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Planting density and flowering inducement agents effect on flowering and productivity of MD2 pineapple variety cultivation on acid sulfate soil in Tien Giang province, Vietnam

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Abstract
MD2 pineapple (*Ananas comosus* L.) was an imported cultivar into Vietnam, which was introduced to the model of growing pineapple on acid sulfate soil of Tien Giang province in 2019. Planting density and flowering rate were major factors incluencing pineapple productivity. Experimenting with planting density and flowering treatment on MD2 pineapples grown in acid sulphate soil of Tan Phuoc dictrict, Tien Giang province aim to determine the plant spacing corresponding to appropriate density and flowering treatment substance to increase flowering rate and yield of MD2 pineapple. The present study were two experiments that were arrange in a randomized complete blocks design (RCBD). The trial (1) was four planting density including T1 (38400 plants/ha), T2 (34100 plants/ha), T3 (30700 plants/ha), T4 (40000 plants/ha). The trial (2) was five dose of flower forcing such as 5 g/L CaC_2, 10 g/L CaC_2, 15 g/L CaC_2, 30ml/L Ethephon and 60ml/L Ethephon. The results indicated that fruit weight without crown produced by treatments T1, T2, T3 (1.575 kg/fruit, 1.543 kg/fruit and 1.605 kg/fruit, respectively) were greater than control T4 (1.390 kg/fruit). Treatment T1 was highest in fruit yield (28.73 tons/ha). At Ethephon 60 ml/L had an earlier flowering time (23.8 days), the a higher percentage of flowering (94.2%). Ethephon 30 ml/L - 60 ml/L were lower shoot crown weight (265.1 g/crown - 288.5 g/crown).

Keywords: Calcium carbide, density, ethephon, MD2 pineapple, flower inducement

Introduction
Vietnam is one of the pineapple growing countries in the world, with a total pineapple producing area of approximately 45295 hectares and a production of 654801 tonnes [21]. The Mekong Delta provinces that grow a large area pineapple, such as Tien Giang (15,500 ha), Kien Giang (7,580 ha), Hau Giang (2,000 ha), Long An (900 ha), Ca Mau, Can Tho, account for 70% of the country's output Queen pineapple, in which Tien Giang and Kien Giang accounting for 80% of the total area. Pineapple area in the North was estimated at 144,000 hectares, with an output of 185.6 thousand tons, accounting for 3.6% of the total area of fruit trees in the region, about 30.6% of the area and 27.5% of pineapple production in the whole country [11]. The MD2 pineapple variety was imported into Vietnam, has been evaluated by the Fruit and Vegetable Research Institute for its adaptability to domestic conditions, and has been recognised as a variety for trial production by the Ministry of Agriculture and Rural Development since 2012. MD2 pineapple was officially recognised for production in the Northern regions and the Mekong Delta in 2018 [10]. MD2 cultivar is preferred because of its sweetness and yellow color [2, 17]. Planting density had a great influence on pineapple yield [9, 6]. Increasing the number of pineapple plants per unit area reasonably was contribute to increasing pineapple yield [6]. Traditionally, pineapple production has used planting densities of around 30,000 plants/ha in low input systems [14, 16]. Previous studies have been grown using varying plant density per hectare Chinese Smooth Cayenne [7] and MD-2 [4]. Variety related to flowering rate and flower forcing agents were factors influencing flowering time and flowering rate of MD2 pineapple. The success or failure of the flowering determined by the number of plants that flowered during the treatment. The fruit grown large when the growing conditions were optimal [1]. In the Mekong Delta, farmers treated Queen pineapple flowers with calcium carbide (CaC_2) however, the flowering time and flowering rate affected by the quality of CaC_2, concentration and flowering treatment. Aplication ethephon to force pineapple flowers is highly effective and is being used widely in many countries. Application of ethylene and ethylene-releasing chemicals like ethephon used to induce flowering [8, 3].

The dose of ethephon for pineapple flower treatment ranges from 1.1 to 4.5 kg/ha. Efficiency flowering can reach 100% of flowering plants, 2-3 weeks earlier [20]. MD2 is a new pineapple variety planted in the acid sulfate soil of Tan Phuoc - Tien Giang. Therefore, it is very necessary to carry out research on planting density and flowering treatment on MD2 pineapples.

Materials and Methods

Place and time: The field trial carried out at Tan Lap and Thanh Tan commune, Tan Phuoc district, Tien Giang province from 2019- 2021. Fruit samples analyzed at Lab of Tien Giang Center of Applied Research and Science Technology Services and Tien Giang University.

Experiment 1: Effect of plants spacing on growth and yield of MD2 pineapple

Pineapple seedling was used sucker weighing 100 to 150 g. The trial was arrange in a randomized complete blocks design (RCBD) consisting of four treatments, each treatment corresponds to the plant spacing (planting density) and five replications. The treatments were T1 (38400 plants/ha), T2 (34100 plants/ha), T3 (30700 plants/ha), control T4 (40000 plants/ha) (Table 1).

