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Effects of plant materials and plant densities on pineapple (*Ananas comosus* var. *srivijaya*) growth under intercropping with young oil palm (*Elaeis guineensis* Jacq.) in lowland area

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Abstract Plant material factor was significantly impacted 'Srivijaya' pineapple D-leaf length at 28–34 WAP. Plant material of 1.5 mg/L BA was the best for D-leaf length (26.45 cm at 34 WAP). The plant density factor was significantly impacted on D-leaf length. The D-leaf width of pineapple was significantly impacted by the plant material factor and was not significantly differed in the plant density factor. However, plant density of 21,687 plants per hectare gave longer D-leaf width. There was no interaction between the two factors for the D-leaf width of the 'Srivijaya' pineapple plants. Plant material from tissue culture fed by BA 1.5 mg/L showed the highest of increasing D-leaf width, reaching 1.56 cm at 31 WAP. After 12 months, plant height reached 15.78 cm at plant density 21,687 plants per hectare and 12.93 cm at plant density 19,275 plants per hectare. For plant material factor, it showed 15.18, 14.75 and 13.12 cm at 1.0, 1.5 and 2.0 mg/L BA respectively. The widest plant width was 86.85 cm at 1.5 mg/L BA and giving 80.33 and 72.28 cm at 1.0 and 2.0 mg/L BA respectively. Plant materials from tissue culture were 99.94% disease-free at the growth stage of pineapple. There was one sucker per plant at 12 months after planting. 'Srivijaya' pineapples grew better at 21,687 plants per hectare in lowland with plant materials from micropropagation fed by 1.5 mg/L BA. The result showed that 'Srivijaya' pineapples were grown well under intercropping with young oil palm fields in lowland area eventhough pineapple plantation on lowland faced problem of flooding.

Keywords: Benzylaminopurine, D-leaf, Intercropping, Lowland, Sucker

Introduction

The third most widely grown commercial tropical fruit in the world is the pineapple (*Ananas comosus* (L.) Merr.). It has excellent flavour, fresh and delicious (Chaudhary *et al.,* 2019). Vitamins, carbs, crude fibre, and calcium

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are just a few of the components found in pineapple fruit that are beneficial to human health. Fresh pineapple fruit is frequently eaten. Bromelain, which is beneficial for anti-inflammatory reasons and lowering swelling in inflammatory diseases, is abundant in freshly ripened pineapples (Hossain *et al*., 2015). However, processed pineapple products such as canned pineapple, wine, candies, citric acid, beverages, vinegar, dried pineapple, jelly, and jam are also made (Chaudhary *et al*., 2019; Hossain *et al*., 2015). Pineapple production totals 27.82 million metric tons in the world (Shahbandeh, 2022). Worldwide, a large number of pineapple cultivars have been produced, although there are hardly any hybrids. One of the best hybrid varieties with good quality and disease resistance was bred by Sripaoraya (2009), and it was named the 'Srivijaya' variety. Resistance to heart rot, root rot and wilt diseases are traits of 'Srivijaya' pineapple. According to the Department of Agriculture (2021) this pineapple variety has thorny leaves, a small crown weight (46.70 grams), a flat flower cup, and outstanding fruit quality. Pineapple plantations can be cultivated as separate crops or as intercrops. One crop that is possible to intercrop with pineapple is young oil palm (*Elaeis guineensis* Jacq.). Oil palm is a perennial plantation crop identified as the world's leading edible oil-producing crop and is usually grown well in tropical countries. The economic life span of oil palm is about 30-35 years and stands at 120–135 plants per hectare (Dissanayake and Palikkara, 2019; Gawankar *et al*., 2018). There is plenty of open space inside young oil palm farms at the beginning of the plantation (age 1-4 years) during the waiting period for producing oil palm. During this time, farmers were not receiving any income from oil palm and were forced to spend money on other agricultural activities like weeding. The time takes for the oil palm to begin producing is a big issue for smallholders who must invest a lot of time, money, and labour before they can start earning money from oil palm farms (Tonye *et al*., 2004).

Intercropping other crops with immature oil palm is possible and practiced, especially by small and medium-scale farmers with suitable crops. A previous study showed that growing banana, pineapple, and elephant foot yam as intercrops in young oil palm orchards for up to 4 years was the best preposition for earning additional returns from juvenile oil palm orchards in the South Konkan region of Sri Lanka (Dissanayake and Palikkara, 2019). Hettiarachchi *et al*. (2020) also reported that pineapple was a highly demandable fruit crop as a better intercrop with young oil palm. The pineapple was commonly grown in a monoculture system (Siebeneichler *et al*., 2019). However, it also had a higher potential to be cultivated for an intercropping culture system (Hettiarachchi *et al*., 2020).

