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Effect of five watering frequencies on growth and yield of various plant parts of container grown Queensland Cayenne pineapples

K. R. Chapman, J. D. Glennie and B. Paxton

Summary

The effect of five watering frequencies (namely, twice weekly, weekly, fortnightly, monthly and 2 monthly) on potted Queensland Cayenne Clone 13 pineapples gave the following responses as frequency was reduced: D leaf length, D leaf weight and thus plant weight reduction within 4 months of planting; a slight reduction in leaf moisture percentage at harvest, at the end of a watering cycle; dry weight reduction of all plant parts (namely, tops, fruit, peduncle, leaves, butt, roots) and thus whole plant dry weight at harvest; a reduction in harvest index (HI); fruit weight was commercially unacceptable for the monthly and 2 monthly waterings even though eye number and thus potential fruit size was unaffected by watering frequency; and leaf area (LA), and dry matter increment (DMI) decreased.

The results indicate the need to investigate the effects of water deficit on pineapples under field conditions.

1. INTRODUCTION

Foote (1955) found that the Cayenne pineapple *Ananas comosus* (L.) Merr when grown in the dry tropics of Queensland gave yield increases of 25% in response to irrigation. Black (1962) reported that pineapples grown in south east Queensland, a major production area, showed marked growth rate reduction during periods of low soil moisture.

Overseas, Py and Tisseau (1965) and Huang and Lee (1969) have demonstrated the favourable effects of water application on the growth and yield of pineapples, also, irrigation is used during pineapple establishment in both Reunion Island and Hawaii (B. Aubert, personal communication 1978).

However, Bartholomew and Kadziman (1977) in their review of the ecophysiology of the pineapple point out that there are no data in the literature which allow the prediction of growth and yield reductions that result from soil water deficits during the development of the pineapple crop.

In recent years, a succession of dry spring and early summer periods in Queensland has generated renewed interest in the response of the pineapple to irrigation. The present study was designed to examine the effects of plant water stress, as generated by varying watering frequencies on the pineapple plant. A pot experiment was chosen for simplicity as an initial approach to identify the extent of likely responses before extending investigations to larger field trials.

2. MATERIALS AND METHODS

Freshly harvested slips of Queensland Cayenne Clone 13 were trimmed, dipped in Difolatan[R] (100 gL^{-1}) for *Phytophthora cinnamomi* control and air dried. The slips were graded by fresh weight and, with fresh weights ranging from 800 to 900 g, planted into a

50:50 sand:peat mixture in 25 L polyethylene pots and grown in a glasshouse. The sand was previously fumigated with methyl bromide, and the following nutrients were mixed into each pot: ammonium sulphate 24 g, super phosphate (single) 8 g, potassium sulphate 11 g, magnesium sulphate 21 g, copper sulphate 0.3 g, zinc sulphate 0.4 g, agricultural limestone 13 g.

Four additional slips of comparable weight were partitioned and dried to a constant weight in a forced draught oven at 50°C and the moisture content was determined. These data were used to compute the dry weights of the slips, leaves and butt, at the beginning of the experiment.

The experiment was planted and initiated in June and in early October all plants received a further 60 g of a 4:5:1 (N:K:Mg) solid fertiliser mixture. All plants were induced to flower in the following January using a solution of 30 mg ethephon plus 3 g urea in 60 mL water per plant.

The trial was harvested in May about 4 months after induction and 11 months after planting.

Experimental design

The experiment was a completely randomised design with five treatments and six replications. Plants were re-randomised monthly.

Treatments:

A—Plants watered to field capacity twice per week

B—Plants watered to field capacity once per week

C—Plants watered to field capacity once per fortnight

D—Plants watered to field capacity once per month

E—Plants watered to field capacity once per 2 months

The treatments were designed to simulate conditions varying from an ideal season to abnormal drought.

Water was applied with a hand held hose. The complete soil surface was watered until free drainage began from the bottom of the pots.

Data records

Continuous records of glasshouse screen temperature and humidity were kept, and a measure of weekly evaporation was obtained using a small galvanised pail 180 mm in diameter and 210 mm deep, filled to within 25 mm of the top. The pan was located in an unshaded position next to the experimental plants.

