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Research Article

Efficacy of Potassium Humate Prepared from Tropical Peat Soil for Maize Growth and Nutrient Uptake under Acidic Soil Conditions of Malaysia

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ABSTRACT

Humic substances have many beneficial effects on soil and plant growth. The peat is an accumulation of partially decayed organic matter that can be used to isolate humic acid from it. The objective of this study was to prepare humic acid from peat soil and determine its effects on maize plant growth in order to consider their agricultural use as organic fertilizers. The isolation and purification of humic acid (potassium humate) from peat soil of Kuala Tatau (Sarawak, Malaysia) was performed in the Ddepartment of Land Management, Universiti Putra Malaysia. A glasshouse experiment was conducted to study the efficacy of prepared humic acid of peat soil (HAPS) by comparatively evaluating it with a commercial humic acid (HAC). Different levels of both humic acids were mixed with macro and micronutrients and applied on maize crop to observe their effect on growth and nutrient uptake in acid soil. There were eleven treatments with different combinations of HAPS and HAC. The positive effects of both humic acid sources were observed on the whole plant growth. The maximum plant height among all treatments was recorded in plots where HAPS along with NPK and $CuSO_4$ were applied. The thickest stems and the highest number of leaves were recorded in the plants which received HAPS + NPK + $CuSO_4$ + $ZnSO_4$. The same trend was observed in the enhancement of total plant dry weight and root dry weight of maize plant. The highest yield was recorded in treatment 9 (HAPS +NPK+ $CuSO_4$ + $ZnSO_4$). Although both types of humic acid increased the crop yield, but HAPS gave significantly better results. This study highlighted that humic acid prepared from peat soil is a worthwhile practice with enormous benefits for soil and crops.

Keywords: Humic acid, Maize, Peat soil, Potassium humate, Nutrient uptake

Introduction

Fertilizers are not humic acids (HA). When used in conjunction with organic or synthetic fertilizers, they can be a useful supplement. Soils, natural water, rivers, sea sediments, plants, peat, materials that have undergone chemical and biological transformations, lignite, oxidized bituminous coal, and leonardite are all sources of humic acid. It makes up between 50 and 90 percent of these goods' organic matter (Ampong et al., 2022). Dark-colored compounds that dissolve in aqueous alkali but are insoluble in acid are known as humic acids, and they are produced from coal. These compounds are also found naturally in some brown coals made of lignite, whereas bituminous coals have little to no alkali-soluble material (Karaca et al., 2005; Skhonde et al., 2006).

A sufficient number of humic compounds in the soil enhances its aggregation, aeration, permeability, water-holding capacity, and the availability and transport of micronutrients (Li et al., 2024). It affects physiological functions and plant growth directly as well as indirectly (Sangeetha et al., 2006; França et al., 2025). It is a nutrient carrier that increases the intake of mineral elements, promotes root length, and acts as a catalyst for biochemical reactions and antioxidant activity. Make crop plants heavier both fresh and dry (Kulikova et al., 2005; Gerke, 2018). In the right proportions, humic acid can promote the growth of primary roots in maize. It also speeds up plant cell division, improves root development, reduces stress deterioration, and improves soil structure, CEC, nutrient retention, and microbial activity (Shahryari and Mollasadeghi, 2011).

Reduce bulk density, lessen soil compaction, raise soil porosity, and speed up chemical (nutrient cycling) reactions to boost water infiltration rate (Zeleke et al., 2005).

By complexing Al and Fe, humic acid (potassium humate) raises the pH of the soil, increases soil microbial activity, improves soil structure, increases CEC, and increases the solubility of P. In problematic soils, particularly sodic and acidic soils, it can give the maize crop a better environment for reaching its maximum yield (Mackowiak et al., 2001; Canellas et al., 2002; Kulikova et al., 2005).

By humifying and mineralizing trash, composting creates products that are high in nutrients and humic compounds. Peat soils, which are found in large parts of Malaysia, are rich in humus and acid reaction since they are primarily composed of peat. Given that peat is a collection of partially decomposed organic matter, humic acid was extracted from it and compared to determine its value as a source of humic acid for nutrient uptake and maize development in acidic soil.

Materials and Methods

Venue of experiment: The experiment was conducted at the Department of Land Management, Universiti Putra Malaysia, Malaysia.

