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EFFECT OF WATER ON GROWTH AND NUTRIENT UPTAKE OF PINEAPPLE

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RINGKASAN

Kehidupan membesar pokok-pokok nenas Masmerah menerima dengan berkesan keatas setiap penambahan sukatan-sukatan air yang di siram. Dalam penumbuhan tinggi pokok. jumlah air yang disiram yang bersamaan dengan 0.8 cm air hujan di dapati adalah yang terbaik sementara penambahan jumlah daun di dapati paling mengalakkan bagi sukatan air yang bersamaan dengan 1.6 cm air hujan. Tambahan pada kekerapan menyiram juga telah didapati menambahkan pembesaran pokok.

Keadaan terendam telah didapati mendatangkan kesan yang sebaliknya keatas penghidupan dan pengambilan unsur hara (nutrient). Paras air yang paling sesuai untuk penghidupan pokok nenas telah dicatitkan sebagai 48 cm dari paras muka bumi. Pengambilan unsur hara secara memuaskan, telah diperhatikan berlaku apabila paras air telah ditempatkan di antara 30-50 cm dari paras muka bumi.

Keadaan kekeringan dan juga keadaan terendam air membantutkan pengeluaran bunga secara biasa (Natural flowering). Sementara penambahan pada kekerapan menyiram telah diperhatikan dapat menambahkan pengeluaran bunga secara biasa. Dengan pemberian air bersamaan 0.8 cm air hujan, sambutan kepada penggalakkan berbunga telah didapati bertambah baik lagi. Dalam pada masa yang sama juga telah diperhatikan iaitu kadar air seperti yang di atas juga adalah yang paling memberansangkan untuk pengeluaran bunga secara biasa.

Purata berat panjang dan garis pusat buah telah didapati menerima secara berkesan keatas pemberian-pemberian air. Sukatan air yang paling baik untuk ketiga-tiga parameters ini adalah pemberian air yang bersamaan dengan 0.8 cm air hujan. Kekerapan menyiram secara perangkaan telah didapati tidak mendatangkan kesan yang bermakna keatas purata berat, panjang dan garis pusat buah.

Sukatan-sukatan air dan kekerapan menyiram secara perangkaan juga tidak mendatangkan apa-apa kesan yang bermakna keatas kandungan gula dan asid buah.

INTRODUCTION

Wherever plants grow, their development is limited to some degree by either too much or too little water, but mostly the latter (KOZLOWSKI, 1968). Generally the soil moisture supplies are rarely at optimal levels during the growing season. Changes in the soil water regime have been reported to affect some physiological processess in the plant which in turn would affect growth, yield and quality of a crop.

For the cultivation of pineapple it has been reported that soils with good supply of water, drainage and aeration will be able to support a good crop provided proper cultural practices are utilized. In Taiwan, according to COLLINS (1960), crowns or slips are normally planted when the soil is moist, so that the young plants can develop quickly an adequate root system before the dry season brings root production to a standstill. Failure to produce sufficient root before the dry season renders the plants less capable of rapid growth when environmental conditions improve. With retarded growth in the early stages of plant development, flower formation may be delayed, although in the later stages a moisture deficit tends to hasten flowering (CHANDLER, 1958). Furthermore it has also been reported that under a given set of temperature conditions, fruit size will be determined very largely by the amount of leaf surface formed before the inflorescence begins to develop and that adequate water is therefore needed in the vegetative phase of growth (VAN OVERBEEK, 1946).

The root system of pineapple is relatively shallow and small and most of the feeding roots are found in the top 30 cm of the soil. This was shown by EKERN (1965) in Hawaii when he found that water withdrawal by pineapple growing in lysimeter 1.5 m deep was confined to the top 30 cm of the soil. This restricted root volume was considered to render most crop extremely sensitive to drought. BLACK (1962) found that pineapple root and shoot growth proceeded vigorously throughout the winter months in Queensland so long as moisture was adequate. However, he further reported that with the onset of a dry spring period considerable root damage and leaf and stem growth was substantially reduced.

Although pineapple can be grown under semi-arid conditions, experience indicates that frequent and dependable rainfall is important to obtain fruit of good size and to ensure that it ripens at the expected time (CHANDLER, 1958). According to GROSZMANN (1948), the seasonal distribution of rainfall should be such as to provide adequate soil moisture throughout the year. Waterlogging caused by excessive late summer rains in southern Queensland was very damaging to the crop and thorough drainage proved necessary (GROSZMANN, 1948). This contrasts with conditions in northern Queensland where drought in the spring months is the main problem and calls for irrigation. Similar recommendations have been made for the culture of pineapples in areas of high and low rainfall in India (SINGH, KRISHNAMURTHI AND KATYAL, 1963).

In contrast to the above findings, GREEN (1963) was of the opinion that there were few other plants so well adapted to drought conditions as the pineapples. In his opinion, however, rainfall rarely limits production, and he points out that irrigation is seldom practised except in very dry areas. COLLINS (1960) reported that in areas with low annual rainfall such as Lanai (one of the Hawaiian islands) the high relative humidity may play an important role in the growth of pineapples.

Pineapple has been described as a crop which is more suited for drier areas for it has been observed that under conditions of very high rainfall, excessive soil moisture and poor drainage, physiological disorders are prevalent and certain particularly damaging pests and diseases thrive (GREEN, 1963). Besides the quality and keepability are reduced under conditions of high soil moisture (MALAN, 1964; COLLINS, 1960).

It appears, therefore, that pineapple should be regarded essentially as a dry-land crop, which will benefit particularly from conditions of adequate, but not excessive, soil moisture during its vegetative phase of development (SALTER AND GOODE, 1967).

MATERIALS AND METHODS

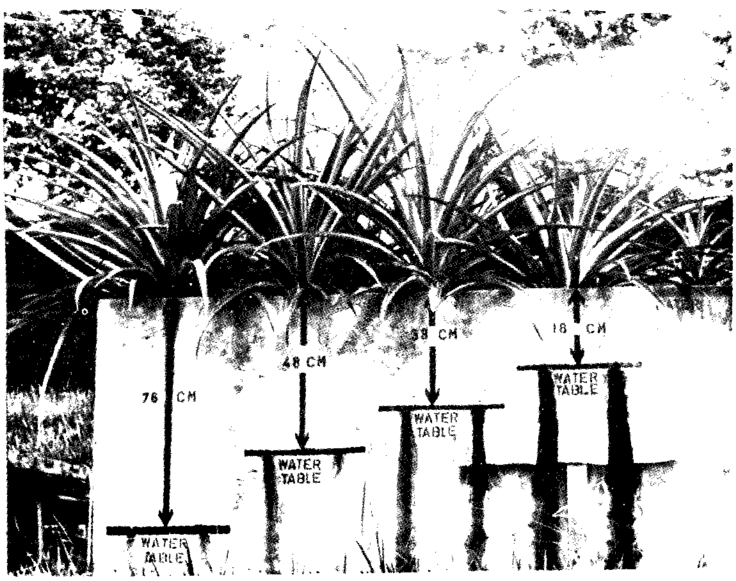
Experiment 1

A concrete tank measuring 240 cm × 400 cm and 125 cm deep was constructed and partitioned into five compartments, each measuring 48 cm × 80 cm × 125 cm. In four of these compartments, two drainage pipes (spaced at 26 cm apart) were placed on either side of each compartment at depths of 18, 33, 48 and 76 cm. Each compartment was then filled with peat soil and water was added until it overflowed through the drainage pipes.

