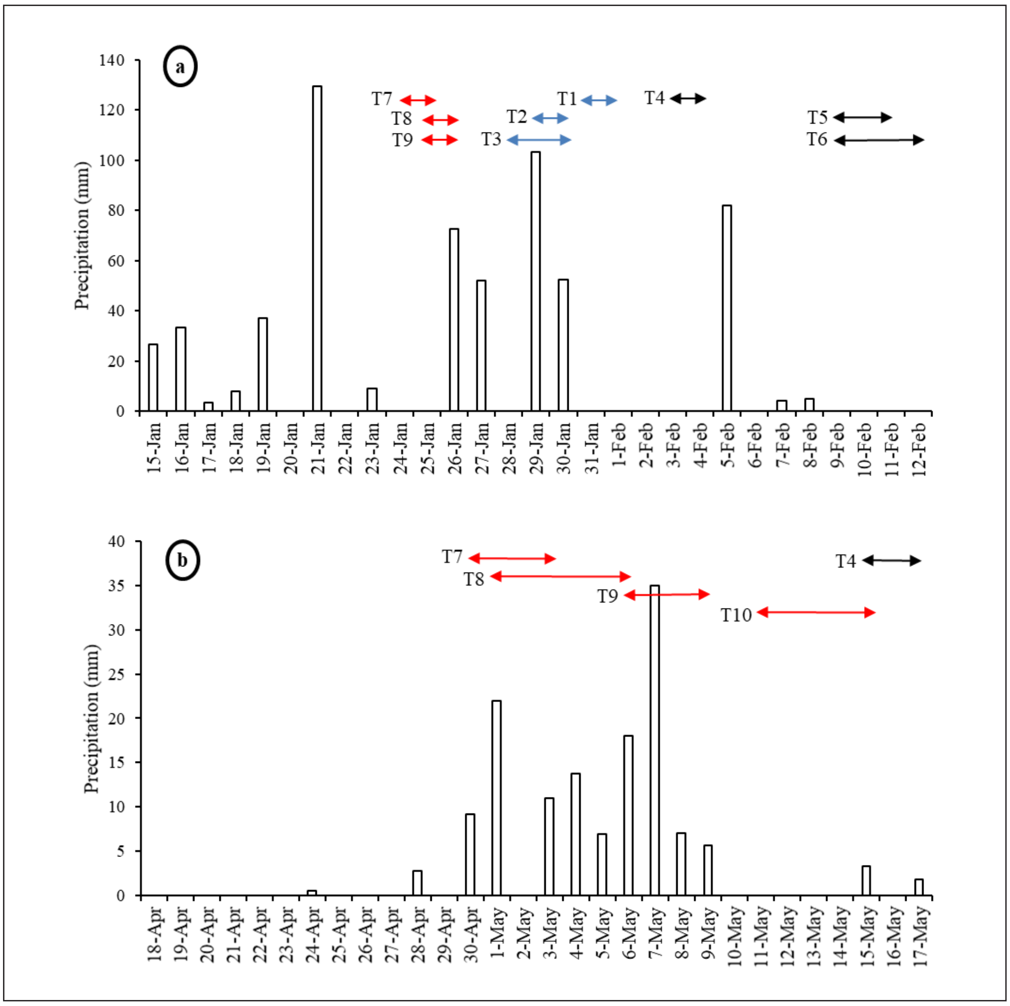

Fig. 2. In situ precipitation at the period prior to harvesting on cv. Pada (a), and cv. Sarawak (b). The double arrow (blue, black, and red represent CaC_2 NAA, and ethephon treatments, respectively) indicates the fruit harvesting period under the specified treatments.

such as total fruit weight (TFW), fruit weight without crown (FW-C), total fruit length (TFL), fruit length without crown (FL-C), fruit diameter (FD), peduncle length (PL) and peduncle diameter (PD) were measured based on six samples from each treatment using a vernier digital caliper and a measuring tape. Then, five fruit samples were washed, peeled, cored and further cut into 1.5 cm^3 cubes to analyze basic chemical properties, i.e., pH, TSS and TA. One-half of the samples were randomly selected and manually extracted using muslin cloths. The TSS of the fruit juice was evaluated using a hand-held refractometer (N1, ATAGO Corp, Japan). 10 mL of fruit juice was then diluted with 40 ml of distilled water to determine the pH (Eutech, pH 700, Singapore). The resultant diluted fruit juice was titrated against 0.1 N NaOH until the pH reached 8.2 ± 0.1, and the TA was calculated using equation 1 (Kamarul Zaman *et al.*, 2016). All tests were performed at 20 °C room temperature, and each sample was measured in triplicate.

$$\% \ TA = \frac{N \times V \times 0.064 \times 100}{S}$$

Where, N is the normality of NaOH used, V is the volume of NaOH used (mL), 0.064 is the equivalent weight of citric acid (g), and S is the weight of the fruit juice sample (g).