Cultivation management should be studied since intercropping systems may have different management than monoculture systems. There are several crucial factors for pineapple plantations, such as plant density and plant material. Plant density is one of the keys to achieving high yields. Plant population, light utilization, and inter-plant competition are all impacted by plant spacing. Utilizing fertilizers and water has an impact on production. To prevent plant competition, the spacing and planting density must be determined to keep costs down. Furthermore, a significant part of the production of pineapples is pineapple plant material. In the field, good plant materials will flourish and bear fruit of the highest caliber. Pineapple plant materials were created via tissue culture, creating healthy plant materials. However, BA utilization may affect growth, and suckers in pineapples and it may affect yield. In addition, some palm plantation areas of the south of Thailand were grown in lowland. These areas used to grow rice but nowadays these areas have been producing palm plantations since 2000 (Local Information Repository of Nakhon Si Thammarat, 2023). Lowland has the characteristic soil type of sandy loam. Sandy, silt, and clay soils are fertile soils suitable for rice cultivation. However, lowland faces the flood as a challenge for pineapple cultivation. Waterlogging prevents proper gas exchange, which raises CO_2 levels and depletes O_2 levels in the soil, both of which inhibit growth by causing root anoxia. Other environmental factors have an effect on pineapple growth, such as temperature, soil type, soil pH, altitude, and slope (Hosea *et al*., 2021). Hence, it is critical to determine the best management, especially for plant densities and plant materials for growth and yield on the 'Srivijaya' pineapple variety production intercropping with young oil palm in lowland. The objectives were to study suitable plant density of the 'Srivijaya' pineapple variety under intercropping with young oil palm, and to study the effect of plant materials of the 'Srivijaya' pineapple variety from tissue culture fed by different BA concentrations.

Materials and methods

The experiment was conducted in a one-year oil palm field in Chalermprakiat district, Nakhon Si Thammarat Province, Thailand dated August 2022 - August 2023 with coordinates 8°10′36″N 100°2′6″E and 100 meters above sea level (Wikipedia, 2023). The plant material was 'Srivijaya' pineapple plantlets from tissue culture propagation. In the first stage, 'Srivijaya' pineapple plant materials were fed with MS+BA 1.0 mg/L, MS+BA 1.5 mg/L, and MS+BA 2.0 mg/L in tissue culture system. 'Srivijaya' pineapple planlets were moved to a greenhouse and were grown in a plastic bag with media containing soil, coconut peat, and rice husk charcoal in a ratio of 1:1:1. The plantlets were fertilized with NPK fertilizer and watered every two days. The characteristics of planting materials were uniform based on age (one year) and size (20–30 cm). Plant materials were healthy and free of disease before being transferred to the field.

A one-year oil palm field was used for this study. A nine-meter triangular oil palm planting pattern was used. The pineapple planting pattern was used in the double and triple rows for the field experiment. A double row of 50 cm x 50 cm x 100 cm was used for 19,275 plants per hectare, and a triple row of 50 cm x 50 cm x 50 cm x 100 cm, or 21,687 plants per hectare. NPK 15-15-15 was used to fertilize pineapple plants for growth. 15 grams per plant were applied at 13 weeks after planting (WAP) in the field. In addition, 200 grams per plant of chicken manure were applied 4 months after planting. Herbicide spraying using bromacil was used to suppress weeds at 3, 6, and 8 months after planting. Pineapple plants were watering if there was no rain.

Experimental research design

This research used a split plot design in a randomized complete block with four replications. The main-plot was plant density having two densities; 19,275 plants per hectare and 21,687 plants per hectare. The sub-plot was plant materials sourced from suckers that were produced by tissue culture using MS medium in three different BA concentrations (1.0 mg/L, 1.5 mg/L, and 2.0 mg/L). It used 200 and 300 plantlets per treatment for 19,275 and 21,687 plant densities, respectively. Therefore, the experiment had 500 plants per BA concentration, for a total of 1,500 plantlets per experiment. Ten plants per treatment in each replication were sampled in each experimental unit for data recording.