Humic acid extraction: Humic acid (potassium humate) was isolated from the peat soil of Kuala Tatau, Sarawak, Malaysia. Samples of peat soil were collected at a depth of 0–15 cm. The protocols suggested by Stevenson (1994) and Susilawati et al. (2007) were used, with slight adjustments, to extract humic acid. A 0.01 M KOH solution was applied to five grams (dry weight basis) of peat soil samples in polypropylene centrifuge bottles, which were then securely sealed with rubber stoppers. The samples were let to acclimate to ambient temperature on a reciprocating mechanical shaker that was set to 180 rpm. At the end of the extraction period, the samples were centrifuged for 15 minutes at 16200 G. The mixture was allowed to remain at room temperature following the decantation of the dark-colored supernatant liquors and the use of 6M H2SO4 and HA to bring the pH of the solution down to 1.0. The extraction was done for four hours, and the fraction was used immediately following acidification for two hours. Following the completion of the fraction, the suspension containing HA was placed in plastic bottles and centrifuged at 16200 G for 10 minutes. The methods outlined by Susilawati et al. (2007) and Ahmed et al. (2004) were used to purify the HA samples. Centrifugation at 16200 G for 10 minutes was used to wash the HA with 50 ml of distilled water to reduce the amount of mineral matter and H2SO4 utilized in the extraction and acidification processes, respectively. Following three iterations of the entire process, the cleaned HA samples were oven-dried at 40°C at a steady pace. Using an elemental analyzer, potassium humate (52 percent HA and 10 percent K2O) was examined. A 10% w/v extractable K analysis was done by AAS. Titration-based functional group was determined following Inbar et al. (1990).

Nitrogen 2.824%, carbon 40.25%, hydrogen 1.140 %, sulfur 3.601%, oxygen 52.15%, C/N ratio 14.25, and carboxylic (phenol 245, carboxylic 360, and total 605 cmol kg^{-1}) are all present in the humic acid of peat soil (HAPS).

Efficacy of humic acid: The effectiveness of the humic acid of peat soil (HAPS) produced at UPM was assessed by comparing it with a commercial humic acid product. The impact of both humic acids on maize development and nutrient uptake in acid soil (Nyalau soil series; Typic Paleudult) was examined in a glasshouse study. Humic acid of peat soil (HAPS) and commercial humic acid (HAC) were mixed with urea, copper, zinc, and control (no nutrients) then applied to the crop.

Treatment details: Ten humic acid and fertilizer treatments were involved in this study, viz., T1= (No fertilizer, control), T2=NPK @ 60-60-40 kg ha^{-1} ,T3=NPK + HAPS @ 20 kg ha^{-1}, T4=NPK + (HAC) @ 20 kg ha^{-1}, T5=NPK + HAPS + $CuSO_4$ @ 6.7 kg ha^{-1}, T6=NPK + HAC + $CuSO_4$ @ 6.7 kg ha^{-1}, T7=NPK + HAPS + $ZnSO_4$ @ 11.2 kg ha^{-1} , T8=NPK + HAC + $ZnSO_4$ @ 11.2 kg ha^{-1}, T9=NPK + HAPS + $CuSO_4$ (5 kg ha^{-1})+ $ZnSO_4$, (10 kg ha^{-1}) T10= NPK + HAC + $CuSO_4$ (5 kg ha^{-1}) + $ZnSO_4$ (10 kg ha^{-1}). The experimental design was CRD. Air dried soil (20 kg/pot) was put in earthen pots containing drainage holes in the bottom. The pots were arranged in randomized block design, replicated three times.

Maize Hybrid-5 variety was used in this experiment which is widely preferred by the local farmers. Six seeds in each pot were sown. The seed was soaked in water for 24 hours followed by incubation. After emergence, three seedlings were allowed to grow in each pot up to tasselling. Irrigation was applied as per requirement of the plants. Fertilizers of P and K were applied @ 60-40 kg ha^{-1} respectively. All P, K, $ZnSO_4$, $CuSO_4$ and 2/3rd N were applied one week after sowing. However, remaining N was split applied 30 and 45 days after sowing. Soil texture was determined using pipette method (Gee and Bauder, 1982), total carbon by LECO CR-412 carbon Analyzer, effective CEC by $BaCl_2$ method (Hendershot and Duquette, 1986), electrical conductivity and pH at 1:2 soil and water ratio (Sonon et al., 2015).

