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A lysimeter study on the effect of watertable on cassava grown on peat

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Key words: watertable, tropical peat, lysimeter studies, cassava

Abstrak

Ubi kayu telah ditanam di dalam lysimeter untuk mengkaji kesan aras air terhadap prestasi dan hasil tanaman ini. Hasil ubi kering didapati paling tinggi pada aras air 15 cm dari permukaan tanah gambut yang digunakan. Perbezaan hasil ketara apabila hasil yang diperoleh pada aras air 30, 45, 60 dan 75 cm dari permukaan tanah dibandingkan. Berat pokok kering (tidak termasuk ubi) juga paling tinggi pada aras air 15 cm dari permukaan tanah, dan penunjuk pungutan hasil (harvest index) tidak berbeza antara setiap aras air yang dikaji. Dalam kajian ini juga, kadar pengecutan tanah gambut bertambah mengikut dalamnya aras air dari permukaan tanah.

Ubi kayu berupaya untuk menyesuaikan pertumbuhannya mengikut aras air di dalam tanah gambut. Apabila aras air tinggi, kebanyakan ubi bertumpu pada permukaan tanah, manakala dalam keadaan aras air yang rendah, ubi juga membesar lebih mendalam.

Abstract

The effect of static watertable on cassava planted on peat was studied in lysimeters. Highest dry root yield was recovered from the watertable fixed at 15 cm below the soil surface. This yield was significantly different from yields obtained at watertables fixed at 30, 45, 60 and 75 cm depths. Similarly, plant dry weight (minus storage roots) was significantly higher at the watertable fixed at 15 cm depth than all the other watertables. Harvest index was not affected by the depth of the watertable. It was also apparent that under these artificial conditions, subsidence of peat during the crop cycle increased with the depth of the watertable.

Cassava shows adaptive ability to grow on peat with different depths of watertable. When watertable was high, the storage roots concentrated near the soil surface. When watertable was low, root growth extended downwards towards the water.

Introduction

Peat is found in large basins over extensive areas along the coasts of Peninsular Malaysia and in Sarawak. It has been estimated that the areas under peat and other organic soils in this country total about 2.4 million hectares (Joseph et al. 1974). Virgin peat is usually waterlogged, and if it is to be used for agriculture, drainage would be of

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Plate 1. Fibre-glass lysimeters with overflow pipes and filler pipes

immediate concern. This operation is costly. Besides, overdrainage of peat can lead to problems such as irreversible drying of the soil, subsidence and rapid loss of nutrients through oxidation processes. Hence, it is important to establish the optimal watertable for the growth and performance of various crop species to be cultivated on the drained peat.

Cassava (*Manihot esculenta* Crantz) has been identified as one of the crops which is adaptable to the inherent low pH of peat (Chew 1976). Other crops include pineapple, coffee, a range of vegetables, and oil palm. The effect of watertable on pineapple has been intensively studied by Tay (1974). In none of the other species has the effect of watertable on the growth and yield been investigated locally to that extent.

Cassava being a root crop is rather intolerant of waterlogging, a condition which promotes root rot. At early crop establishment, too much water in the soil inhibits the regenerative growth of the cuttings, namely the putting forth of roots and shoots. High soil moisture content may also affect the quality of the roots at harvest, by relative reduction by weight of the starch content.

As an initial step in developing appropriate production technology for cassava cultivation on peat, the optimal watertable for growth of the crop and uptake of applied nutrients is an important consideration. The use of lysimeters is particularly suited to such studies as these containers provide for the precise control of the watertable at specified depths over the whole crop season which would otherwise be difficult to achieve under field conditions.

Materials and methods

The lysimeters used were fibre-glass tanks which measured 90 cm x 55 cm x 140 cm deep. Overflow pipes were fixed at both end-sides of each lysimeter at 15 cm intervals, the first pair of pipes being at 20 cm from the top rim of the lysimeter *(Plate 1)*. By plugging the overflow pipes with rubber stoppers, five watertables ranging from 15 cm to 75 cm could be imposed. A filler pipe situated at one corner of each lysimeter ran the whole depth of the tank. This ensured that water was filled into the lysimeter from the bottom up.