Table 1: Experimental treatments

Treatment	Plant spacing (cm) (AxBxC)	Planting density (plant/ha)
T1	50 x 80 x 40	38 400
T2	50 x 80 x 45	34 100
T3	50 x 80 x 50	30 700
T4	50 x 50 x 50	40 000

A: Spacing between row, B: aisle between double rows, C: Spacing between plant on the same row

Experiment 2: Effect of flowering inducement on flowering rate and yield of MD2 pineapple

The field trial carried out at Thanh Tan commune, planting density was 38400 plants/ha. The trial arranged in a randomized complete block design (RCBD) with four replications and five treatments. The five treatments were 5 g/L CaC_2, 10 g/L CaC_2, 15 g/L CaC_2, 30ml/L Ethephon and 60ml/L Ethephon. When the plant matured, observation the plants had signs switches from juvenile (the vegetative growth stage) into maturity stage (the generative growth stage) and the flowering substances sprayed on the apical of pineapple in the early morning.

Data collection

Number of leaves (leaves/plant): Count the total number of leaves on the pineapple plant;

D leaf length (cm): Measured from the base of the D leaf to the tip of the D leaf (measure at before flowering treatment); Flowering time (days): Time from plants treated to flowers (The stage of inflorescence emergence was observed red color at heart, known as 'red heart' due to the reddish peduncle bracts); Flowering rate (%):(Number of flowering plants/total number of treated plants) x 100; Weight of crown (g/crown): Weighed 20 crown/replica; Fruit weight (g/fruit): Mean value of 20 fruits in the treatment; Actual yield (kg/m2): Weigh all of the fruits on the trial plot; Fruit firmness (kg/cm^2) using digital penetrometer; Total soluble solids (Brix %) content measured by hand refractometer (ATAGO, Japan).

Data analysis

Data was collection and analyzed using analysis of variance (ANOVA), and Duncan's Multiple Range Test (DMRT) was using for means comparison when treatments were significant using MSTATC program.

Results and discussion

The results of soil analysis when conducting the experiment recorded a low pH, indicating an acidic level. Total N was moderate, but total P was low. Ca^{2+}, K^+ were low. The organic matter content in the soil was rather level. Because of the acid sulfate soil, both Al^{3+} and Fe_2O_3 levels were high.

Table 2: The results of soil analysis in the acid sulfate soil of Tan Phuoc, Tien Giang

Data analysis	Results	Evaluation	Data analysis	Results	Evaluation
pH- H_2O	4.0	Acidity	Ca^{2+} (meq/100 g)	1.62	Low
pH - KCl	3.5	Acidity	EC (mS/cm)	0.89	Low
Total N (%)	0.07	Medium	Organic matter (%)	8.4	Rather
P (mg/kg)	3.2	Low	Fe_2O_3 (%)	1.4	High
K^+ (meq/100g)	0.22	Low	Al^{3+} (meq/100 g)	13.4	High

Effect of planting distance on grown and yield of MD2 pineapple

The total number of leaves on the plant and the D leaf length during the flowering stage of the treatments were not statistically significant. The total number of leaves per plant ranged from 42.5 to 44.1 leaves/plant. Leaf length "D" varies from 82.7 cm, to 89.8 cm, respectively. Flowering rates between treatments ranged from 85.4% to 93.2% and there was no statistically significant difference (Table 3).

Table 3: Number of leaves, D leaf length and flowering rate of MD2 pineapple in different density

Treatment	Number of leaves (leaves/plant)	D Leaf length (cm)	Flowering rate (%)
T1	42.5	84.4	89.6
T2	44.0	83.5	93.2
T3	43.5	82.7	92.5
T4	44.1	89.8	85.4
F (5%)	ns	ns	ns

ns: Non-significant.

The results of Table 4 revealed that there was a statistically significant difference in the weight of shoot crown and fruit weight. Treatments T1, T2, T3 corresponding to planting densities of 38400 plants/ha, 34100 plants/ha, 30700 plants/ha (1.575 kg/fruit, 1.543 kg/fruit and 1.605 kg/fruit, respectively) produced fruit weight and weight of shoot crown significantly different from T4 (40000 plants/ha). The fruit weight and weight of shoot crown of T4 were 1.390 kg/fruit and 345.3 g/crown. The highest fruit yield in treatment T1 (28.73 tons/ha) was significantly different from the other treatments. T3 (23.54 tons/ha) gave the lowest yield. The effect of planting density on fruit weight and pineapple yield carried out in many countries around the world [13, 15, 5]. Increasing plantation densities (up to 55500 plants/ha) did not have significant effects on the weight without crown [12]. Low planting densities (close to 30000 plants/ha) are an alternative to low-input, mechanized systems [16]. The fruit mass and yield of 'Sensuous' pineapple can be improved through appropriate planting density [18]. The appropriate density pineapple will bring optimal yield and economic efficiency, however depending on the conditions of each region, farming methods and market requirements. The results showed that the average fruit weight was decrease when the planting density increased exceedingly. In addition, it related to the cultivar and the reasonable spacing in the field.