The variables measured were D-leaf length and width, plant height, plant width, average of new suckers, heart rot and root rot, as well as wilt disease. Data on D-leaf length and width was recorded using a caliper and a ruler from the most recently longest and widest leaf of pineapple. The characteristics of heart rot and root rot are the rot of pineapple plants in the apical meristem; the leaf color changes to yellow; stunted growth and death. Wilt disease is identified by wilt in the leaves of pineapple; the leaf color changes to orange from the tip part, and the leaf texture is soft. Data was collected and analyzed using analysis of variance (ANOVA). The Duncan Multiple Range Test was used for the mean difference analysis at 5 % and 1 % levels.

Results

The growth of 'Srivijaya' pineapple effected by plant materials and plant densities

Pineapple plants were grown under intercropping with young oil palms on lowland (Figure 1). The pineapple plants still receive plenty of sunshine for the photosynthesis of pineapples. Oil palm plants and 'Srivijaya' pineapple plants have separate root systems. Oil palm roots are deeper than pineapple roots, which are shallower from the surface. As a result, despite being intercropped, pineapple plants continue to thrive and absorb nutrients well. Lowland in Chalermprakiat district was still supportive of pineapple growth. It showed the flooding caused by heavy rain was one of the challenges of lowland area which had to be dealt with manually to drain the water to ditchs (Figure 2 and 3).

1 WAP a 49 WAP 1 WAP b 49 WAP

Figure 1. 'Srivijaya' pineapple plant grows in different densities a. 19,275 plants/ha b. 21,687 plants/ha

Figure 2. Flood at pineapple field at 2 months after planting during heavy rain in lowland (Chalermprakiat district, Nakhon Si Thammarat, Thailand)

Figure 3. Ditch in oil palm field in lowland area (Chalermprakiat District, Nakhon Si Thammarat, Thailand

Effect of plant materials and plant densities on the growth of 'Srivijaya' 6 weeks after applying fertilizers (34 WAP) showed that the plant materials had a significant impact on D-leaf length, plant width, and number of new suckers. Other variables showed no significant difference in value. The results showed no interaction between plant materials and plant densities in all variables at 34 weeks after planting (Table 1).

Table 1. Effect of plant densities and plant materials on growth and disease resistance of 'Srivijaya' variety under intercropping system with young oil palm in lowland after applying NPK fertilizers for 6 weeks (34 WAP)

Factors	D-leaf length (cm)	D-leaf width (cm)	Plant height (cm)	Plant width (cm)	Sucker/ plant	Diseases (%)
Plant densities (D)						
19,275 plants/ha	23.01	1.49	6.88	48.40	0.08	0
21,687 plants/ha	23.91	1.52	7.42	50.11	0.35	0
Plant materials (M)						
1.0 mg/L BA	23.31^{b}	1.50	7.63	48.68^{ab}	0.20	0
1.5 mg/L BA	26.45^{a}	1.61	7.29	52.49^{a}	0.33	0
2.0 mg/L BA	20.63^{b}	1.40	6.54	46.60^{a}	0.38	0
D	ns	ns	ns	ns	ns	ns
M	**	ns	ns	*	ns	ns
D X M	ns	ns	ns	ns	ns	ns
CV (%)	16.23	12.45	15.37	9.77		-

ns-no significant; *significant at p≤0.05; **significant at p≤0.01; means in the same column followed by the same letter were not significantly different according to Duncan's multiple range test, p<0.05

D-leaf length and increasing D-leaf length of 'Srivijaya' pineapple

The data were compared on D-leaf length and increasing D-leaf length of 'Srivijaya' pineapple per 3 weeks starting 28–34 WAP under different plant densities and plant materials in lowland (Table 2). The results of variance analysis showed that at 28–34 WAP, plant materials impacted D-leaf length from 28 WAP to 34 WAP but had no significant effect on increasing D-leaf length. Plant densities were not significantly affected by both D-leaf length and increasing D-leaf length. There was no interaction between the two factors of D-leaf length and increasing D-leaf length in 'Srivijaya' pineapple (Table 2).

