THE EFFECTS OF DIFFERENT WATER TABLE CONDITIONS IN PEAT SOILS ON SELECTED SOIL CHEMICAL PROPERTIES AND GROWTH RESPONSE OF *BRASSICA RAPA L. VAR. CHINENSIS*

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Abstract

The fluctuating water table in peat systems induces alternating aerobic and anaerobic conditions, thereby influencing specific soil chemical properties and subsequently impacting nutrient uptake efficiency by plants cultivated in such environments. This study aims to analyse selected soil chemical properties and evaluate the growth performance of *Brassica rapa L. var. Chinensis* cultivated in peat soils subjected to varying water table levels. Peat soil samples were collected from Tangkak, Johor, Malaysia. Experimental treatments comprised four distinct water table levels: T0 (control) at 0 cm; T1 at 5 cm; T2 at 10 cm; and T3 at 15 cm below the soil surface, respectively. The samples were arranged in a Completely Randomised Design (CRD) within a greenhouse environment. Results revealed significant differences in soil pH, soil available phosphorus (P), and soil exchangeable potassium (K) and magnesium (Mg) among treatments. Multiple comparisons analysis indicated that T3 (peat soil with a 15 cm water table level) exhibited the highest concentrations of soil available P, soil exchangeable K and Mg, as well as a higher soil pH compared to other treatments. Correlation tests between treatments unveiled significant interactions among soil exchangeable K, calcium (Ca), and Mg, as well as soil pH. However, no substantial differences were observed in the growth performance of *Brassica rapa L. var. Chinensis* across treatments. Consequently, this study suggests dynamic fluctuations in soil chemical properties, particularly soil pH, exchangeable K, Ca, and Mg, in peat soils at various water table levels, without significant effects on the growth of *Brassica rapa L. var. Chinensis.*

Keywords: nutrient, soil, sustainability, uptake, water table

Introduction

Malaysia boasts an extensive expanse of peat soils, estimated at 2.6 million hectares nationwide. The largest concentration of peatlands resides in Sarawak, encompassing approximately 1.6 million hectares of peat land (Melling, 2016). Tropical peat soils exhibit unique hydrological characteristics, characterised by a high-water table within the system (Andriesse, 1988), which profoundly influences the formation and functioning of peatland ecosystems. The fluctuating water table creates alternating aerobic and anaerobic conditions, thereby impacting forest types and nutrient flux within peat systems (Melling, 2016; Padfield et al., 2015). This dynamic environment also influences specific soil chemical properties, subsequently affecting the efficiency of nutrient uptake by plants cultivated in peat soil (Kassim & Yaacob, 2019). Previous studies have indicated a positive soil nutrient balance when the water table in peat fluctuates between depths of 40-80 cm. Conversely, fluctuations between 0-40 cm depths have resulted in the highest levels of nutrient deficiency in experimental treatments (Kassim & Yaacob, 2020). This finding may hold relevance for peat environments equipped with proper drainage systems, enabling effective control and maintenance of water flow (Mutert et al., 1999; Veloo et al., 2015). However, there remains a significant knowledge gap regarding peat soils lacking adequate drainage systems, where water fluctuation often remains minimal, particularly during the wet season (Agus et al., 2020). This condition is frequently observed in regions dominated by vegetable and cash crop cultivation (Morley, 1981). Therefore, the present study seeks to analyse selected soil chemical properties and assess the growth performance of *Brassica rapa L.* cultivated in peat soils subjected to varying water table levels.

Materials and Methods

Sample Collection

The peat soil sample for the experiment was collected from Tangkak, Johor, Malaysia (Coordinates: 2°15’03.1” N, 102°33’39.8” E). The sampling area is situated in a flat terrain adjacent to an oil palm plantation and consists of moderate to deep peat, with an organic layer exceeding 150 cm from the soil surface. The humification degree predominantly exhibits sapric characteristics within the upper 25 cm profile. Initial analysis of the soil samples focused on selected properties, specifically soil bulk density, pH, exchangeable potassium (K), calcium (Ca), magnesium (Mg), and available phosphorus (P).