Statistical analysis

The software package SAS JMP Pro 14.3 was used to run the statistical analysis. The Shapiro-Wilk and Levene tests was selected to check normality and homogeneity of variance of the data, respectively. As the data is normally distributed and the variance was homogenous, a one-way analysis of variance (ANOVA) with Tukey test for mean comparison was performed. The significant baseline of data was $p<0.05$.

RESULTS AND DISCUSSION

Fruit physical properties

The pineapple fruit size would determine farm efficiency or profitability. One of the practices that helped determine fruit grade was its TFW. For the cv. Pada, the TFW ranged from 1131.3 to 1307.2 g (Table 2), whereas for cv. Sarawak these values ranged from 1372.2 to 1650.1 g (Table 3). To date, there is no established record of fruit grade for cv. Pada. However, for cv. Sarawak, the TFW mainly ranges from small to medium grade (Federal Agricultural Marketing Authority, n.d.). Besides, there was no significant difference between TFW and FW-C observed on cv. Pada, and TFW on cv. Sarawak in response to different AIF practices. In the case of FW-C on cv. Sarawak, T7 was significantly higher than T4 and T10. The higher FW-C in T7 clearly reflected the higher FD, TFW, and FL-C, although the last two variables stated were not significantly different.

Plant hormones assist in inflorescence or fruit development. Typically, the development is contributed by the cell activities such as cell multiplication and cell elongation. The type of hormones that regulate those cell activities depends on the plant species. In pineapple species, auxin and gibberellin have been reported to increase cell activities (Li *et al.*, 2011); however, in blueberries, this has been shown to decrease (Cano-Medrano & Darnell, 1997). During the development of the pineapple fruit, cell multiplication is dominant during early development, while at late development cell elongation activities are dominant (Wee & Rao, 1979). Under most circumstances, ethylene is capable of downregulating gibberellin and auxin levels in plants. The type of hormones used in the present study, i.e., CaC_2, NAA, and ethephon, would end up with increasing ethylene levels in plants, but their mechanism in biosynthesis of that ethylene was different (Yang 1969; Yu & Yang, 1979; Hansen & Grossmann, 2000; Cunha, 2005). As the application of these hormone concentrations increases, the level of ethylene biosynthesis would also increases (Khan *et al.*, 2008; Sun *et al.*, 2015; Torres *et al.*, 2021). Such conditions would further downregulate the gibberellin and auxin levels in the plant (Kim *et al.*, 2018). Therefore, the possibility of underdeveloped fruit would also increase when the pineapple plant was treated using a higher concentration of hormone-derived ethylene. This hormone crosstalk may partly explain the case of a significant higher of FL-C in T7 in comparison with T3. A similar trend was also in other related studies (Bhowmick *et al.*, 2011).

Meanwhile, on FD, the negative effect was recorded among ethephon treatments on cv. Sarawak, but inconsistent on cv. Pada, either based on CaC_2 or ethephon treatments. Although auxin promotes cell activities, most NAA (auxin source) treatments contributed to lower FD than others (Table 2). Another consideration of this assumption that may be of interest is that the fruit samples used were lacking in the generalization of the population due to the limited sampling units as a result of poor AIF response under NAA treatments (Sam Nureszuan *et al.*, 2021). Besides, the NAA treatments resulted in a prolonged vegetative stage or late inflorescence emergences. In that case, two possibilities were suspected to cause lower FD under the auxin treatments, namely nutrients and plant size effect, although both were not examined during the study. The nutrient depletion might be high under NAA treated plants because of the late inflorescence emergence stage or prolonged fruit harvesting date (Figure 2). Based on fertilizer recommendations by the Malaysian Pineapple Industry Board (n.d.), the last fertilization was carried out a month before