The length of the D leaf, as defined by Sideris, Krauss and Young (1938), was measured monthly *in situ* on all plants for the first 2 months, and then fortnightly up to and just after flower initiation when D leaf extension growth stopped. The true D leaf was removed at 4 months and the next longest of the D leaves was then measured. Similarly, at 6 months a further removal was done.

Fruit were harvested at 11 months when they were colouring. Fresh weights were recorded for tops, fruit, peduncle, leaves, butt and roots. Subsamples of each of these were taken from each plant to determine dry matter percentages and weight of various plant parts and total plant dry weights. Dry matter increment (DMI) was determined from initial and final plant dry weights. Harvest index (HI) was calculated from the ratio between dry weight of the fruit and dry weight of other plant parts at harvest.

Leaf area (LA) was determined at the conclusion of the experiment using a leaf area/ leaf fresh weight relationship for 10 leaves of different size sampled from each treatment at random. Leaf area was measured using a planimeter to trace leaf outlines over a glass plate.

3. RESULTS

Evaporation data, temperature and relative humidity

Evaporation from the small evaporation pan in the glasshouse during the course of the experiment totalled 871 mm, compared with U.S. Weather Bureau Class A pan evaporation located nearby outside the glasshouse which recorded 1220 mm of evaporation.

Glasshouse screen temperatures in the cooler months had a daily range of 15° to 27°C and in the warmer months 25° to 32°C. These compare with monthly mean minimum temperatures of 6.9° to 7.5°C for the cooler months and 17.8° to 19.3°C in the warmer months. Monthly mean maximums for the comparable periods ranged from 20.7° to 21.4°C and 28.1° to 28.6°C.

Relative humidity in the glasshouse had daily means between 65 and 80% in the cooler months and 75 and 82% in the warmer months. These ranges were very similar to daily mean relative humidities.

These data indicate the comparison between glasshouse and outside ambient conditions during the course of the experiment.

D leaf development

At the end of the second 2 monthly drying cycle (4 months after planting) D leaf length was shortest for the least frequent watering treatment E (Figure 1). This difference still existed at the end of the third 2 month drying cycle (6 months), at flower induction (7 months) and at 7½ months, when the final D leaf lengths were measured.

D leaf dry weight and fresh weight were generally greater for the frequent waterings, but leaf moisture percentage was more uniform with differences only beginning to appear at harvest (Table 1).

Table 1. D leaf dry weight (g), fresh weight (g) and moisture percentages for three sampling times, with respect to watering frequency

Sampling	Watering frequency					l.s.d.	
	A	B	C	D	E		
	Twice weekly	Once weekly	Once fortnightly	Once monthly	Once 2 monthly	1%	5%
End of second drying cycle							
Dry wt (g)	3.97	3.75	3.93	3.38	2.49	1.34	1.01
Fresh wt (g)	28.82	26.02	28.60	22.52	15.72	7.08	5.19
Moisture (%)	86.19	85.57	86.24	84.96	84.10	n.s.	n.s.
End of third drying cycle							
Dry wt (g)	9.33	8.22	8.76	7.23	5.03	1.53	1.13
Fresh wt (g)	58.23	55.63	63.77	48.23	32.12	8.41	6.16
Moisture (%)	83.97	85.21	86.24	84.97	84.34	n.s.	n.s.
Final sampling at harvest							
Dry wt (g)	11.46	10.05	11.23	9.45	6.78	2.17	1.59
Fresh wt (g)	81.27	65.24	67.71	50.96	40.84	12.31	9.02
Moisture (%)	85.59	84.61	83.32	81.45	83.26	2.11	1.56