Two uniform sized slips of the Masmerah cultivar were planted at 31 cm apart along the longer side of each compartment on 10 January 1969. There were five treatments *viz.* water-logging and water-tables at 18, 33, 48 and 76 cm from the soil surface. The water regime of the soil was maintained by daily addition of water. Fertilizer application was according to TAY, WEE AND CHONG (1968).

After eleven months the plants were pulled out and studied for growth differences. The leaves were cleaned, separated into leaf tips and bases and composited for each treatment. They were then analyzed for N, P and K following the method of TAY, KEE AND WEE (1969). The analysis for Ca and Mg was by the EDTA method.

The experiment was repeated, on 7 July, 1972. In this experiment growth measurements (plant height and leaf number) were taken at monthly intervals starting from the third month after planting to the time of flower induction. The mean fruit weight, length and diameter were also recorded at harvest.



MEAN FRUIT WEIGHT (kg) 1.23 1.38 1.35 1.10 0.33

THE CONCRETE TANK USED FOR THE EXPERIMENT

Experiment 2

The design of the experiment was 4 × 3 factorial in randomized block with four replications. The single plot technique was used.

Uniform size Masmerah slips were planted in peat contained in black polythene bags measuring 46 × 51 cm. Planting was carried out on 3 January 1972 and the cultural practices involved were as described by WEE, SEOW, TAY AND TAN (1968). The rate, proportion and frequency of fertilizer application were according to TAY (1973).

The treatments were as presented in *Table 1.*

TABLE 1. LEVELS AND FREQUENCY OF WATERING

Level of water bag^{-1} (cm rainfall equivalent)	0	0.8	1.6	2.4
Frequency of watering		Daily	Weekly	Monthly

The plants were kept in the station's greenhouse for the duration of the experiment. Flower induction was carried out on 3 January, 1973 at a rate of 25 ml calcium carbide solution with a concentration of 6 g CaC_2 l^{-1} water. Flower count was started seven weeks before the date of flower initiation and was carried out at weekly intervals until eight weeks after the date of flower initiation. Growth measurements were also taken at monthly intervals, starting from the third month after planting to the time of flower induction. The fruit were harvested at three eyes ripe and the weight, sugar and acid contents of each fruit were determined according to TAY *et al.* (1968).

RESULTS AND DISCUSSION

Effect of watering levels on growth

Varying amount of water was found to affect plant growth significantly from the third month after planting to the time of flower initiation (*Figure 1*). Faster growth was observed for all the treatments when compared with the control. The best growth as reflected by the plant height was given by the treatment of 0.8 cm rainfall equivalent (*Figure 1*).

Increasing the amount of water (above 0.8 cm) led to a depression in the increment of plant height. The emergence of leaves was also significantly affected by the amount of water added, especially after the seventh month. Water treated plants had consistently more leaves compared to the control during the vegetative phase of the growth cycle (*Figure 2*). The greatest number of leaves was found in plants treated with 1.6 cm rainfall equivalent.

The best growth of pineapple as reported above was obtained with the first level of watering (0.8 cm rainfall equivalent) with less growth on either side of this water regime. This finding was also observed by KOZLOWSKI (1968) on plants in general where he recorded that plant development was limited to some degree by either too much or too little water. This according to him was due to changes in soil moisture regime which had been reported to affect physiological processes in the plants which in turn would affect growth, yield and quality of a crop.

Effect of frequency of watering on growth

The frequency of watering was observed to influence the growth of plant although statistical differences between treatments were only detected on the fourth and fifth months after planting for the plant height (*Figure 3*) and eighth, ninth and tenth months for the number of leaves (*Figure 4*). However, in both these two parameters of growth, more frequent watering was noted to have a more favourable effect. Daily watering induced plant height increment and leaf formation most, followed by weekly and monthly watering.

More frequent watering had been observed to increase the tendency of better growth and yield. This observation would mean that an equitable and evenly distributed rainfall was ideal for growth and fruit development. This speculation was based on the observation by GROSZMANN (1948) who found that the seasonal distribution of rainfall in Queensland, Australia should be such as to provide adequate soil moisture throughout the year in order to get a good crop of pineapple.

Effect of depth of water-table on growth and fruit characters

The moisture content in the root zone of a crop is determined in part by the level of water-table from the soil surface. The higher the water-table the higher will be the moisture content of the soil in the rhizosphere. In our experiments, a water-table of 33 cm appeared to be optimum for the growth of pineapple as indicated by the parameter of plant height (*Figure 5*). Water-table which was nearer the soil surface *e.g.* 18 cm was found to retard growth and the severity of growth retardation tended towards the condition of waterlogging (*Figure 5*). However, a water-table at 48 cm was found to result in plants having the biggest fruit (*Table 2*). This retardation in growth as the soil tended towards waterlogging condition could be due to a reduction in the redox potential. In peat where the water-table is constantly at the surface, reducing conditions usually occur just below the ground level *i.e.* just below the water-table level. Work carried out by PEARSALL (1950) showed that a redox potential below 300 mV when Eh was corrected to pH 5 was expected to indicate reducing conditions and it was further reported that in drained peat as measurements were made down the profile the potential dropped below 300 mV and there was a corresponding change to wet mushy peat, smelling of hydrogen sulphide characteristic of reducing conditions. However, as the water-table was lowered a reduction in plant height was observed as shown by water-table maintained at 48 cm and 76 cm from the surface (*Figure 5*). It appears therefore that the moisture regime in the root zone of pineapple is very vital for the growth and the maintenance of the water-table at a constant and fixed depth is very critical.