Table 1. The treatments used in cv. Pada and cv. Sarawak

Treatment	Description
T1	0.5% CaC_2
T2	1.0% CaC_2
T3	1.5% CaC_2
T4	5 ppm NAA
T5	10 ppm NAA
T6	15 ppm NAA
T7	120 ppm ethephon + 2% urea + 0.04% $CaCO_3$
T8	240 ppm ethephon + 2% urea + 0.04% $CaCO_3$
T9	360 ppm ethephon + 2% urea + 0.04% $CaCO_3$
T10	600 ppm ethephon + 2% urea + 0.04% $CaCO_3$

Note: CaC_2 and ethephon used were commercially graded, while NAA was analytical grades.

Table 2. Physical properties of pineapple fruit on cv. Pada

Treatment	TFW (g)	FW-C (g)	TFL (cm)	FL-C (cm)	FD (cm)	PL (cm)	PD (cm)
T1	1131.3 ± 120.2	1030.7 ± 122.2	25.3 ± 3.3	13.5 ± 1.1 ab	13.0 ± 0.5 abc	20.4 ± 1.4 cd	2.5 ± 0.1
T2	1209.8 ± 104.5	1109.0 ± 101.4	25.7 ± 2.1	13.5 ± 0.6 ab	13.2 ± 0.3 ab	22.1 ± 1.4 abcd	2.3 ± 0.2
T3	1255.8 ± 102.6	1152.3 ± 85.3	25.0 ± 2.2	13.0 ± 1.0 b	13.0 ± 0.2 abc	17.9 ± 0.7 e	2.4 ± 0.2
T4	1307.2 ± 236.2	1173.5 ± 235.6	26.7 ± 1.5	14.5 ± 0.9 ab	13.0 ± 0.5 cb	23.4 ± 2.0 a	2.6 ± 0.2
T5	1171.8 ± 173.2	1057.4 ± 174.0	25.0 ± 1.4	13.2 ± 1.3 ab	12.6 ± 0.4 cb	22.6 ± 1.6 abc	2.4 ± 0.3
T6	1183.4 ± 108.6	1022.3 ± 93.1	25.3 ± 1.2	13.2 ± 0.8 ab	12.45 ± 0.4 c	22.8 ± 1.4 ab	2.4 ± 0.2
T7	1268.4 ± 153.4	1127.8 ± 123.0	25.2 ± 3.7	14.8 ± 0.9 a	13.2 ± 0.2 ab	21.4 ± 0.8 abcd	2.4 ± 0.1
T8	1247.7 ± 113.0	1155.2 ± 114.2	25.8 ± 2.9	14.5 ± 0.6 ab	13.6 ± 0.4 a	20.9 ± 1.1 bdc	2.3 ± 0.3
T9	1221.6 ± 138.2	1133.5 ± 112.8	24.9 ± 2.5	14.3 ± 1.1 ab	13.3 ± 0.4 ab	20.2 ± 0.6 de	2.3 ± 0.3

Note: The value indicates mean ± standard deviation, with n=6. Statistical analysis of parametric test using ANOVA indicates a significantly different (p<0.05, Tukey's test), represented by a different alphabet, where a>b>c>d>e, meanwhile the non-alphabet indicated no significant difference among the treatments

Table 3. Physical properties of pineapple fruit on cv. Sarawak

Treatment	TFW (g)	FW-C (g)	TFL (cm)	FL-C (cm)	FD (cm)	PL (cm)	PD (cm)
T4	1372.2 ± 188.81	1074.39 ± 170.88 b	39.48 ± 2.17	15.0 ± 1.41	11.1 ± 0.49 b	20.6 ± 1.02 a	2.23 ± 0.10
T7	1650.1 ± 127.99	1398.4 ± 165.97 a	39.7 ± 1.52	16.7 ± 1.74	12.4 ± 0.45 a	19.8 ± 0.60 a	2.35 ± 0.10
T8	1486.0 ± 207.28	1182.8 ± 189.67 ab	39.7 ± 1.74	16.2 ± 2.10	11.6 ± 0.86 ab	20.3 ± 0.67 a	2.22 ± 0.21
T9	1387.2 ± 131.62	1113.6 ± 116.13 ab	38.7 ± 0.90	15.1 ± 0.69	11.3 ± 0.58 b	20.2 ± 1.18 a	2.22 ± 0.12
T10	1409.8 ± 211.06	1092.9 ± 210.70 b	40.4 ± 1.88	14.6 ± 1.89	11.1 ± 0.51 b	17.9 ± 1.04 b	2.23 ± 0.10