Table 2. Effect of plant densities and plant materials on D-leaf length and increasing D-leaf length of 'Srivijaya' pineapple at 28-34 WAP in Chalermprakiat district, Nakhon Si Thammarat

Factors	**D-leaf length (cm)**			**Increasing D-leaf length (cm)**	
	28 WAP	31 WAP	34 WAP	31 WAP	34 WAP
Plant densities (D)					
19,275 plants/ha	21.81	22.27	23.01	0.46	0.74
21,687 plants/ha	22.36	22.89	23.91	0.53	0.64
Plant materials (M)					
1.0 mg/L BA	21.56^{b}	21.91^{b}	23.31^{b}	0.35	0.83
1.5 mg/L BA	24.93^{a}	25.62^{a}	26.45^{a}	0.69	0.83
2.0 mg/L BA	19.77^{b}	20.21^{b}	20.63^{b}	0.44	0.42
D	ns	ns	ns	ns	ns
M	**	**	**	ns	ns
D X M	ns	ns	ns	ns	ns
CV (%)	15.21	15.19	16.23	44.04	38.86

ns-no significant; **significant at $p \leq 0.01$; means in the same column followed by the same letter were not significantly different according to Duncan's multiple range test, $p<0.05$

Plant material factor from sucker growth in tissue culture systems using 1.5 mg/L BA was the longest D-leaf per 3 weeks observed. D-leaf length of 'Srivijaya' pineapple per 3 weeks starting at 28–34 WAP under different plant densities and plant materials was shown in Table 2. The results of variance analysis showed that at 28–34 WAP, pineapple was significantly impacted by the plant material factor and not significantly different by the plant density factor. There was no interaction between the two factors and the D-leaf length of the 'Srivijaya' pineapple plants. Plant materials from tissue culture fed by 1.5 mg/L BA were the most effective in improving D-leaf length, reaching 24.93, 25.62, and 26.45 cm at 28, 31, and 34 WAP. This indicates that there was no relationship between the higher concentrations of BA and the increased D-leaf length of 'Srivijaya' pineapple plants in Chalermprakiat district. The increase of D-leaf length reached 0.74 cm in plant density (19,275 plants/ha), and plant materials from 1.0 mg/L BA and 1.5 mg/L BA induced 0.83 cm at 6 weeks after fertilizing application (WAF).

D-leaf width and increasing D-leaf width of 'Srivijaya' pineapple

The D-leaf width of 'Srivijaya' pineapple at every 3 weeks starting at 28–34 WAP in Chalermprakiat effected by plant densities and plant material was shown in Table 3. The results of variance analysis showed that at 31 WAP and 34 WAP, pineapple was significantly impacted by the plant material factor and not significantly different by the plant density factor. There was no interaction between the two factors and the D-leaf width of the 'Srivijaya' pineapple plants.

Plant material from tissue culture fed by BA 1.5 mg/L was the highest to improve D-leaf width, reaching 1.56 cm and 1.61 cm at 31 and 34 WAP. However, plant materials from tissue culture fed 1.0 mg/L and 2.0 mg/L had a lower effect on D-leaf width. It indicated that there was no relationship between the higher concentrations of BA and the increased D-leaf width of 'Srivijaya' pineapple plants in Chalermprakiat district.

Table 3. Effect of plant densities and plant materials on D-leaf width of 'Srivijaya' pineapple at 28-34 WAP in Chalermprakiat district

Factors	**D-leaf width (cm)**			**Increasing D-leaf width (cm)**	
	28 WAP	31 WAP	34 WAP	31 WAP	34 WAP
Plant densities (D)					
19,275 plants/ha	1.34	1.40	1.49	0.06	0.10
21,687 plants/ha	1.37	1.46	1.52	0.09	0.06
Plant materials					
1.0 mg/L BA	1.37^{ab}	1.44^{a}	1.50	0.07	0.06
1.5 mg/L BA	1.46^{a}	1.56^{a}	1.61	0.10	0.06
2.0 mg/L BA	1.24^{b}	1.28^{b}	1.40	0.05	0.12
D	ns	ns	ns	ns	ns
M	*	**	ns	ns	ns
D X M	ns	ns	ns	ns	ns
CV (%)	11.46	12.82	12.45	45.93	36.71

ns-no significant; *significant at $p \leq 0.05$; **significant at $p \leq 0.01$; means in the same column followed by the same letter were not significantly different according to Duncan's multiple range test, $p<0.05$

The increasing D-leaf width of the 'Srivijaya' pineapples at 31 and 34 WAP was studied for different plant densities and plant materials. The variance analysis showed that there was no interaction between the two parameters and the increasing D-leaf length in 'Srivijaya' pineapple was unaffected by pineapple at 31 and 34 WAP. However, data showed that the pineapple's D-leaf length increased by less than 1 cm after three weeks and six weeks of fertilizing at 31 WAP.