TABLE 2. EFFECT OF WATER-TABLE ON THE MEAN FRUIT WEIGHT, LENGTH AND DIAMETER

Water-table	Mean fruit weight (kg)	Mean fruit length (cm)	Mean fruit diameter (cm)
0 (waterlogging)	0.33	8.3	8.5
18 cm	1.10	14.0	11.4
33 cm	1.35	15.5	11.5
48 cm	1.38	15.6	11.8
76 cm	1.23	15.5	11.1

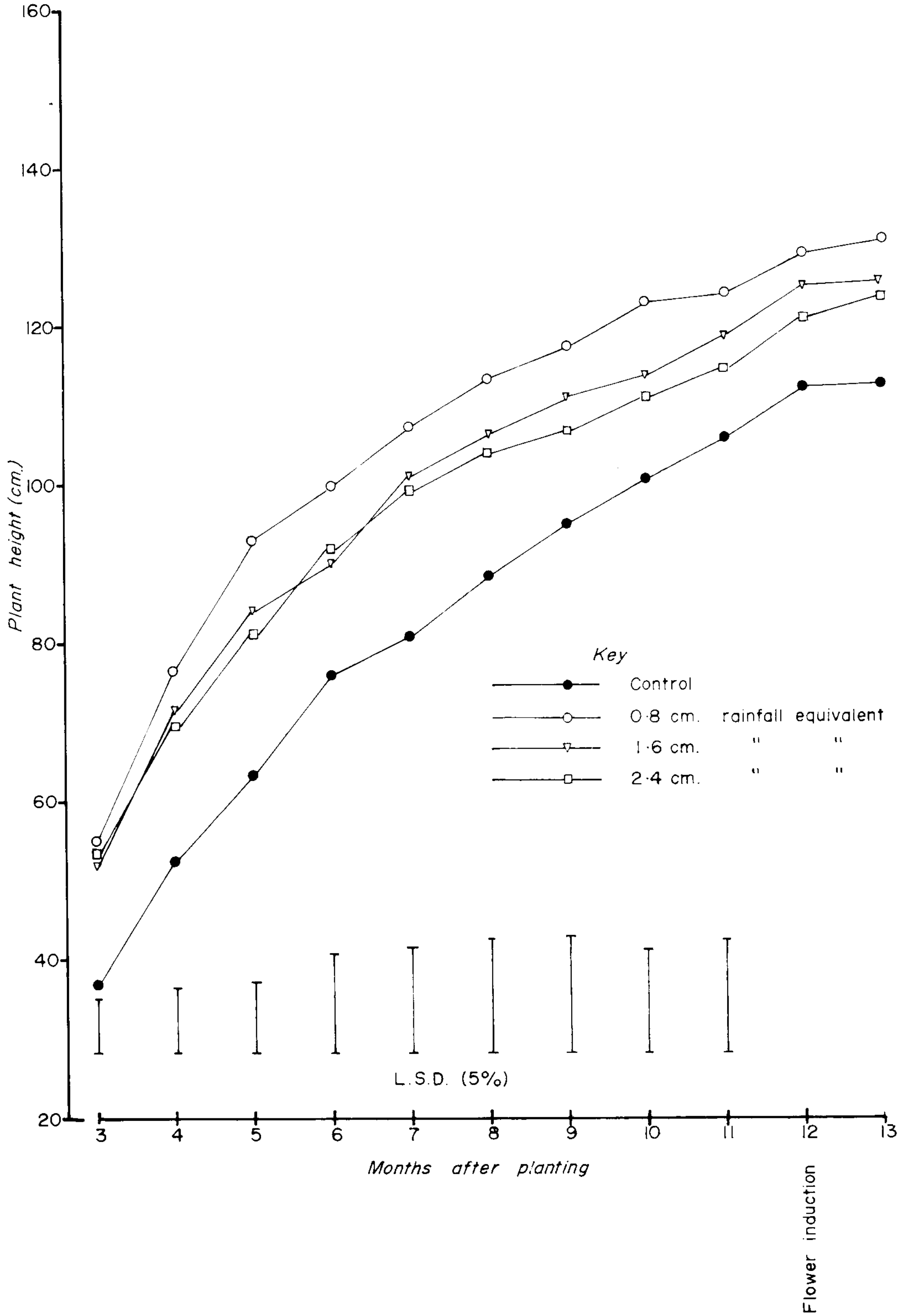