Sample Preparation and Treatments

Brassica rapa L. var. chinensis seeds were germinated following the standard procedure recommended by the Department of Agriculture (DOA), Malaysia, and transplanted after 14 days of germination. The standard procedure for growing *Brassica rapa L. var. chinensis* was adhered to, wherein fertiliser (NPK 15:15:15) was applied at a rate of 4 grams per plant, and routine weed removal was conducted. The collected soil samples were placed into designated containers with dimensions of approximately 40 cm in height and 15 cm in width. Holes were strategically constructed at specific depths to facilitate water drainage, thereby enabling maintenance of the water table level according to the respective treatments outlined in **Table 1**.

Table 1 Treatments

Treatment	Details
T0	Water table level is at 0 cm from the soil surface
T1	Water table level is at 5 cm below the soil surface
T2	Water table level is at 10 cm below the soil surface
T3	Water table level is at 15 cm below the soil surface

Experimental Design

The experiment was conducted in a controlled environment within a greenhouse. The treatments were arranged using a Completely Randomised Design (CRD) with three (3) replications for each treatment, as illustrated in **Figure 1** below.

T2R1	T0R2	T1R2	T3R3
T2R2	T1R1	T2R3	T0R3
T0R1	T3R1	T3R2	T1R3

Notes:
1. T0 = Water table level is at 0 cm from the soil surface, T1 = Water table level is at 5 cm below the soil surface, T2 = Water table level is at 10 cm below the soil surface, and T3 = Water table level is at 15 cm below the soil surface.
2. R is representing the number of replications (R1 = Replication 1, R2 = Replication 2, R3 = Replication 3)

Figure 1 Experimental design

Sample Analysis

The soil samples were collected at the conclusion of the experiment (40 days after the harvesting of *Brassica rapa L. var. chinensis*) and underwent a series of preparations before proceeding to selected soil chemical analyses. They were dried, crushed, and sieved to ensure uniformity. Soil available phosphorus (P) was determined using the Bray (II) method (Bray and Kurtz, 1945), while soil exchangeable bases (potassium (K), calcium (Ca), and magnesium (Mg)) were extracted using the ammonium acetate method (Schollenberger and Simon, 1945) before being subjected to ICP-OES analysis (Perkin Elmer). Soil pH was analysed using a 1:10 (sample:water) ratio and measured with a pH meter (Mettler Toledo). Plant growth performance, including the number of leaves and plant height, was monitored weekly. All data obtained were subjected to statistical analysis using IBM SPSS Statistics version 26.

Results and Discussion

Selected Soil Chemical Properties

Table 2 presents the selected soil chemical properties of peat soils initially and at different water table levels corresponding to the treatments.

Table 2 Selected soil chemical properties of peat soils at different levels of water table

Soil Properties	Initial	After Treatments Application			
		T0	T1	T2	T3
Bulk density (g/cm^3)	0.45	-	-	-	-
Mean soil pH (in water)	4.99	5.73^{ab}	5.74^{ab}	5.56^{a}	5.98^{b}
Mean soil available P (mg/kg)	6.588	1559.33^{a}	1835.00^{a}	3370.00^{a}	4943.67^{b}
Mean soil exchangeable K (mg/kg)	26.01	3283.00^{a}	5043.67^{b}	3804.67^{ab}	5524.00^{c}
Mean soil exchangeable Ca (mg/kg)	288.1	419.47^{a}	567.07^{a}	596.63^{a}	586.07^{a}
Mean soil exchangeable Mg (mg/kg)	12.69	107.25^{a}	130.93^{ab}	97.96^{a}	175.17^{b}

Notes:
1. T0 = Water table level is at 0 cm from the soil surface, T1 = Water table level is at 5 cm below the soil surface, T2 = Water table level is at 10 cm below the soil surface, and T3 = Water table level is at 15 cm below the soil surface.