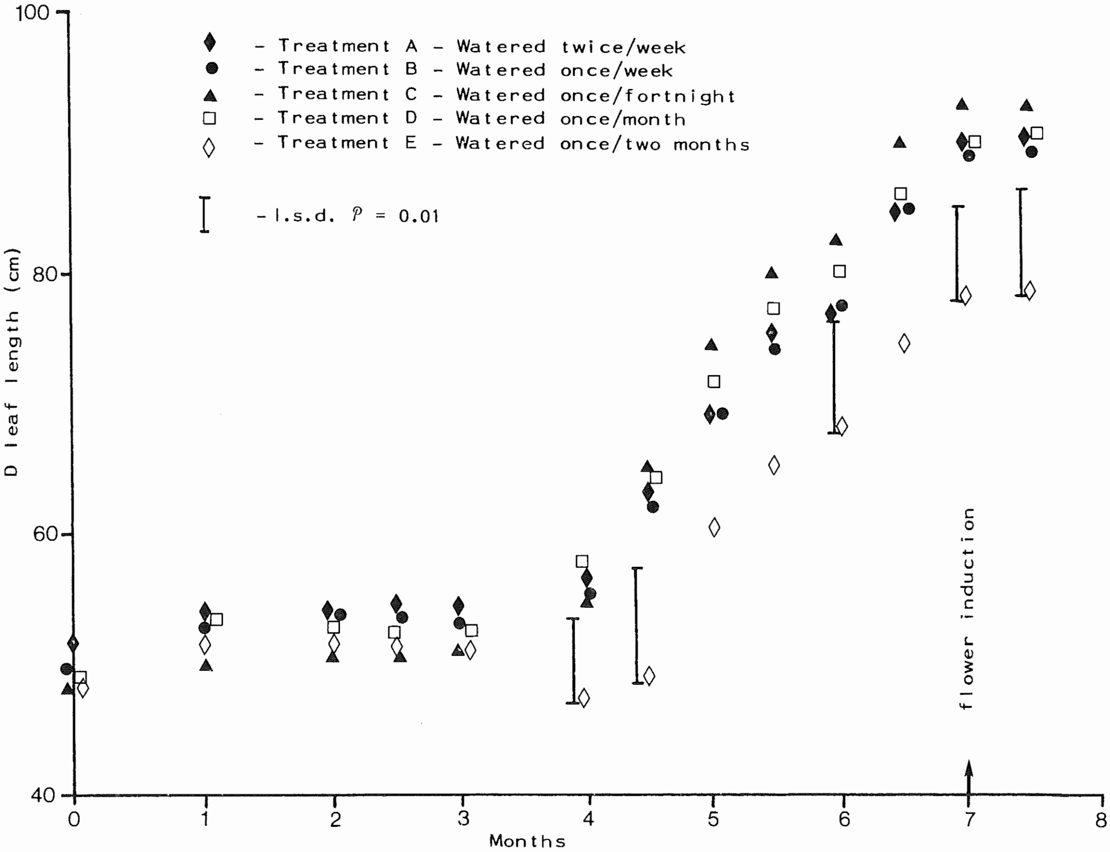

Figure 1. D leaf length of pineapple as influenced by five watering frequencies.

Table 2. Dry weight (g) of various plant parts at harvest, as influenced by watering frequency

Plant parts	Watering frequency					l.s.d.	
	A	B	C	D	E		
	Twice weekly	Once weekly	Once fortnightly	Once monthly	Once 2 monthly	1%	5%
Tops	42.99	38.64	27.51	16.79	10.23	23.14	16.97
Fruit	176.74	209.78	108.97	52.42	24.55	59.66	43.75
Peduncle	39.70	33.99	15.71	14.50	3.54	9.92	7.27
Leaves	329.61	293.96	257.29	230.54	159.66	6.69	4.91
Butt	61.32	59.91	68.09	62.15	37.98	9.90	7.26
Roots	69.33	71.21	71.91	55.00	42.24	19.22	14.09
Whole plant	719.69	707.49	549.48	431.40	278.20	80.08	58.71
Harvest index (HI)	0.2455	0.2971	0.1665	0.1207	0.0849	0.1168	0.0857

Weights of various plant parts

Significant responses ($P<0.01$) are apparent with respect to watering frequency for all plant parts (dry weight) (Table 2). The least frequent waterings resulted in the smallest dry weights at harvest.

Table 3 contains weights of the fresh fruit at harvest.

Table 3. Fresh weight of fruit (kg) at harvest

Watering frequency					l.s.d.	
A	B	C	D	E		
Twice weekly	Once weekly	Once fortnightly	Once monthly	Once 2 monthly	1%	5%
1.63	1.61	1.22	0.61	0.36	0.24	0.18

Derived growth parameters

Growth parameters are contained in Table 4. Leaf areas (LA) were determined from leaf fresh weights.