Figure 1. Effect of levels of watering on the plant height

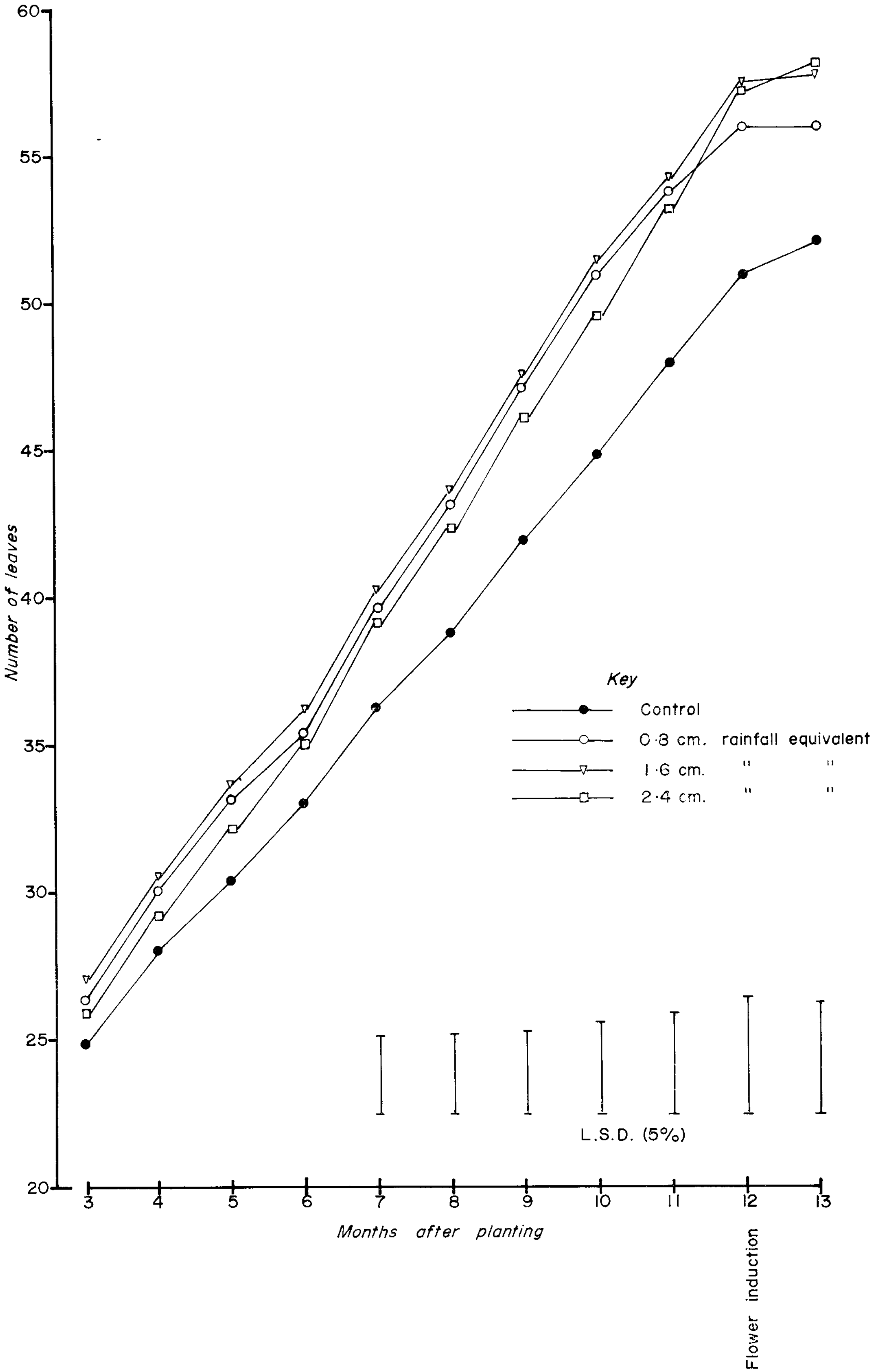


Figure 2. Effect of levels of watering on the number of leaves

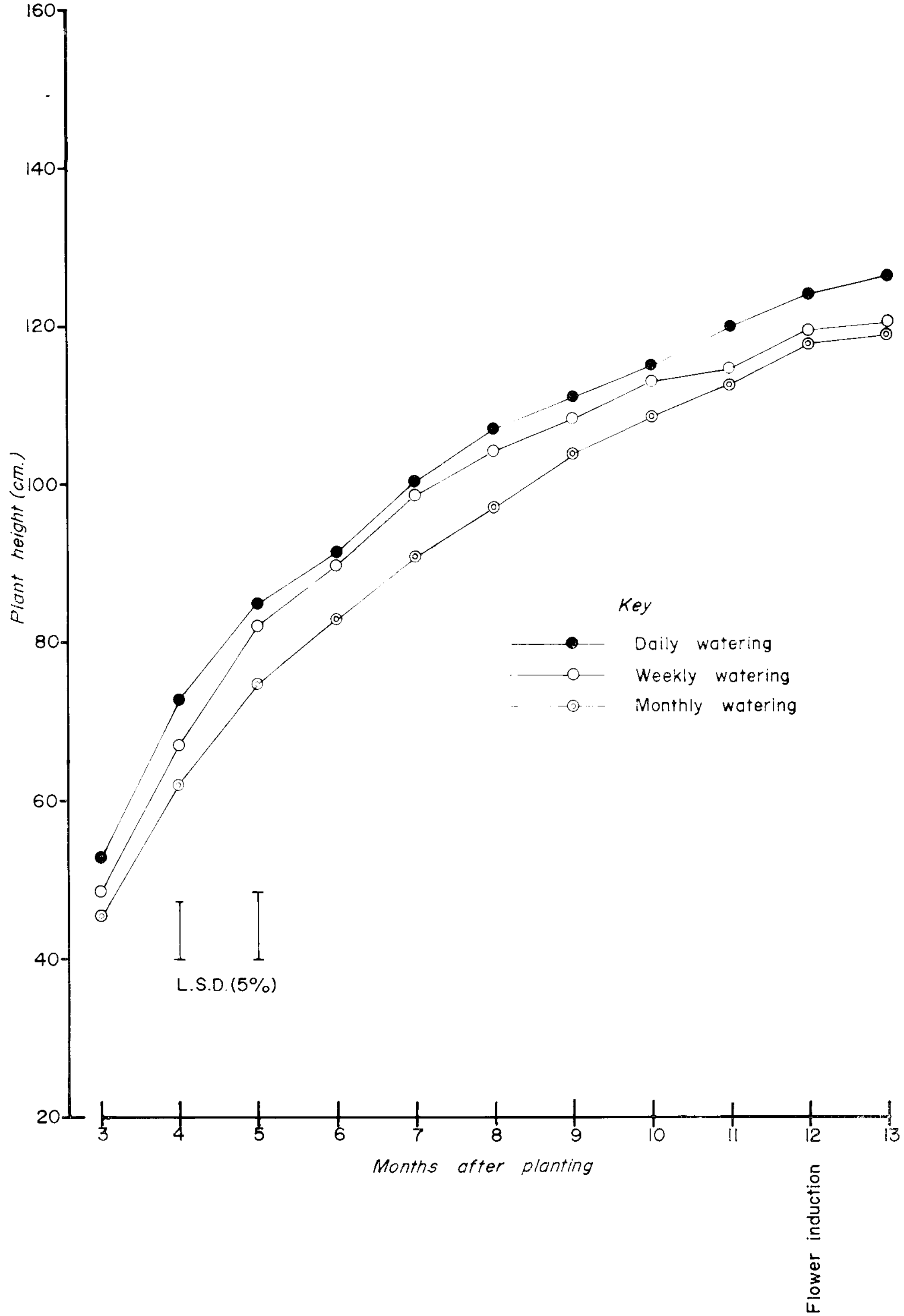


Figure 3. Effect of frequency of watering on the plant height