2. Different letter followed in a same row indicates there is a significant difference at p-value $\leq$0.05

The initial data indicates a low soil bulk density of the sampled soil, with a value of 0.45g/cm^3. This aligns with the typical soil bulk density for well-decomposed peat materials in tropical regions, which are often less than 0.5g/cm^3 (Andriesse, 1988) due to the smaller particle sizes of sapric material (Deboucha et al., 2008). Additionally, it is suspected that nearby oil palm plantation activities, including the presence of drainage systems and vegetation, have influenced the decomposition processes and microstructures of the peat soils at the sampling area (Könönen et al., 2015; Azmi & Kassim, 2022). The significant increase in soil available phosphorus (P), soil exchangeable potassium (K), calcium (Ca), and magnesium (Mg) for all treatments can be attributed to the application of NPK (15:15:15) fertiliser, compared to the initial soil samples. Regarding available P, a significant difference is observed between T3 (water table level at 15 cm below the soil surface) and other treatments. This difference may be due to the release of P in the upper 15 cm aerobic layer, where there is a low potential for aluminium (Al) and iron (Fe) fixation (Cheong and Ng, 1977), as evidenced by the high soil pH of T3 (as shown in **Table 2**). Similarly, significant differences in soil exchangeable K and Mg are observed between T3 and other treatments. The higher exchangeable bases observed in T3 (water table level at 15 cm below the soil surface) may be attributed to the low water table level, which inhibits the leaching of K. It is well-known that a significant portion of K in peat is highly mobile and prone to leaching in the presence of water (Kassim & Yaacob, 2020). The findings of this study also suggest that lowering the water table to approximately 15 cm from the soil surface results in a higher soil pH, likely induced by the decomposition process in the aerobic environment of peat materials on the surface (Kassim & Yaacob, 2019). Overall, the results indicate a fluctuating pattern of exchangeable bases (K, Ca, and Mg) and soil available P in this study, which is likely related to soil pH fluctuations. The fluctuation of soil pH is suspected to be due to the alternate movement of H^+ ions in the soil, further influencing the nutrient cycling of the soils (Neina, 2019).

Plant Growth Performance

In this study, plant growth performance was evaluated based on two parameters: plant height and the number of leaves produced. Data collection occurred biweekly, with manual measurements taken. The results were presented cumulatively to depict the progression of plant growth from transplantation to the harvesting period.

Plant Height

The data regarding plant height for *Brassica rapa L.* planted in peat soil under varying water table levels is illustrated in **Figure 2**. Statistically, no significant differences were observed in plant height across all treatments.

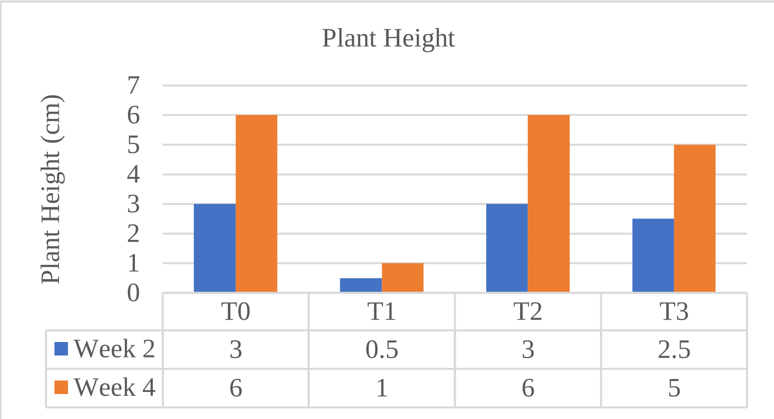

Figure 2 Plant height

Number of Leaves

The number of plant leaves for each treatment is depicted in **Figure 3** below. Statistically, no significant differences were observed in the number of leaves produced between treatments.