Peat soil collected from a newly reclaimed area was used to fill the lysimeters in layers corresponding to the order of excavation from the field. This was to ensure that the soil in the lysimeters reflected as closely as possible the profile under natural conditions. Thereafter, the peat was flooded with peat water (collected from a field drain near the sampling site) and allowed to settle for about 2 months before beginning the experiment. At 3 weeks before the watertable regimes were imposed, the top 15 cm peat layer in all the lysimeters was drained to facilitate liming. The different watertable treatments were maintained by adding peat water daily through the filler pipes. Any excess water would drain from the unplugged overflow pipes above the imposed watertables.

The commercially grown cassava cultivar, Black Twig, was used in this study. This cultivar has been shown to be very adaptable to peat (Chew 1977; Tan

Table 1. Soil chemical analyses before planting and at harvest

	Before planting*		At harvest	
	0–15 cm	15–30 cm	0–15 cm	15–30 cm
pH (H_2O) 1:5	3.36	3.36	3.91	3.46
Conductivity (μS/cm)	60.55	58.08	143.73	88.14
NO_3 Nitrogen (ppm)	45	50	32	71
NH_4 Nitrogen (ppm)	23	25	30	81
Water-soluble K (ppm)	34	35	79	91
P (μg/g)	43	43	111	27

*Before liming
After liming: pH = 4.06; Conductivity = 81.74 μS/cm

1985). Two cuttings of 23 cm length taken from mature stems were planted centrally positioned in a vertical orientation at a distance of 45 cm apart in each lysimeter.

The lysimeters were arranged in a space open to the sky in two rows following a north-south orientation such that the five watertable treatments were set out in a randomized complete block design, with four replications. The watertable treatments were imposed 1 day before the cuttings were planted.

Initial determination of the soil pH established that the equivalent of 2 t of ground magnesium limestone per hectare (using the rate of liming established by Chew in 1976) was the amount of lime required to raise the pH to around 4.0. Liming was carried out 3 weeks before planting.

At planting, a fertilizer mixture corresponding to 250 N:50 P_2O_5:150 K_2O in kg/ha was applied, supplemented with 10 kg of copper sulphate per hectare. The fertilizers were banded around each planted cutting in a shallow trench and covered with soil. Due to the general non-vigorous appearance of the plants at around 5 months after planting, a top-dressing equivalent to 36 N:18 P_2O_5:66 K_2O in kg/ha was applied in the same fashion.

Weeds were controlled manually whenever necessary.

Soil samples were collected up to 30 cm depth at the start of the experiment (before and after liming), and after harvest. The samples were analysed for pH, NO_3-N and NH_4-N as well as total N, P (by Bray II method), water-soluble K, and soil conductivity.

The crop was harvested at about 9 months after planting, and data were collected on plant height, fresh and dry weights of stems, leaves, cuttings and storage roots, harvest index (weight of storage roots divided by total plant weight), total storage root number, perpendicular depth of storage root growth, number of stems per cutting, length of the longest storage root, starch content, and the subsidence of peat in the lysimeter.

Results and discussion

Data on the initial soil samples and those collected at harvest are given in *Table 1.* Liming raised the pH (1:5 water) from a mean of 3.36 to 4.06, and increased conductivity from 59.3 to 81.7 μS/cm. The pH at harvest had dropped to 3.68 and conductivity had increased to 115.9 μS/cm. The initial increase in soil pH after liming and the subsequent fall after several months conform with the observations by Tay (1972) and Leong (1982). The increase in conductivity values after liming and at harvest is probably due to dissolution of the liming material, subsequent effect of liming causing an increased rate of mineralization, and the residual effect of added fertilizers.