Plant height and increasing of plant height of 'Srivijaya' pineapple plants

The highest plant height of 'Srivijaya' pineapple, which used plant materials from 1.0 mg/L BA gave the highest plant height and was significantly different from higher BA concentration treatments at 40 to 49 WAP. Moreover, plant densities had significant impact on the plant height of 'Srivijaya' pineapple at 28, 43, 46 and 49 weeks after planting (Table 4).

Table 4. Effect of plant densities and plant materials on plant height of 'Srivijaya' pineapple at 28-49 WAP in Chalermprakiat district

Factors	**Plant height (cm)**						
	28 WAP	31 WAP	34 WAP	40 WAP	43 WAP	46 WAP	49 WAP
Plant densities (D)							
19,275 plants/ha	4.61^{b}	5.61	6.88	8.20	9.03	10.11^{b}	12.93^{b}
21,687 plants/ha	5.74^{a}	6.38	7.42	8.48	9.64	12.33^{a}	15.78^{a}
Plant materials (M)							
1.0 mg/L BA	5.64	6.54	7.63	9.06^{a}	9.95^{a}	12.16^{a}	15.18^{a}
1.5 mg/L BA	5.29	6.03	7.29	8.59^{b}	9.75^{ab}	11.88^{ab}	14.75^{ab}
2.0 mg/L BA	4.60	5.41	6.54	7.36^{c}	8.30^{c}	9.62^{c}	13.12^{b}
D	*	ns	ns	ns	ns	*	*
M	ns	ns	ns	**	*	**	**
D X M	ns	ns	ns	ns	ns	ns	ns
CV (%)	19.86	16.38	15.37	14.40	14.64	18.19	19.38

ns-no significant; *significant at $p \leq 0.05$; **significant at $p \leq 0.01$; means in the same column followed by the same letter were not significantly different according to Duncan's multiple range test, $p < 0.05$

The increasing plant height of the 'Srivijaya' pineapples at 31 - 49 WAP was studied for different plant densities and plant materials (Table 5). Data showed that the pineapple's plant height increased more than 1 cm at plant density 19,275 plants/ha at 34 WAP. One year after planting, total increasing of plant height of 'Srivijaya' pineapple in Chalermprakiat district reached 10.03 cm at 21,687 plants/ha and it was higher than increasing plant height total at 19,273 cm (8.32 cm). However, the increasing plant height total reached 9.46 cm for plant material using 1.5 mg/L BA.

Plant width and increasing of plant width on 'Srivijaya' pineapple plants

There was not significantly affected and no interaction between the two different plant densities on plant width of 'Srivijaya' pineapple at 31, 34, 37, 40, 43, 46, 49 WAP (Table 6). Plant materials containing 1.5 mg/L BA were the best for plant width as well as 1.0 mg/L BA since 28 to 49 WAP. However, 2.0 mg/L BA gave the best for increasing plant width (Table 7).

Table 5. Effect of plant densities and plant materials on increasing plant height of 'Srivijaya' pineapple at 31-49 WAP in Chalermprakiat district

Factors	Increasing plant height (cm)						
	31 WAP	34 WAP	40 WAP	43 WAP	46 WAP	49 WAP	Total
Plant densities (D)							
19,275 plants/ha	1.00[a]	1.28	1.32	0.83	1.08	2.82	8.32
21,687 plants/ha	0.64[b]	1.03	1.06	1.17	2.69	3.44	10.03
Plant materials (M)							
1.0 mg/L BA	0.91	1.08	1.44	0.94	1.32	3.02	9.54
1.5 mg/L BA	0.74	1.26	1.30	1.16	2.13	2.88	9.46
2.0 mg/L BA	0.81	1.13	0.83	0.89	2.21	3.5	8.52
D	*	ns	ns	ns	ns	ns	ns
M	ns	ns	ns	ns	ns	ns	ns
D X M	ns	ns	ns	ns	ns	ns	ns
CV (%)	48.60	43.73	64.44	44.64	61.98	46.77	21.79

ns-no significant; *significant at $p \leq 0.05$ means in the same column followed by the same letter were not significantly different according to Duncan's multiple range test, $p<0.05$

Table 6. Effect of plant densities and plant materials on plant width of 'Srivijaya' pineapple at 28-49 WAP in Chalermprakiat district