Table 4: Weight of crown, fruit weight and yield of MD2 pineapple in different density

Treatment	Crown weight (g/crown)	Fruit weight (kg/fruit)	Yield (Tons/ha)
T1	254.2c	1.575a	28.73a
T2	260.0b	1.543a	25.18b
T3	285.5b	1.605a	23.54c
T4	345.3a	1.390b	26.11b
F (5%)	*	*	*

* Significant at 5% level, mean with the same letters are not different by Duncan, ns: Non-significant

Effect of flowering inducement on flowering rate and yield of MD2 pineapple

The total number of leaves on the plant and the D leaf length at the pre-flowering stage were not statistically significant between the treatments. The total number of leaves varied from 40.7 to 43.0 leaves/plant and the D leaf length varied from 82.8 to 85.0 leaves/plant (Table 5). This indicated that the pineapple plants in the experimental plots grew equally, evenly and the plants were qualified for flowering treatment. Flowering treatments affected on the flowering time and flowering rate of MD2 pineapple. Flowering treatments with Ethephon at 60 ml/L and 30 ml/L had an earlier average flowering time of 23.8 days and 26.0 days, respectively, with a significant difference when compared to CaC_2 treatments at doses of 5g/L and 15 g/L (32.0 days and 34.5 days). At dose 60 ml/L ethephon gave flowering rate was 94,2% follow by 30 ml/L Ethephon and 15 g/L CaC_2. Using Ethrel at concentration 1200 ppm on eleven months old "MD2" pineapple plants was the highest rate flower inducing and red apical development [19].

Table 5: Effect of forcing flower agents on number of leaves, D leaf length and flowering of MD2 pineapple

Treatment	Number of leaves (leaves/plant)	D leaf length (cm)	Flowering time (days)	Flowering rate (%)
5 g/L CaC_2	42.7	85.0	34.5^b	86.5^b
10 g/L CaC_2	40.7	83.6	32.0^b	89.2^b
15 g/L CaC_2	43.0	82.8	29.6^{ab}	91.5^a
30 ml/L Ethephon	42.5	84.2	26.0^a	93.3^a
60 ml/L Ethephon	41.3	83.4	23.8^a	94.2^a
F	ns	ns	*	*

* Significant at 5% level, mean with the same letters are not different by Duncan, ns: Non-significant.

The results showed that there was no statistical difference in fruit weight between treatments Ethephon and CaC_2. Fruit weight ranged from 1.545 kg/fruit to 1.643 kg/fruit. However, there was a clear difference in the crown weight (Table 6). The treatments CaC_2 5 g/L, CaC_2 15 g/L (358.5 g/crown and 364.2 g/crown, respectively) were significantly different from those treated with Ethephon 30 ml/L and Ethephon 60ml/L (smaller crown weight 265.1 g/crown and 288.5 g/crown, respectively). There was no statistically significant difference in yield. Yield ranged from 20.9 to 22.8 tons per hectare. The Brix, fruit firmness index of the MD2 pineapple variety were unaffected by flower forcing agents (ranging from 13.1% to 14.6% and 1.63 to 1.70 g/cm^2, respectively) (Table 6). The fruit weight (with crown) presented significant variations according to the treatment, with values ranging from 1.69 kg to 2.04 kg per fruit [12]. The fruit chemical properties were not to affect by planting density [18].

Table 6: Effect of forcing flower agents on crown weight, fruit weight and yield of MD2 pineapple

Treatment	Crown weight (g/crown)	Fruit weight (kg/fruit)	Yield (tons/ha)	TSS (Brix %)	Fruit firmness (kg/cm^2)
5 g/L CaC_2	364.2^a	1.545	20.9	13.1	1.65
10 g/L CaC_2	320.0^a	1.643	21.7	14.5	1.68
15 g/L CaC_2	358.5^a	1.596	22.5	13.9	1.63
30 ml/L Ethephon	265.1^b	1.620	22.3	14.6	1.70
60 ml/L Ethephon	288.5^b	1.604	22.8	14.5	1.65
F	*	ns	ns	ns	ns

* Significant at 5% level, mean with the same letters are not different by Duncan, ns: Non-significant

Conclusions

The results of the study shown that plantation densities suitable was increased fruit weight and yield in acid sulfate soil of Tan Phuoc- Tien Giang. The aplication of 30- 60 ml/L Ethephon resulted an earlier flowering time (23.8 days to 26.0 day), a higher percentage of flowering (93.3 to 94.2%). Ethephon 30 ml/L - 60 ml/L were lower shoot crown weight (265.1 g/crown - 288.5 g/crown). The TSS contents and fruit firmness of the harvested fruits did not significant differencent. Based on the results, it is recommended that farmers in the area can increase their planting densities correcponding to plant spacing suitability, since it improves the fruits yield per ha without affecting the quality of the harvested fruit.

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