Watertable had a significant effect on the subsidence of the peat contained in

Table 2. Effect of watertable on various plant growth characteristics of cassava cultivar Black Twig

Watertable (cm)		Dry matter content of roots (%)	Depth of root growth (cm)	Dry matter content of 'tops' (%)	Fresh wt. of 'tops' (g/plant)	Harvest index
Initial	Final					
15	11.2	41.4a	17.9b	26.5a	720a	0.80ab
30	24.1	32.8ab	18.9ab	23.5ab	620b	0.80ab
45	37.2	29.8b	20.2ab	19.8b	660ab	0.78bc
60	51.4	29.8b	19.7ab	20.6b	640ab	0.79abc
75	65.1	29.4b	21.1a	19.0b	620b	0.77c

Values bearing the same letter/s are not significantly different from one another according to the new Duncan Multiple Range test ($p < 0.05$)

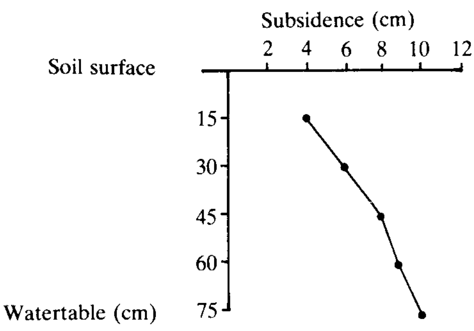

Figure 1. Effect of watertable on subsidence in peat

the lysimeter. Subsidence increased progressively with the lowering of the watertable *(Figure 1)*, a phenomenon reported earlier by Stephens and Johnson (1951). This led to the 15 cm watertable treatment becoming effectively at 11 cm while the 75 cm watertable treatment was at 65 cm from the soil surface at the termination of the study *(Table 2)*.

It should be reiterated that, in the study, the peat in the lysimeters had a very disturbed profile. This 'reconstituted' profile was allowed only 2 months to gain equilibrium, and watertable treatments were imposed only a day before the start of the study. As a result, the degree of subsidence is much greater than would be expected from drainage of peat under natural conditions.

Initial establishment of the cuttings was excellent with no need for replacements. An infestation by scales during a dry spell of weather led to the poor top growth of the plants from 4 months up to the harvest. The pesticide methamidophos was used at the recommended rate to keep the scales in check.

The effect of watertable on cassava yield may be clearly seen in *Figure 2*. Dry root yield per plant was highest when watertable was at 15 cm (or effectively 11 cm) from the soil surface ($p < 0.05$). From 30 cm (effectively 24 cm) downwards, there were no significant differences in dry root yield although there was a slight trend of yield reduction as watertable was lowered. It was also observed that the storage roots in the '15 cm' treatment developed very close to the soil surface, probably to avoid 'getting its feet wet' and because of the lateral restriction of the lysimeter walls. There was also a general tendency for the storage roots to grow to a greater depth as watertable was lowered *(Table 2)*. Root dry matter content was also highest at the '15 cm' watertable (not significantly different from that at '30 cm' watertable), being much lower as the watertable was maintained at '45 cm' or more.

The effect of watertable on dry 'top' (leaves, stems and cutting) weight showed a trend similar to the effect on dry root yield. Dry 'top' weight was significantly higher at the '15 cm' watertable *(Figure 2)*. The dry matter content of the 'tops' was also affected in a manner like the dry matter content in the roots. Effects on the