Statistical Analysis: The data were subjected to analysis of variance (ANOVA). The means were compared by Tukeys' test at 5% probability level, using the Statistical Analysis System (SAS) software.

Results and Discussion

Our experiment's findings demonstrated that using humic acid in combination with other fertilizers improves maize production and growth. Both humic acids, HAPS and HAC, increased plant height, stem girth, leaves per plant, root dry weight, total plant dry weight, and N, P, K, and Cu uptake when two humic acid sources were compared to determine their effectiveness. Since humic acid derived from peat soil (HAPS) produced noticeably better results than commercial humic acid, it can be used as a dependable supply of humic acid. It was discovered that adding Zn (10 kg ha^{-1}) and Cu (5 kg ha^{-1}) along with humic acid was an effective way to increase yields.

These positive results may be due to the role of humic acid in improving the uptake of mineral elements and promote the root length (Mackowiak et al., 2001; Chen et al., 2004). The increased nutrient uptake by plant was due to the presence humic molecules which are macro and micronutrient carriers, humic substances also promote various biochemical processes such as photosynthesis and nucleic acid synthesis (Chen et al., 2004). The positive effects on number of leaves per plant, root dry weight and stem girth can be ascribed due to the direct interaction of humic substances with plant physiological and metabolism processes. The humic acid application also enhances biometric factors of plant growth such as the measurement of shoot and root length, fresh and dry weights of every maize organ (Song et al., 2022).

The positive effects of humic acid were observed on the whole plant growth. The agronomic factors of maize crop are presented in Table 1. The plant height increased with application of both of humic acid sources HAPS and HAC in compare to control. The maximum plant height among all treatments was recorded in plots where HAPS along with NPK and $CuSO_4$ were applied followed by the plots with application of HAC accompanied by NPK, $CuSO_4$ and $ZnSO_4$. Both sources of humic acid showed positive effects on the stem grith of the maize plant.

The thickest stem was recorded in the plants which received HAPS + NPK + CuSO4 + ZnSO4 (T9) followed by the treatment 7 and 8. The number of plant leaves also significantly increased in all treatments in compare to control. The highest number of leaves among the

Table 1. Effect of humic acid of peat soil (HAPS) and commercial humic acid (HAC) mixed with urea, Cu and Zn on maize growth

Treatment	Plant height (cm)	Stem girth (cm)	Leaves per plant	Root dry weight (g)	Total dry weight (g)	Cob yield kg/m^2
T1. (No fertilizer)	36.5g	1.4e	10.7d	2.2d	9.1h	0.79h
T2. NPK @ 60-60-40 kg ha^{-1}	99.5f	2.5d	14.7c	3.9c	20.7g	1.27h
T3. NPK + HAPS @ 20 kg ha^{-1}	122.3e	2.7cd	15.3b	5.1a	26.2e	1.45g
T4. NPK + HAC @ 20 kg ha^{-1}	119.1d	2.9c	16.3a	4.8b	24.4f	1.34f
T5. NPK + HAPS + CuSO4 @ 6.7 kg ha^{-1}	138.6a	3.0c	16.7a	5.2ab	29d	1.56d
T6. NPK + HAC + CuSO4 @ 6.7 kg ha^{-1}	135.2b	3.1bc	15.0b	5 .0ab	26.3e	1.48e
T7. NPK + HAPS + ZnSO4@ 11.2 kg ha^{-1}	128.2c	3.2b	15.3b	4.7b	31.4c	1.72b
T8. NPK + HAC + ZnSO4 @11.2 kg ha^{-1}	129.8c	3.4b	15.3b	5.1ab	29.9d	1.60c
T9. NPK + HAPS + CuSO4 + ZnSO4	135.2b	3.8a	16.7a	5.5a	34.7a	1.78a
T10. NPK + HAC + CuSO4 + ZnSO4	134.1b	3.4b	15.0b	5.2ab	31.5b	1.73b

Values with the same letter within columns are not significantly different at p 0.05.