Factors	Plant width (cm)						
	28 WAP	31 WAP	34 WAP	40 WAP	43 WAP	46 WAP	49 WAP
Plant densities (D)							
19,275 plants/ha	42.75	44.50	48.40	57.47	65.11	72.55[b]	75.39
21,687 plants/ha	45.72	47.28	50.11	56.22	68.50	79.99[a]	84.22
Plant materials (M)							
1.0 mg/L BA	44.24[ab]	46.01[ab]	48.68[ab]	55.71[ab]	64.95[b]	75.83[ab]	80.33[ab]
1.5 mg/L BA	47.38[a]	49.31[a]	52.49[a]	61.36[a]	74.00[a]	84.24[a]	86.85[a]
2.0 mg/L BA	41.09[b]	42.35[b]	46.60[a]	53.45[b]	61.46[b]	68.75[b]	72.28[b]
D	ns	ns	ns	ns	ns	*	ns
M	*	*	*	*	**	*	*
D X M	ns	ns	ns	ns	ns	ns	ns
CV (%)	11.65	11.29	9.77	10.98	12.58	14.96	14.57

ns-no significant; *significant at $p \leq 0.05$; **significant at $p \leq 0.01$; means in the same column followed by the same letter were not significantly different according to Duncan's multiple range test, $p<0.05$

Average of new suckers of 'Srivijaya' pineapple plants before flowering

Every three weeks, more suckers were added to the population (Table 8). Plant densities and plant materials had no significant impact on the average number of new suckers at 28 to 49 WAP. New suckers of 'Srivijaya' pineapple plants that grow in higher plant density (21,687 plants/ha) were bigger than 19,275 plants/ha in the growing period. There was no significant average of new suckers per plant in different BA levels (Figure 4).

Table 7. Effect of plant densities and plant materials on increasing plant width of 'Srivijaya' pineapple at 31-49 WAP in Chalermprakiat district

Factors	**Increasing plant width (cm)**						
	31 WAP	34 WAP	40 WAP	43 WAP	46 WAP	49 WAP	Total
Plant densities (D)							
19,275 plants/ha	1.75	3.90	9.06	7.64	7.44	3.06	32.86
21,687 plants/ha	1.57	2.83	6.11	12.28	11.49	4.25	38.53
Plant materials (M)							
1.0 mg/L BA	1.26	2.66	6.85	8.01	7.29	2.61	31.51
1.5 mg/L BA	1.78	3.18	7.04	9.24	10.24	3.85	36.09
2.0 mg/L BA	1.94	4.25	8.87	12.64	10.88	4.50	39.48
D	ns	ns	ns	ns	ns	ns	ns
M	ns	ns	ns	ns	ns	ns	ns
D X M	ns	ns	ns	ns	ns	ns	ns
CV (%)	34.71	40.67	60.25	45.24	53.41	80.64	23.91

ns - no significant at 0.05 according to Duncan's multiple range test at $p \leq 0.05$

Table 8. Effect of plant densities and plant materials on average of new suckers of 'Srivijaya' pineapple at 28-49 WAP in Chalermprakiat district

Factors	**Average of new suckers (sucker)**						
	28 WAP	31 WAP	34 WAP	40 WAP	43 WAP	46 WAP	49 WAP
Plant densities (D)							
19,275 plants/ha	0.02	0.08	0.09	0.14	0.29	0.29	1.18
21,687 plants/ha	0.10	0.35	0.51	0.87	0.93	0.93	1.80
Plant materials (M)							
1.0 mg/L BA	0.10	0.11	0.20	0.53	0.63	0.64	1.54
1.5 mg/L BA	0.00	0.38	0.33	0.51	0.61	0.63	1.41
2.0 mg/L BA	0.08	0.15	0.38	0.48	0.59	0.58	1.52
D	ns	ns	ns	ns	ns	ns	ns
M	ns	ns	ns	ns	ns	ns	ns
D X M	ns	ns	ns	ns	ns	ns	ns
CV (%)							

ns - no significant at 0.05 according to Duncan's multiple range test at $p \leq 0.05$

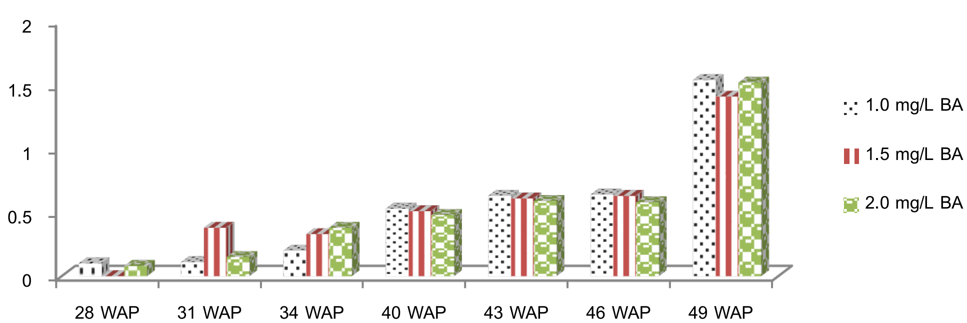

Figure 4. Number of new sucker of Srivijaya pineapple in Chalermprakiat district effeccted by different plant materials