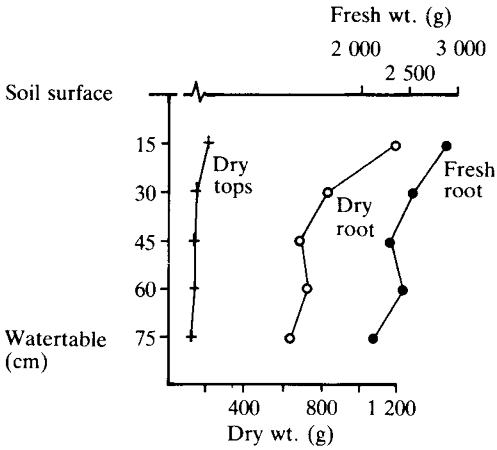

Figure 2. Effects of watertable on fresh root weight, dry root and top weights of cassava

fresh weights of roots and 'tops' were less dramatic, although the trend remained largely the same. Harvest indices were fairly constant through the various watertables, despite a tendency to decrease towards lower watertables. No significant effects were observed on the total root number and starch content of the roots.

It would appear that cassava has a fair tolerance for high watertables, and when the watertable is lowered from 15 cm to 30 cm depth, root yield is reduced. In this study, the reduction is as much as 30%, increasing to 47% when the watertable was lowered to 75 cm from the soil surface. The storage roots showed an adaptive feature in concentrating near the soil surface (to the extent of being exposed above the soil) when the watertable was high. This characteristic helps the roots to avoid being steeped in water, thus preventing the occurrence of root rot while water was always readily available within reach of the plant's roots. An interesting parallel may be drawn from the saturated soil culture of soybean advocated in Australia which increased grain yield by 65% and 71% when the watertable was maintained at 3 cm and 15 cm from the soil surface respectively (Nathanson et al. 1984). Similarly, the modified hydroponic technique practised at AVRDC (Asian Vegetable Research and Development Center), Taiwan, whereby vegetable plants are suspended in water culture with the top portion of their roots exposed for aeration, may work on the same principle.

In clover, orchardgrass and tall fescue, highest shoot yields were reported for a watertable at 15 cm depth when no surface water was added (Williamson and Kriz 1970). When surface water was applied, watertable depth had little effect on clover yields whereas, orchardgrass and tall fescue produced higher yields at 30 cm and 50 cm depths respectively. For all the watertable depths studied, most of the roots of these crops were found in the upper 25 cm of the soil between the watertable and the surface.

Quite unexpectedly, a high watertable did not decrease the dry matter content of the roots; indeed, the reverse appears to hold.

It should of course be pointed out that under natural field conditions, such precise control of the watertable will be close to impossible. Variations may be expected within a field, depending on an area's proximity to drains and other water bodies. At the same time, fluctuations will also occur within a season, depending on the prevailing rainfall patterns and the rate at which water is pumped in or out to maintain a given watertable. Both these factors may lead to the storage roots being steeped in water for a few hours to a few days. This condition is highly detrimental to the crop as it leads to oxygen starvation of the roots, subsequent root rot, or even death of the plant if prolonged. Campbell (1973) has reported that in mineral soil, oxygen depleted from 16% to 4% in the soil atmosphere within 24 h after flooding. In peat, dissolved oxygen is reduced from 18 ppm to 2 ppm after 2 days of stagnant flooding (Tay, T. H., MARDI, Serdang, pers comm. 1988). In tobacco, flooding for more than 48 h significantly reduced leaf yield by more than 60% of the yields of unflooded plants (Campbell 1973).

Another point which needs to be stressed is that the development of storage roots near the soil surface, and indeed exposure above the soil, due to high watertable may lead to yield losses to pests (such as rats) as well as the problem of lodging in windy locations.

Given the limitation of an artificially induced static watertable in this study, what may be concluded is that for the cultivation of cassava on peat, drainage of the soil need not be too excessive. As it is practically impossible to maintain a watertable at 15 cm throughout the crop growth cycle, this should serve as the upper limit for watertable fluctuations at any time during the crop cycle. At the same time, the watertable should not drop too much below this 15 cm limit if high root yields from cassava are to be expected. Precisely, what should be the lower limit for watertable fluctuations cannot be inferred from the current results, except that it probably should not be 30 cm or more when root yield is significantly reduced. The results of this study require verification under field conditions.

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