Note: The value indicates mean ± standard deviation, with n=6. Statistical analysis of parametric test using ANOVA indicates a significant difference (p<0.05, Tukey test), which is represented by a different alphabet, where a>b, meanwhile the non-alphabet indicated no significant difference among the treatments

AIF began. Also, the precipitation was somewhat high following the AIF period (Figure 1) which in turn reflects the rate of nutrients leached out. The longer the period from AIF application to the harvesting stage, the greater the amounts of nutrients that could be leached out, resulting in a lower amount of nutrients supplied to the fruit during the fruit development stage. In terms of the plant size effect, the larger the plant size generally causes a lower response to AIF (Py *et al.*, 1987). The size of planting materials is important as it would determine the plant size, especially during the AIF period, and previous studies (Tan & Wee, 1973; Norman, 1976; Fassinou Hotegni *et al.*, 2014) established that the plant size during AIF has a high positive correlation with the matured fruit size. Since the sucker used in the present study ranged from 300-500 g; thus, plant and fruit size variation may have happened.

The antagonistic effect of cell activities due to ethephon or CaC_2 treatments were apparent on the PL. There are several advantages of shorter PL, such as prevention of fruit lodging as the resistance of fruit PL increased as well as a lower sunburn effect due to less exposure of fruit to the sunlight or shading effect which due to the leaves of neighbouring plant. The T3 on cv. Pada, and T10 on cv. Sarawak exhibits significantly shorter PL; however, PD was not affected among the treatments. The trend of PL reduction in agreement with Liu *et al.* (2020), which demonstrated using ethephon but the magnitude of the reduction of PL in the present study (12% to 19% [T3 vs T1 and T2—cv. Pada]; 10% to 12% [T10 vs T7, T8, and T9—cv. Sarawak]), were lower than Liu *et al.* (2020) which reported more than 50% of PL reduction. It was found that the PL on both cv. Pada and cv. Sarawak in T9 did not significantly reduce when compared with a lower concentration than the same type of hormone (T7 and T8). The magnitude effect of PL reduction depended on the concentration used, which could be reflected by the reduction of auxin and gibberellin levels. This may partly explain the lack of significance of PL between ethephon, NAA, and CaC_2 treatments, as claimed by other authors (Butrat & Wangmuang, 2004). For the NAA treatment, particularly T4 on cv. Pada, these were found to exhibit significantly longer PL than most other treatments, which agrees with the mechanism of auxin's role in promoting cell activities. Also, our finding of the NAA effect on the PL corroborated with previous studies (Py *et al.*, 1987).

Fruit chemical properties

In terms of fruit chemical properties, there is no consensus regarding the response to AIF practices (Dass *et al.*, 1975; Norman, 1977; Py *et al.*, 1987; Butrat & Wangmuang, 2004; Shamsul Alam *et al.*, 2010; Dayondon & Valleser, 2018). Typically, the pH, TSS, and TA on cv. Pada ranged from 4.15-4.30, 16.8-18.5 °Brix, and 0.43%-0.51%, respectively. Meanwhile, these properties on cv. Sarawak were recorded at 3.84-3.91, 15.9-16.2 °Brix, and 0.40%-0.47% (Table 5). Overall, the properties of cv. Sarawak, particularly on TSS and TA, were within the acceptable ranges as reported by the Department of Agriculture (n.d.).

The present study found that only cv. Pada exhibited significant variation, particularly on fruit TSS and TA (Table 4). The TSS under NAA treatments (T5 and T6) were significantly higher than the majority of other treatments. The finding of the present study contradicted Butrat and Wangmuang (2004) and Shamsul Alam *et al.* (2010), who claimed that the TSS was lower under NAA treatment in comparison to ethephon. Perhaps the TSS is less likely influenced by the hormones but seems triggered by the precipitation conditions during the study period, particularly during the harvesting or ripening periods (Food and Agriculture Organization, 2021). The ripening period in this context is defined as the period of early fruit ripening to reach maturity index 5, which approximately took around ten days between those stages (Deka *et al.*, 2005). By computing the precipitation during the ripening period, the higher TSS recorded in that T5 and T6 corresponded with lower precipitation levels. Therefore, the dilution effect was assumed to be low under such conditions, eventually increasing the TSS value (Guichard *et al.*, 2001). This dilution mechanism may partly explain previous findings, where no significant effect was reported by Norman (1977) which may have been due to similar harvesting days, meanwhile, the significant effects claimed by Butrat and Wangmuang (2004) were due to different harvesting days.