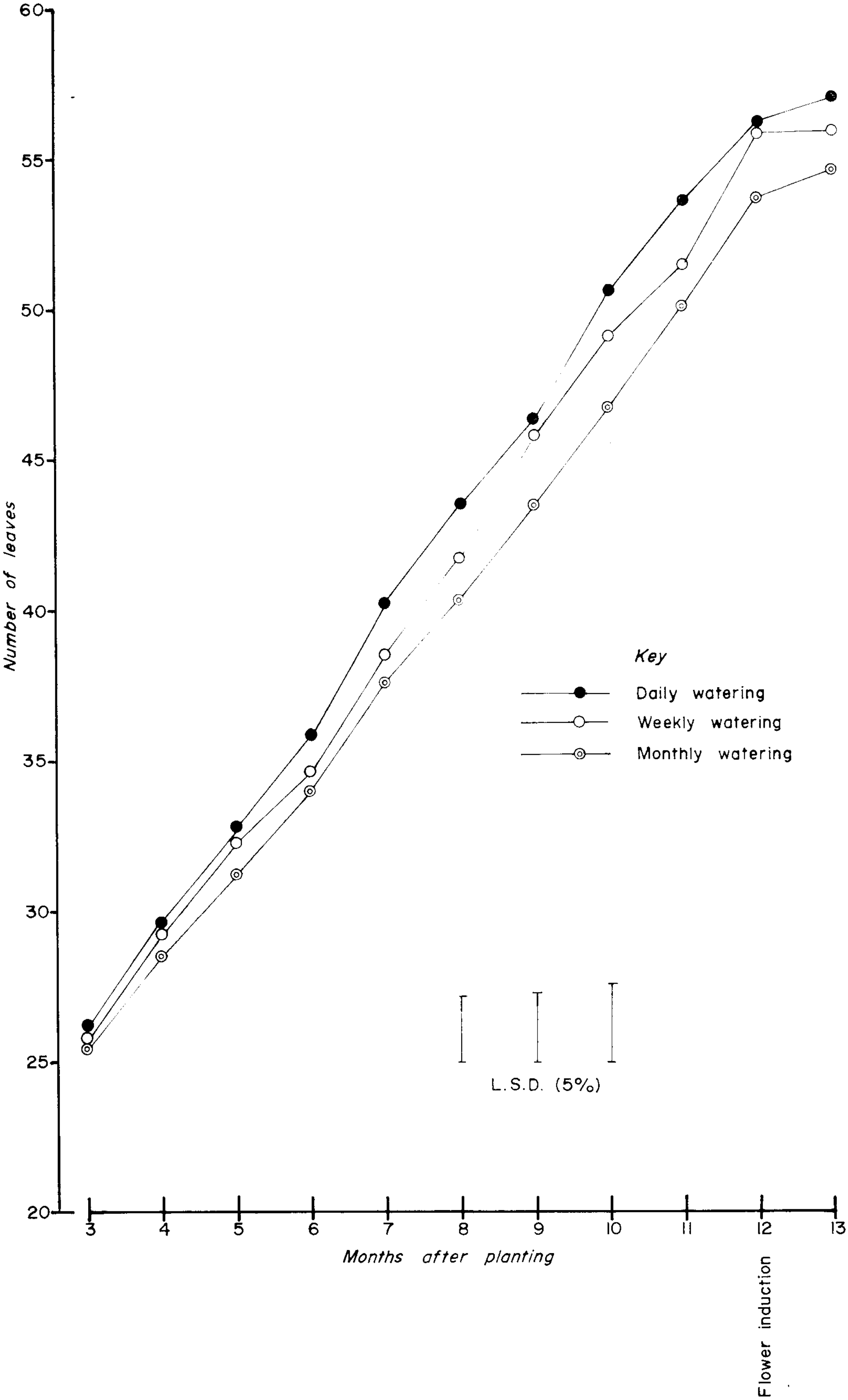


Figure 4. Effect frequency of watering on the number of leaves

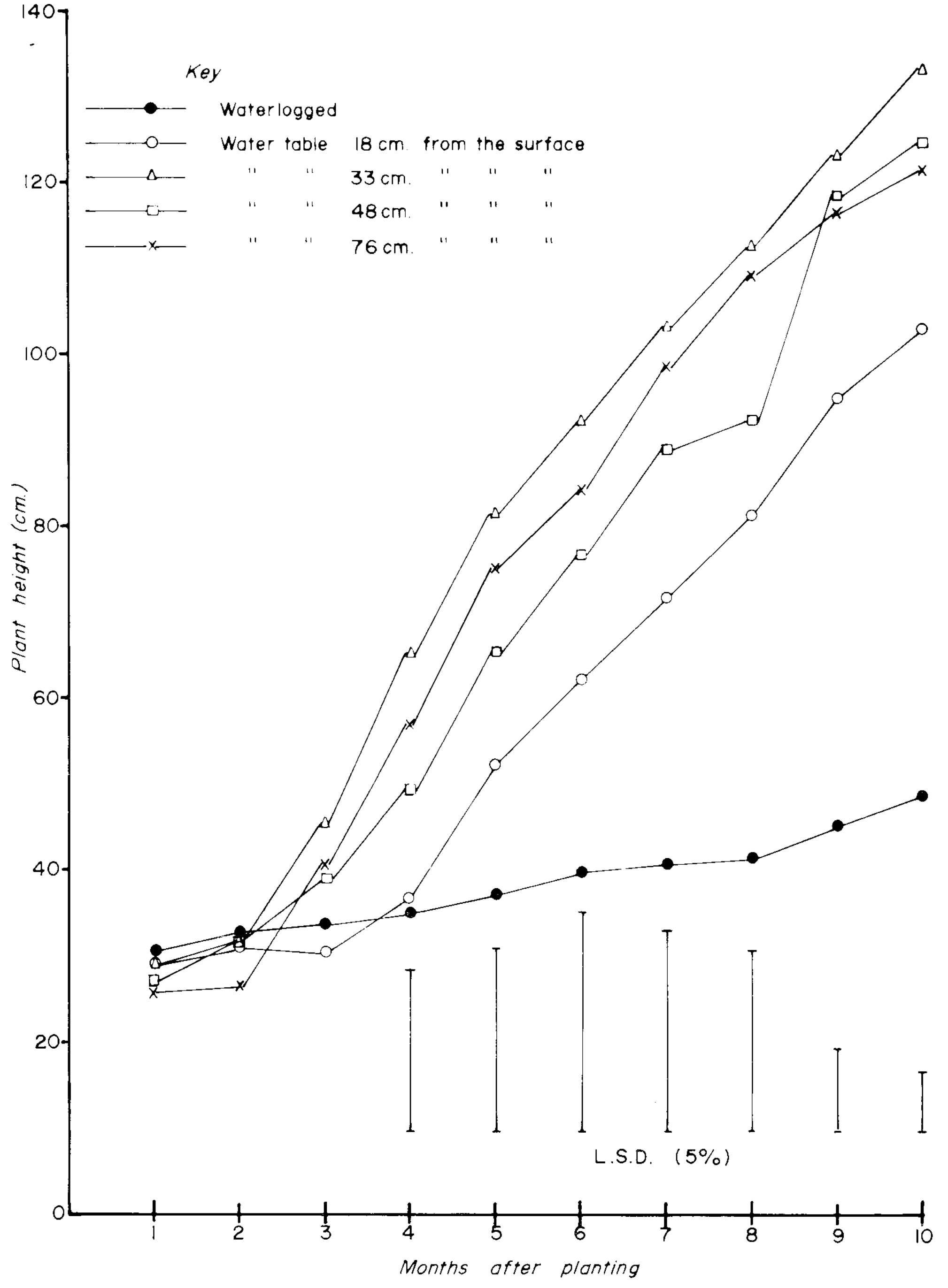


Figure 5. Effect of depth of water-table on the plant height

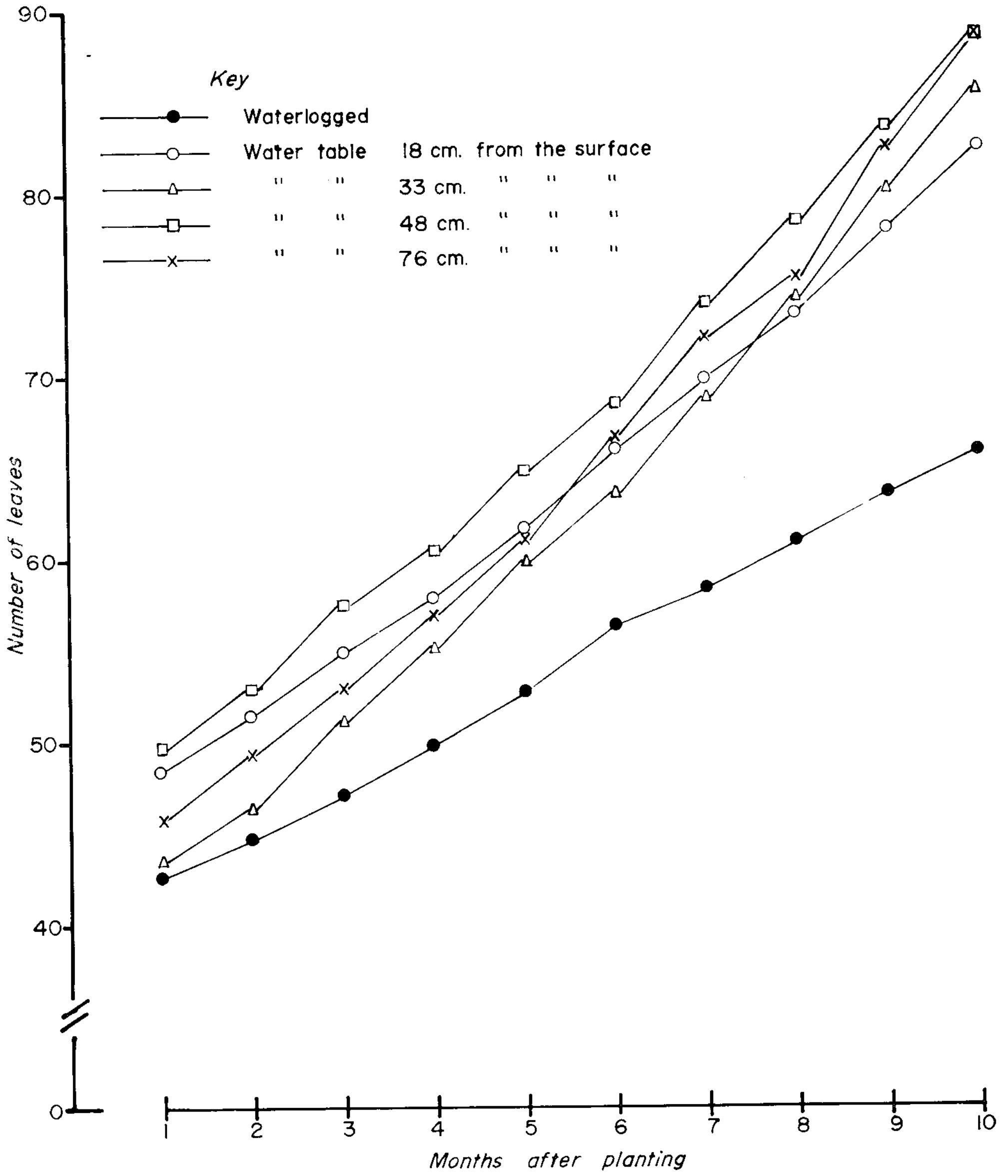


Figure 6. Effect of depth of water-table on the leaf number.