Disease occurrence in growth stage of 'Srivijaya' pineapple under intercropping with young oil palm

There were no infections from 28 to 46 weeks unless at 49 weeks (Table 9). There were only 0.06 % cases of heart rot, 0% cases of root rot, and 0% cases of wilt disease. This indicates that the heart rot, root rot, and wilt diseases are not harmful and 99.94% of 'Srivijaya' pineapple plants were free diseases.

Table 9. Effect of plant densities and plant materials on disease occurrence of 'Srivijaya' pineapple at 28-49 WAP in Chalermprakiat district

Factors	**Disease Occurrence (%)**						
	28 WAP	31 WAP	34 WAP	40 WAP	43 WAP	46 WAP	49 WAP
Plant densities (D)							
19,275 plants/ha	0	0	0	0	0	0	0.06
21,687 plants/ha	0	0	0	0	0	0	0
Plant materials (M)							
1.0 mg/L BA	0	0	0	0	0	0	0
1.5 mg/L BA	0	0	0	0	0	0	0.06
2.0 mg/L BA	0	0	0	0	0	0	0

Discussion

Effect of plant density and plant material on growth of 'Srivijaya' pineapple in lowland

The area space for 'Srivijaya' pineapple growth under the cropping system with young oil palm was enough and available. The growth of 'Srivijaya' pineapple under intercropping young oil palm field presented the growth variables at 28 to 49 WAP. However the area remains vacant in oil palm gardens. Hence, both pineapple plants and oil palm can grow well in the field. 'Srivijaya' pineapple plants under intercropping system with young oil palm have growth and disease resistance not different from growing monocropping of pineapple. However, the challenge of pineapple cultivation in lowland was flooding when there was heavy rain even when any drain system in the oil palm field. Flooding impacted on waterlogging conditions in soil. Waterlogging stress restricts energy metabolism, prevents aerobic respiration, and interferes with a number of plant growth processes. In response to the stress of waterlogging, plants adjust their morphological structure, energy metabolism, signalling pathways, and endogenous hormone production. Under waterlogging stress, plants exhibit changes in their morphological structure, photosynthesis, respiration, damage from reactive oxygen species, synthesis of plant hormones, and signaling cascades. Stress from waterlogging has a negative impact on vegetative and reproductive growth, which can result in harvest failure or yield loss (Pan *et al*., 2021).

D-leaf growth of 'Srivijaya' pineapple in lowland

The study found that plant material factor significantly impacted 'Srivijaya' pineapple D-leaf length at 28-34 WAP, with 1.5 mg/L BA was the best plant material. The plant density factor did not significantly impact D-leaf length. There was no relationship between BA concentration and increased D-leaf length in 'Srivijaya' pineapple plants. Both plant materials gave no significant effect to increasing D-leaf length of 'Srivijaya' pineapple in Chalermprakiat district. This study is agreed with Valentina *et al*. (2023) found that increasing D-leaf length was no significant difference. The increasing D-leaf length in lowland has longer reached 0.74 cm compared to 0.49 cm in highland at 6 weeks after fertilizer application (WAF) (Valentina *et al*., 2023).

Plant width of 'Srivijaya' pineapple in lowland

The plant components had a big impact on the 'Srivijaya' pineapple's plant width. For BA concentrations, plant material from 1.5 mg/L BA gave the best to support plant width growth and reach 86.85 cm a year after planting, with no significant difference to 1.0 mg/L BA. In contrast, the smallest width of 'Srivijaya' pineapple plants in Chalermprakiat district had the greatest BA concentration at 2.0 mg/L. The width of the pineapple did not significantly increase affected by plant density. The overlapping of the basal leaves, which creates shade and lowers evaporative loss as well as weed growth, is one of the many benefits of high-density planting. Due to the intense plant density, the rapidly growing leaves had tendency to twist and grow upright, giving the fruits a natural covering to protect them from sunburn and producing shiny, evenly colored fruits (Assumi *et al*., 2021).