The mechanism of dilution effect also influences fruit TA by which the higher precipitation generally reduces the TA (Pérez-Pérez *et al.*, 2009; GarcÍa-Tejero *et al.*, 2010; Etienne *et al.*, 2013). However, T5 and T6 (low precipitation conditions during the ripening period) had significantly lower TA than those in T1 (high precipitation conditions during the ripening period). Py and Tisseau (1965, as cited in Dorey *et al.*, 2016) also reported the contradicting trend of the dilution effects on pineapple. Similar trend patterns have been found in other plant species, e.g., apple (Wang *et al.*, 2019), grape (des Gachons *et al.*, 2004), and orange (Silveira *et al.*, 2020). Presumably, the mild water stress (from 22 to 25 Jan), followed by markedly higher precipitation conditions (from 26 Jan to 30 Jan) in T1 (Figure 2a), promotes the translocation of photosynthetic assimilates to the fruit, which then metabolized to form organic acid (Saradhuldhat, 2005).

Table 4. Chemical properties of pineapple fruit on cv. Pada

Treatment	pH	TSS (°Brix)	TA (%)
T1	4.19 ± 0.08	16.9 ± 0.18 d	0.51 ± 0.02 a
T2	4.30 ± 0.08	16.8 ± 0.26 d	0.44 ± 0.03 bc
T3	4.19 ± 0.04	17.2 ± 0.17 d	0.45 ± 0.02 bc
T4	4.16 ± 0.06	17.2 ± 0.17 d	0.43 ± 0.02 c
T5	4.16 ± 0.1	18.5 ± 0.3 a	0.43 ± 0.02 bc
T6	4.15 ± 0.09	18.3 ± 0.23 ab	0.44 ± 0.03 bc
T7	4.23 ± 0.07	17.9 ± 0.18 bc	0.47 ± 0.03 abc
T8	4.20 ± 0.08	17.7 ± 0.18 c	0.47 ± 0.02 ab
T9	4.23 ± 0.07	17.8 ± 0.2 c	0.44 ± 0.01 bc

Note: The value indicates mean ± standard deviation, with n=5. Statistical analysis of parametric test using ANOVA indicates a significant difference (p<0.05, Tukey test), which is represented by a different alphabet, where a>b>c>d, meanwhile the non-alphabet indicated no significant difference among the treatments.

Table 5. Chemical properties of pineapple fruit on cv. Sarawak

Treatment	pH	TSS (°Brix)	TA (%)
T4	3.84 ± 0.10	16.2 ± 0.19	0.47 ± 0.03
T7	3.91 ± 0.15	15.9 ± 0.21	0.43 ± 0.05
T8	3.85 ± 0.09	16.1 ± 0.17	0.43 ± 0.05
T9	3.85 ± 0.10	16.0 ± 0.26	0.40 ± 0.03
T10	3.87 ± 0.10	16.0 ± 0.28	0.46 ± 0.04

Note: The value indicates mean ± standard deviation, with n=5.

CONCLUSION

Some of the fruit's physical properties vary under different AIF treatments for both cv. Pada and cv. Sarawak. The use of low hormone concentration mostly results in better physical properties, but PL is desired when a higher concentration is used. Meanwhile, only cv. Pada exhibits significant variation in fruit chemical properties, particularly TSS and TA; however, the variation seems like reflected with precipitation conditions during which time conditions differed during the ripening period. Also, some of these findings could provide a better understanding amongst pineapple farmers, particularly regarding the AIF effect, subsequently, the farmers will be more aware when practicing the AIF by selecting the appropriate hormone concentrations. Any future research especially under controlled growing conditions (e.g., nutrient, seedling or plant size, and soil moisture) might be of interest in order to further enlighten the effects of AIF practices whether on the fruit's physical or chemical properties.

ACKNOWLEDGEMENTS

We thank Ministry of Higher Education, Malaysia for the Fundamental Research Grant Scheme (FRGS/1/2019/ WAB01/UPM/02/18).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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