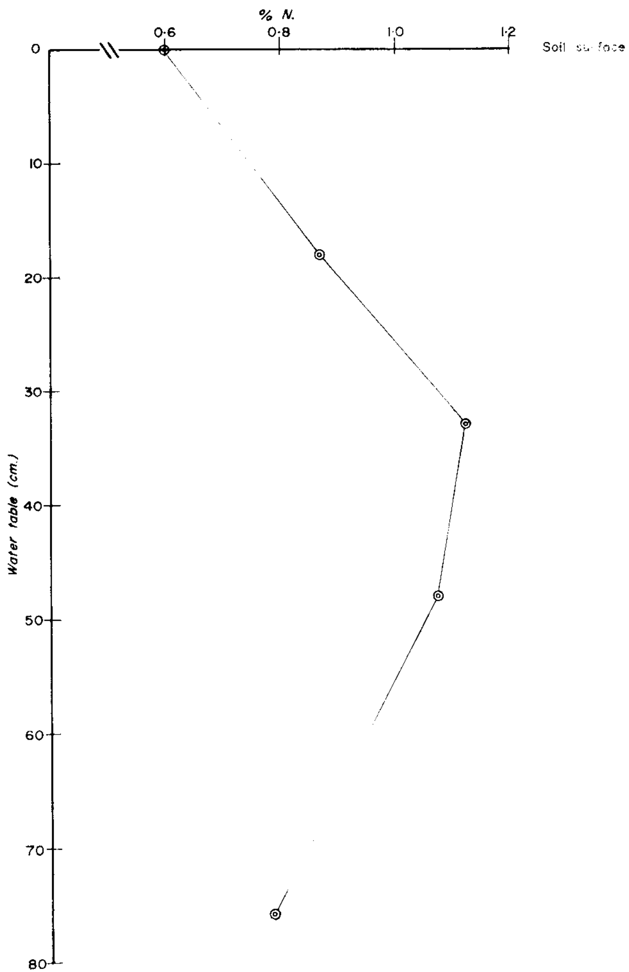


Figure 7. *Effect of water-table on the leaf nitrogen content*

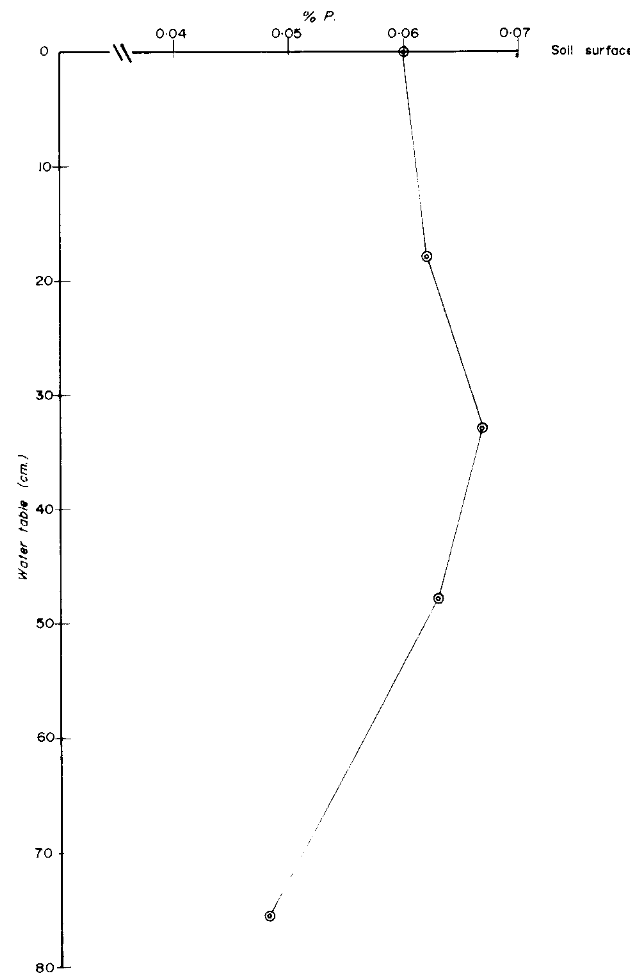


Figure 8. *Effect of water-table on the leaf phosphorus content*

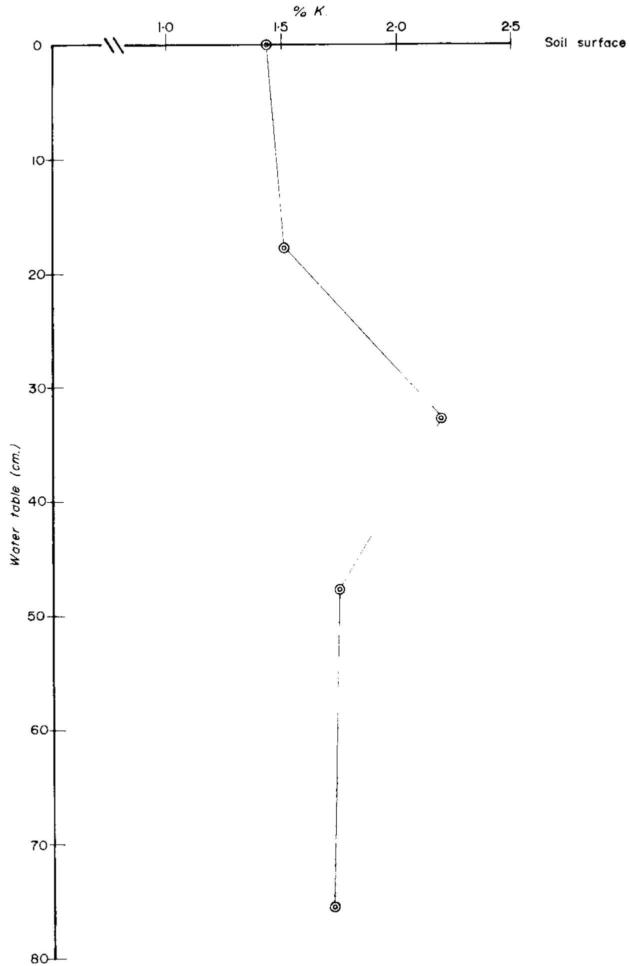


Figure 9. Effect of water-table on the leaf potassium content

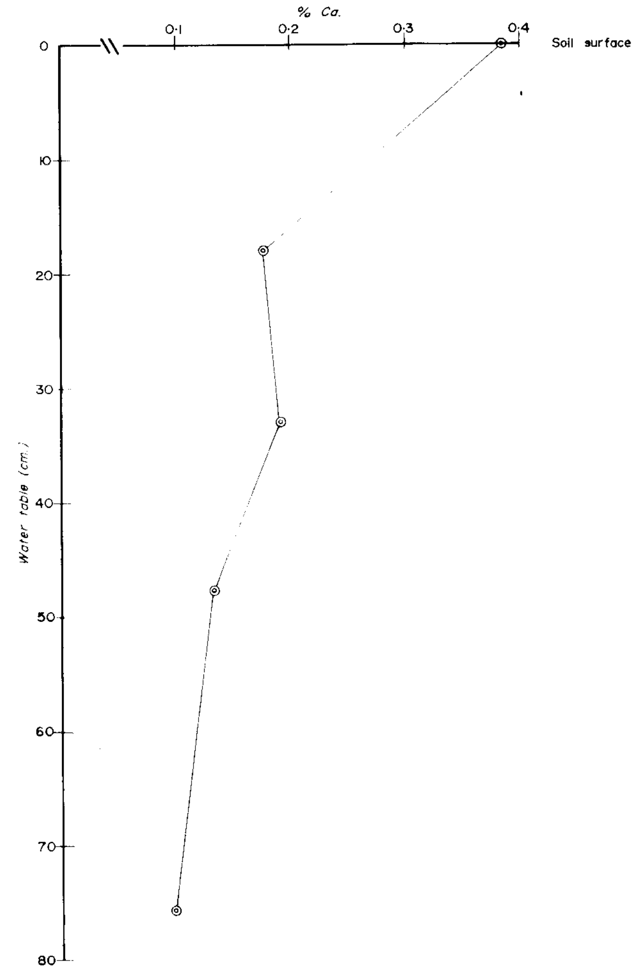


Figure 10. Effect of water-table on the leaf calcium content

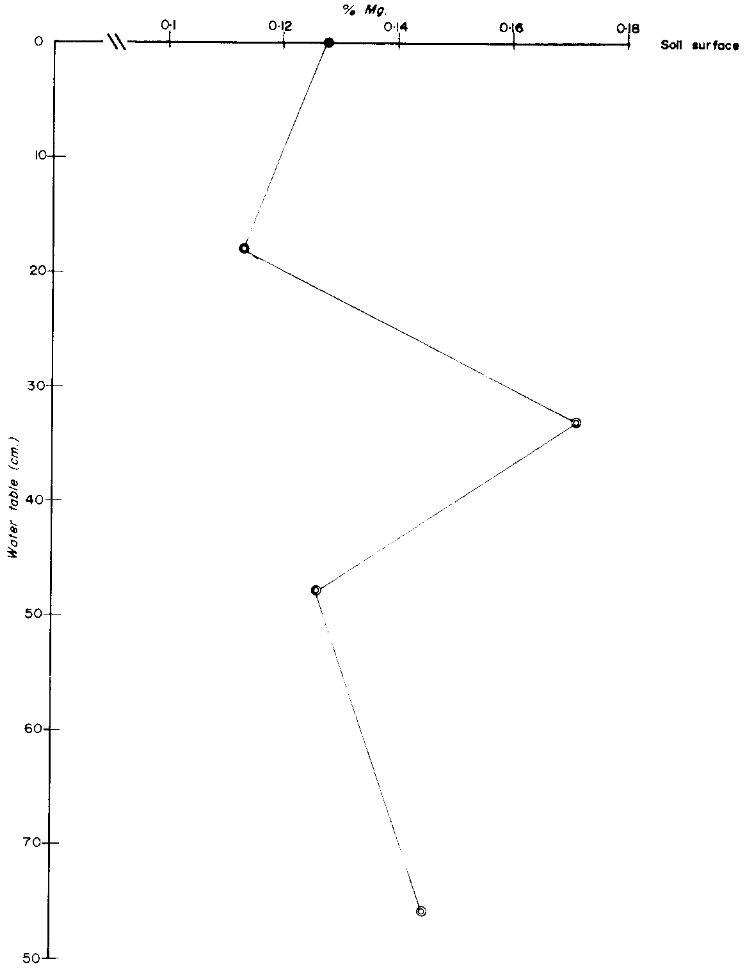


Figure 11. Effect of water-table on the leaf magnesium content

The depth of water-table was also observed to influence the number of leaves of a plant, although no statistical significant differences between treatments were detected (*Figure 6*). Waterlogging condition was definitely an adverse factor affecting leaf number development and the best water-table depth appeared to be at 48 cm from the surface.

Effect of depth of water-table on the leaf N, P, K, Ca and Mg contents

The effects of varying depths of water-table on the leaf N, P, K, Ca and Mg contents are shown in *Figures 7* to *11*. It appeared that prolonged waterlogging would affect the leaf contents of these five major nutrient elements. However, with the lowering of the water-table the leaf nutrient contents were generally increased. But subsequent lowering below a certain depth resulted in a decrease in uptake. It would seem that maintaining water-table at 30 to 50 cm from the soil surface was optimum because maximum uptake occurred under the condition described. There was, however, an exception to this general trend in the uptake of calcium where a decreasing leaf Ca value was recorded with increasing depth of the water-table (*Figure 10*).

The above observations could be attributed to a number of factors *viz.* soil moisture variation, degree of aeration, soil temperature and changing soil pH resulting from the varying water regime. These factors can either affect the nutrient uptake individually or in combination. The mechanism on how these factors affect nutrient uptake of pineapple under local conditions is still not known. Further studies along these lines would be carried out.