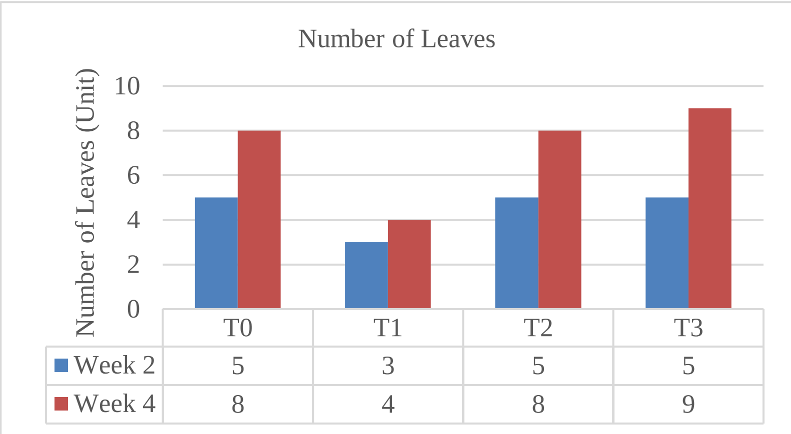

Figure 3 Number of plant leaves

Correlation between Parameters

The correlation between parameters is presented in **Table 3**.

Table 3 Correlation between parameters

		Soil_P	Soil_K	Soil_Ca	Soil_Mg	Soil_pH	Plant_Number of Leaves
Soil_K	Pearson Correlation	.600*					
	Sig. (2-tailed)	.039					
	N	12					
Soil_Ca	Pearson Correlation	.159	.418				
	Sig. (2-tailed)	.621	.177				
	N	12	12				
Soil_Mg	Pearson Correlation	.703*	.862**	.700*			
	Sig. (2-tailed)	.011	.000	.011			
	N	12	12	12			
Soil_pH	Pearson Correlation	.571	.708**	.769**	.927**		

	Sig. (2-tailed)	.052	.010	.003	.000		
	N	12	12	12	12		
Plant_Number of Leaves	Pearson Correlation	.525	-.200	.061	.099	.141	
	Sig. (2-tailed)	.080	.532	.851	.760	.662	
	N	12	12	12	12	12	
Plant_Height	Pearson Correlation	.524	-.164	.038	.164	.238	.770**
	Sig. (2-tailed)	.080	.610	.905	.610	.456	.003
	N	12	12	12	12	12	12

Notes:
*Treatment is significant at the 0.05 level (2-tailed)
**Treatment is significant at the 0.01 level (2-tailed)

From **Table 3**, a significant correlation is evident between soil available P and soil exchangeable K, Ca, Mg, and soil pH, respectively. The negative relationship between these parameters suggests that soil pH tends to increase the exchangeable bases while reducing soil available P. This is consistent with the nature of phosphorus, where availability is often linked to P-fixation in the soil (Strawn et al., 2020). The high water table levels in peat soils facilitate an increase in P-immobilisation, leading to higher levels of sorbed P and subsequent leaching (Hashim et al., 2019). The significant positive relationship between soil pH and exchangeable bases is well-documented and attributed to the reduction of hydrogen ions, thereby enhancing the availability of bases in the soil (Havlin, 2020).

Conclusion

This study suggests that Treatment 3 (T3), where the water table is situated 15cm below the soil surface, results in significantly higher concentrations of soil exchangeable K, Ca, and Mg, as well as a higher soil pH compared to other treatments. In conclusion, there are dynamic changes in soil chemical properties, specifically soil pH, soil exchangeable K, Ca, and Mg, in peat soil at different water table levels, with no significant effects observed on the growth performance of *Brassica rapa L.*

Ethics Statement

The research conducted does not require research ethics approval.

Authors' Contribution

Writing – Original draft preparation, Nadia Maisarah, A.; Literature Review and Methodology, Salwa, A., – Review and editing, Nur Qursyna B. K.

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Conflict of interests

This article has no conflict of interests.

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