Table 2. Effect of humic acid of peat soil (HAPS) and commercial humic acid (HAC) mixed with urea, Cu and Zn on nutrient concentration in maize

Treatment	N %	P %	K %	Zn (µ/g)	Cu (µ/g)
T1. (No fertilizer)	0.79h	0.05d	1.77i	9.14h	1.81f
T2. NPK @ 60-60-40 kg ha^{-1}	1.63f	0.07c	2.32h	11.00g	1.92e
T3. NPK + HAPS @ 20 kg ha^{-1}	1.63f	0.07c	2.57f	14.12d	2.01d
T4. NPK + HAC @ 20 kg ha^{-1}	1.66e	0.08b	2.50g	13.11e	1.95de
T5. NPK + HAPS + CuSO4 @ 6.7 kg ha^{-1}	1.71d	0.07c	2.66de	12.33f	8.51a
T6. NPK + HAC + CuSO4 @ 6.7 kg ha^{-1}	1.70d	0.07c	2.61e	11.41g	7.25c
T7. NPK + HAPS + ZnSO4 @ 11.2 kg ha^{-1}	1.60g	0.09a	2.75c	24.25b	7.82b
T8. NPK + HAC + ZnSO4 @ 11.2 kg ha^{-1}	1.76c	0.09a	2.68d	22.08c	7.12c
T9. NPK + HAPS + CuSO4 + ZnSO4	1.91a	0.08b	2.89a	26.42a	8.50a
T10. NPK + HAC + CuSO4 + ZnSO4	1.84b	0.09a	2.80b	24.14b	7.80b

Values with the same letter within columns are not significantly different at p 0.05.

treatments was in treatment 4, 5 and 9, there was no significant difference among these treatments. The same trend was observed in the increase of total plant dry weight and root dry weight of maize plant as treatment 4, 5 and 9 gave better results. Although both humic acid sources HAC and HAPS were effective in compare to control and among these two the HAPS applied pots were harvested with significantly higher total plant and root dry weight the plants treated with T9 harvested with significantly higher dry weight (Table 1).

The application of both humic acid source HAPS and HAC enhanced the plant uptake of nitrogen, phosphorus, potassium, zinc and copper in comparison to control pots where no humic acid source was used. The highest N content of maize plants was recorded in T9 followed by T10. The P concentration was higher in plants of pots with levels T7, T8 and T10, there was no significant difference among these treatments. The highest K content was in T9 where HAPS were applied along with Zn and Cu. The Zn and Cu concentration of plant also significantly increased (Table 2). The results of our experiment have shown that humic acid have positive significant effect on macro and micronutrient uptake in maize plant. This increased nutrient uptake by plant may be due to the accelerated nutrient cycling reactions caused by humic substances. Numerous studies in previous years, such as those of Canellas et al. (2002), Wang et al. (2022) reported that application of humic acid enhances the soil nutrient availability to plant due to improved soil properties. The results of our study are in accordance with the observations of Fouda (2021) who stated that there was significant increase in nutrient uptake in humic acid treated plants.

As the humic acid improved all agronomic parameters and nutrient uptake of the plant so these ones ultimately positively affected comb yield. Although at all levels of humic acid irrespective of source maize grain production increased but the highest yield was recorded in the treatment 9 (HAPS +NPK+ $CuSO_4$ + $ZnSO_4$) followed by T 7 and 10. The HAPS applied pots gave significantly higher comb yield in compare to other treatments. The HAPS applied pots were harvested with yield increase of 30 to 40% in compare to plots where humic acid was not used and only NPK were applied (T2). The humic acid prepared from peat soil gave 10% higher yield in compare to commercial humic acid at same combination with other nutrients N, P, K, Zn and Cu.

Conclusion

The making of humic acid from the peat soil and results of our experiment on maize crop showed that HAPS is a natural humic substance and demonstrated positive effects on plant growth. These outcomes suggest that the use of humic acid prepared from peat soil can make various scientific and economic advantages for fertilizer industry and growers.

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Conflict of Interest

No competing interests are disclosed by the authors.

Author Contribution

AAS: Conceptualization, preparation of humic acid, chemical analysis, conduct of experiment and writing first draft of MS; MSS: Execution of experiment, data analysis, editing all drafts of MS; MSL: Editing all drafts of MS; ZB & MAS: Literature review, format and style. All authors approve and assume the responsibility of the content of MS.

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