Effect of watering levels and frequency on flowering response

It appeared from the results that both drought and waterlogging conditions would depress natural flowering (*Table 3*). Under conditions of moisture stress and waterlogging it had been observed that growth of the plant were retarded. This retardation took place from the initial stages of plant development since the plants were exposed to these treatments. The report by CHANDLER (1958) that growth retardation in the early stage of plant development would delay flower formation appeared to explain our observations.

TABLE 3. EFFECT OF LEVELS OF WATERING ON FLOWERING RESPONSE

Levels of watering bag^{-1} (cm rainfall equivalent)	No. of plants flowered		
	Natural	Induced	Total
0	0	12	12
0.8	5	7	12
1.6	1	11	12
2.4	0	12	12

The treatment of 0.8 cm rainfall equivalent was most conducive for natural flowering to occur. It was further observed that plant with this 0.8 cm rainfall equivalent treatment had responded completely to flower induction five weeks from that date while the other treatments had plants which took one to three weeks more to completely respond to the flowering induction *e.g.* the control plant (no water) took eight weeks before all the plants responded to the flowering stimulus. This observation further comfirmed the report by CHANDLER (1958) on the effect of initial retarded plant growth on flower formation.

Increasing watering frequency was observed to enhance natural flowering of the Masmerah cultivar. However, it had no significant effect on the percentage response of induced flowering (*Table 4*).

TABLE 4. EFFECT OF FREQUENCY OF WATERING ON FLOWERING RESPONSE

Frequency	No. of plants flowered	
	Natural	Induced
Daily	3	14
Weekly	2	14
Monthly	1	14
Total	6	42

Under practical conditions the water levels and frequency can be compared to the amount and frequency of rainfall. It may appear impossible to control our rainfall pattern but with the advent of techniques like "cloud seeding" a day may come when we will be able to control our rainfall (both its amount and frequency) and hopefully effectively controlling our pineapple flowering behaviour. A more practical approach would be to consider the probability of introducing the practice of irrigation. On this subject, studies on the rate and frequency of irrigation would have to be conducted. Furthermore, the economics of such an undertaking would have to be looked into, assuming that the technical knowhow is available.

Despite the above problems, it appears that there is now another line of research to be intensified in our never ending effort to control flowering of pineapple with the ultimate objective of evening out fruit production throughout the year.

Effect of watering level and frequency on the yield

Mean fruit weight responded significantly to water treatment ($P < 0.05$). Increasing watering level from 0 to 0.8 cm rainfall equivalent resulted in 50% increase on fruit weight. Subsequent increase in the amount of added water resulted in a decline in the fruit weights but they were consistently higher compared to the control (*Table 5*). No statistical significant effect was detected for watering frequency on the mean fruit weight although more

TABLE 5. EFFECT OF WATERING LEVELS ON THE MEAN FRUIT WEIGHT

Levels of watering bag^{-1} (cm rainfall equivalent)	Mean fruit weight (kg)
0	1.19
0.8	1.73
1.6	1.60
2.4	1.41
L.S.D (5%)	0.34

TABLE 6. EFFECT OF WATERING FREQUENCY ON THE MEAN FRUIT WEIGHT

Watering frequency	Mean fruit weight (kg)
Weekly	1.40
Monthly	1.47
L.S.D. (&5%)	0.34
Daily	1.58

frequent watering was found to increase it (*Table 6*). Interaction between watering levels and frequency was also observed to have no significant effect on the mean fruit weight. These findings were in keeping with reports by CHANDLER (1958) that frequent and dependable rainfall was important to obtain good size fruits.

Effect of watering levels and frequency on mean fruit length and diameter

Water treatments caused the mean fruit length ($P < 0.05$) and diameter ($P < 0.01$) to increase significantly. The increases of these two parameters were most striking to the first level of watering with subsequent increase in the watering levels causing a decline in both the mean fruit length and diameter (*Table 7*).

TABLE 7. EFFECT OF WATERING LEVELS ON THE MEAN FRUIT LENGTH AND DIAMETER

Level of watering bag-1 (cm rainfall equivalent)	Mean fruit	
	length (cm)	diameter (cm)
0	14.0	11.2
0.8	16.9	12.7
1.6	16.2	12.4
2.4	15.2	12.0
L.S.D. (5%)	1.82	1.38

The mean fruit length and diameter did not respond statistically to watering frequency although more frequent watering tended to increase the values of these two parameters (*Table 8*) and no interaction effect between watering levels and frequency was also observed.

TABLE 8. EFFECT OF WATERING FREQUENCY ON THE MEAN FRUIT LENGTH AND DIAMETER

Watering frequency	Mean fruit	
	length (cm)	diameter (cm)
Daily	16.2	12.4
Weekly	15.4	11.8
Monthly	15.1	12.1
L.S.D. (5%)	1.82	1.38

Effect of watering levels and frequency on fruit sugar and acid contents

Varying water treatments did not affect fruit and acid contents significantly (*Tables 9* and *10*).

TABLE 9. EFFECT OF WATERING LEVELS ON THE FRUIT SUGAR AND ACID CONTENTS

Watering levels bag-1 (cm rainfall equivalent)	Sugar content (°Brix)	Acid content (%)
0	12.2	0.52
0.8	11.5	0.62
1.6	11.0	0.57
2.4	11.3	0.45
L.S.D. (5%)	n.s	n.s

TABLE 10. EFFECT OF WATERING FREQUENCY ON THE SUGAR AND ACID CONTENTS

Watering frequency	Sugar content (°Brix)	Acid content (%)
Daily	11.1	0.55
Weekly	11.8	0.54
Monthly	11.6	0.53
L.S.D. (5%)	n.s.	n.s.

These findings were in contrasts to those reported by MALAN (1954) and COLLINS (1960) who found that fruit quality was reduced under conditions of high soil moisture.

SUMMARY

Vegetative growth of the Masmerah pineapple responded significantly to increasing levels of watering. In the development of plant height 0.8 cm rainfall equivalent was optimum while leaf number increment was most responsive with 1.6 cm rainfall equivalent. Increasing frequency of watering was also observed to enhance vegetative growth.

Waterlogging was found to affect growth and nutrient uptake adversely. The optimum water-table for pineapple growth was noted to be at 48 cm from the soil surface. Favourable nutrient uptake was observed to occur when the water table was maintained in the range of 30-50 cm from the soil surface.

Drought and waterlogging retarded natural flowering while increasing watering frequency was observed to enhance it. With the treatment of 0.8 cm rainfall equivalent, the response to flower induction was better. At the same time it was observed that this water regime was most conducive for natural flowering.

The mean fruit weight, length and diameter responded significantly to water treatments. The optimum watering level for development of these three parameters was 0.8 cm rainfall equivalent. Watering frequency had no statistically significant effect on mean fruit weight, length and diameter.

Watering levels and frequency had no statistically significant effect on the first sugar and acid contents.

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