Table 4. The influence of watering frequency on leaf area and dry matter increment of pineapple

Growth parameter	Watering frequency					l.s.d.	
	A	B	C	D	E		
	Twice weekly	Once weekly	Once fortnightly	Once monthly	Once 2 monthly	1%	5%
Leaf area initial (LA_1) (cm^2)	4 004	3 870	3 599	3 596	3 447	157.6	115.5
Leaf area at harvest (LA_2) (cm^2)	11 960	11 721	10 320	10 456	8 126	1974	1147
Dry matter increment (DMI) (g)	583.36	575.78	427.02	312.75	160.95	83.41	31.41

4. DISCUSSION

The effect of watering frequency (soil moisture deficit) on D leaf length and D leaf fresh weight was established within 4 months of planting (Figure 1 and Table 1). The data in Figure 1 at 4 months are for the next longest of the D leaves, since the true D leaf was sampled at this stage, thus the apparent discrepancy in D leaf growth, particularly with respect to treatment E. Sanford (1961) has previously shown that D leaf weight is well correlated with plant weight up to D leaf weights of 60 to 70 g. Thus, we suggest that total plant weight was significantly affected by watering frequency quite early in the life of the plant.

Moisture as a percentage of the fresh weight of D leaves was consistent for the various treatments and was only reduced in the final sampling at harvest after six (2 monthly) drying cycles or twelve (1 monthly) cycles. However, recent work by George and Chapman (unpublished data) shows that, while moisture percentage may be similar for D leaves from different plants, relative water content as defined by Barrs and Weatherley (1962) may vary by as much as 16%.

Dry weights of all plant parts were significantly reduced at the least frequent watering rates (Table 2). The dry weights of tops, fruit and peduncle were more reduced by decreased frequency than were other vegetative plants parts. This demonstrates that the developing fruit, tops and peduncle (that is, floral parts) are strongly influenced by water availability.

Twice weekly and once weekly waterings produced the greatest dry weights of plant parts at harvest, except for butt weights and root weights, which were greatest at fortnightly waterings (Table 2). DMI was also influenced by watering frequency (Table 4) and even the fortnightly watered plants suffered significant reductions.

The fruit produced by treatments D and E were commercially unacceptable, both with respect to size and internal quality of fruit (Table 3, Plate 1). Fruit from D and E were hard and lacking in juice and were less mature at harvest. While fresh weight of fruit at harvest differed between treatments A and E by a factor of 4.5, dry weight differed by a factor of 7.2 (Table 2). This demonstrates that dry weight varied more than water content in response to watering frequency.

Eye number (the number of fruitlets per fruit) was similar for all treatments. Induction took place midway through a 2 monthly drying cycle. It appears that watering frequency did not appreciably influence eye numbers (that is, potential fruit size) and that its major effect was on fruit filling.

HI was greatest for the once weekly watering and least for the 2 monthly treatment (Table 2). Plant stature differences were not obvious even 7 months after planting.

At planting, leaf area (LA_1) was different after different treatments (Table 4). The differences resulted from leaf trimming, to produce slips of near comparable weights. The trimming changed leaf areas and slip weights as only the older leaves are removed during the process.

Leaf areas (LA_2) at harvest were considerably greater for the well watered treatments, with differences as great as a factor of 1.47, while dry matter increment (DMI) differences were greater by a factor of 3.62. These factor differences suggest that either net assimilation rate (NAR) or leaf area duration (LAD) or both are appreciably influenced by watering frequency.

NARs for pineapple range from about 0.4 to greater than 2.0 g $dm^{-2} day^{-1}$, and are about one tenth those of mesophytic crop plants. However, the crop growth rates of pineapple are high at 15 g m^{-2} day^{-1} because of high LAIs of 10 or greater which persist for several months in the field (Bartholomew and Kadziman 1977) and thus give high values for LAD.

In conclusion, the experiment shows the very significant effects of watering frequency on growth and yield of the pineapple. The results point to the need to quantify these effects under field conditions which, as indicated, differed considerably from glasshouse conditions during the course of the experiment. Furthermore, studies which measure plant water stress and growth analysis parameters are required to provide an understanding of how stress brings about the effects found in this experiment.

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The authors are officers of the Horticulture Branch of the Queensland Department of Primary Industries stationed at the Maroochy Horticultural Research Station at Nambour, Q. 4560.

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