Plant height of 'Srivijaya' pineapple in lowland

Plant height is a crucial growth trait that is directly related to yield, which is positively correlated with plant productivity, as claimed by Omotoso and Akinrinde (2013). According to Omotoso and Akinrinde (2013), a prime growth characteristic directly related to yield and favourably correlated with plant productivity is plant height. The height of pineapples was affected differently by plant materials and plant densities at 49 or a year after planting, but there were no significant combination factors.

The plant height of the 'Srivijaya' pineapple after one year in Chalermprakiat was 15.18 cm (1.0 mg/L BA), 14.75 cm (1.5 mg/L BA), and 13.12 cm (2.0 mg/L BA). It showed that the fewest BA concentrations used to produce planting materials from tissue gave the highest height of 'Srivijaya' pineapple plants on the field. In addition, plant densities with 21,687 plants/ha gave 15.18 cm in 3 rows arranged, higher than pineapple grown with 19,275 plants/ha. Since higher density pineapple plants will compete with other plants to take light for photosysthesis. So, higher plant density showed higher fo plant height. However, this result was shorter than study by Jalil *et al*. (2019), plants grown in mineral soil reached 25 cm of plant height at 11 weeks after planting. Plant height of 'Srivijaya' pineapple was shorter due to flooding. The Srivijaya pineapple growth faced challenges for waterlogging and flooding when it rained heavily. It had an impact on the growth However, Srivijaya pineapple still grow and will give the fruit. According to Hosea *et al*. (2021), pineapples thrive in well-drained, aerated soils with good water retention, such as loams, sandy loams, and clay loams with no heavy clay or rock within one metre, and clayey soils are not recommended for pineapple cultivation.

New suckers at growth stage of 'Srivijaya' pineapple in lowland

Traditional pineapple plants frequently use slips, crowns, and suckers as plant materials. Unfortunately, it takes longer, roughly 16 to 18 months following pineapple harvesting (Sulaiman *et al*., 2020). As a result, the tissue culture method can be used to find a solution because it can deliver a lot of plant materials quickly. The other issue with using material from tissue culture is that too many suckers form prior to flowering, which affects the fruit's quality and size (Zhang *et al*., 2016). Similar to the study of Markos (2014) found that before flowering, there are a lot of suckers that result in lower fruit quality, such as shrinking fruit diameter. Then, the pineapple will distribute its nutrients to fruit and suckers. New suckers continued to grow slowly during the growth stage, following the main suckers as plant material.

In plant tissue culture, stem elongation and apical dominance are primarily regulated by plant growth regulators (Sulaiman *et al.,* 2020). Many suckers develop when pineapple is replanted in the field due to growth regulators (BA) in the tissue culture method. In Chalermprakiat, 'Srivijaya' pineapples were grown in plant density 21,687 plants/ha and occurred more sucker compared to 19,275 plants/ha during 28-49 WAP. Plant materials from 2.0 mg/L BA and 1.0 mg/L BA gave close average number of new suckers, 1.52 and 1.54 suckers respectively.The number of new suckers in higher plant density induced more sucker. It due to the higher number of plants in an area was bigger probably imply more suckers. However, higher BA concentrations induced more suckers in the field. It was confirmed that effect of higher BA from tissue culture induced more new shoots until the cultivation on field (Valentina *et al*., 2020).

Diseases of 'Srivijaya' pineapple in lowland

Key issues in pineapple plant cultivation include diseases. Heart rot, root rot, and wilt disease are the three main ailments that affect pineapples. According to Sripaoraya (2009) and the Department of Agriculture (2021), the 'Srivijaya' variety had a strong resistance to heart rot and wilt disease. At 28 WAP up to 46 WAP, plant materials grown in tissue culture were completely free of disease. Clean planting materials are produced by plant materials from tissue culture, and they can thrive in similar environments (Jackson *et al*., 2016).

However, at 49 WAP, the disease occurrence of 'Srivijaya' pineapple only infected 0.06 percent of cases of heart rot disease. In conclusion, the incidence of heart rot, root rot and wilt disease attacks was less than 1%, indicating a 99% resilience of 'Srivijaya' pineapples to these diseases. This result was also close to previous research from Valentina *et al.* (2023), which showed that plant materials from tissue culture gave 100% resistance to diseases at the growth phase of 'Srivijaya' pineapple in highland (Thungyai district, Nakhon Si Thammarat, Thailand).

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