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Potential Use of Sea Water for Pineapple Production in BRIS Soil

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ABSTRACT

An experiment was conducted to determine the response of four sea water treatments on an improved pineapple genotype "N-36" grown in Beach Ridges Interspersed with Swales (BRIS) soil. Sea water treatments were prepared by substitution of K with Na ions i.e., 0% (in control), 15%, 30% and 60% of required K doses were replaced by Na ions from sea water. Treatment effects were non-significant up to 30% sodium replacement from sea water. Na replacement (60%) showed significant impact on different growth parameters at different stages (8-10 months after planting). However, the fruit yield, the final target of crop harvest was not adversely affected at significance level. Therefore, sea water irrigation can easily fulfil 60% dose of potassium fertilizer by sodium ions for the production of pineapple in BRIS soil.

Key Words: BRIS soil; Pineapple; Sea water; Irrigation; Sodium; Potassium

INTRODUCTION

Water body covers about 71% of the earth surface. In spite of its magnitude, irrigation water is a resource of crucial consideration in agricultural production. The BRIS (Beach Ridges Interspersed with Swales) soils are the sandy marine deposits, which mainly developed along with a narrow belt ranging from 3 to 12 km fringing the east coast of Peninsular Malaysia. The estimated total area of BRIS soils in Peninsular Malaysia is about 162,000 hectares and accounts for 1.23% of the total land area (Zahari *et al.*, 1982). Most of the crops planted on BRIS soil did not perform well partly because of the high surface soil temperature, low water holding capacity, low organic content, high infiltration rate and low nutrients availability. Introduction of crops that can be productive on BRIS soil seems to be one of the possible solutions to this long known problem of the BRIS area. Pineapple is ideal plant for such type of soil. BRIS soil provides a well-aerated, deep rooting zone, which is suitable for improved pineapple growth and production under optimal management of irrigation and nutrients (Ashok *et al.*, 2002).

Scarcity of fresh water for irrigation is also a constraint for agriculture in this soil area. Moreover, crops in this region demand a comparatively higher amount of irrigation because of very low water retention capacity of soil. Therefore, using saline water in irrigated agriculture would be an interesting option (Karlberg *et al.*, 2004) in the BRIS area. Seawater can be used as one of the alternative nutrient resource for halophyte crops, which contains high concentration (4665 & 225 mgL^{-1}) of Sodium (Na^+) and Potassium (K^+), respectively. Halophyte is salt tolerant crops ("salt plants"- grow at high salt concentration) (Yufdy, 2004).

Pineapple requires high amount of potassium fertilizer application, which is a costly item in total production system. It might also need some amount of Na cation, which can replace part of K ions (Joomwong, 2006). The requirement of Na for this species is very small. To avoid the salt accumulation in the wetting front Na application would be more fruitful with irrigation water rather than the topdressing as granular fertilizer. However, a little information is available in this aspect. Therefore, a research was undertaken with the objectives to evaluate the suitability of sea water as a partial fulfilment of fresh water irrigation and to determine the effect of sodium, as a replacement of potassium, on pineapple in BRIS soil.

MATERIALS AND METHODS

The experiment was conducted at the field of Department of Agriculture Commodities Center, Rhu Tapai,

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Terengganu in the coast of the South China Sea, where the area is dominated by BRIS soil. An improved genotype 'N-36' of pineapple (*Ananas comosus*), popularly grown in the farmers' field of Malaysia, was selected for the research. Ground suckers with an average length of 30 cm having 20 leaves were planted on the 20th March, 2004. A population of 62,117 plants per hectare was maintained with a double-row planting system of 76.2 cm×55.9 cm×24.4 cm. The unit plot size was 12.2 m×24.4 m. The number of plants per plot was 1800. Pineapple field was covered with black silk sunshine type plastic mulch.

Calculation was made to determine the amount of seawater requirements to replace the potassium (K) with sodium (Na) and it was found that 0, 2.32, 4.65 and 9.31 L seawater per day per block was required to substitute 0, 15, 30 and 60% of K, respectively. For a safe preparation and to avoid any precipitation of fertilizers, calculated seawater for each block/treatment was increased to a same amount (9.31 L) by adding irrigation water. Then, the amount of calculated fertilizers for each block was dissolved in that solution, separately. A recommended and calculated amount of dry fertilizers were added slowly into the seawater solution one by one. The amount of exploitable stock solution was prepared to use for two weeks time. Water was pumped through a PVC pipe of 50 mm diameter with a valve on the main line to control the operation pressure. Two grooved disc filter were fitted before and after pump to remove suspended materials from the water entering the irrigation line. Desired levels of fertilizer concentrations or fertilizers dissolved with seawater solution were injected by injector from a concentrate stock solution tank through a micro tube connected to the main line and then to sub-main line to the lateral lines.

The injection rate was proportional to the irrigation water e.g., one-liter fertilizers/seawater solution to 1000 liters of irrigation water through a drip fertigation system. Three rates of 15, 30 and 60% of Na in seawater to substitute K were used. In addition there was a control treatment, where 100% K was supplied from fertilizer and totally free from seawater. Hence, there were four treatments. Treatments of Na for K substitution were assigned based on 300 kg K ha^{-1} (4.82 g/plant) required by the plant. Sodium was given in the form of seawater mixed with irrigation water. The applied seawater was characterized with pH 7.88 and EC 44.40 dS m^{-1} containing Na (4665 mg L^{-1}), K (225 mg L^{-1}), Ca (365 mg L^{-1}) and Mg (1120 mg L^{-1}). The amount of applied fertilizers (except K) and irrigation water was equal for each block. However, the amount of seawater varied according to the percentage of Na substitution for K. Treatments summary is show in the following chart.

Treatment#	K from seawater	K from fertilizer	Total K	Na	Na+K	Na for K substitution
T1	0.00 g	4.82 g	4.82 g	0.00 g	4.82 g	0%
T2	0.04 g	4.06 g	4.10 g	0.72 g	4.82 g	15%
T3	0.08 g	3.29 g	3.37 g	1.45 g	4.82 g	30%
T4	0.16 g	1.76 g	1.92 g	2.90 g	4.82 g	60%

The required fertilizers (N @ 530.7 kg ha^{-1}, P_2O_5 @ 225.5 kg ha^{-1}, KCl @ 198.3 kg ha^{-1}, MgO @ 72.3 kg ha^{-1}, CaO @ 55.0 kg ha^{-1}, Fe @ 26.5 kg ha^{-1} & CuO @ 11.7 kg ha^{-1}) were dissolved with equal volume (9.31 L) of water and applied with irrigation water accordingly. The depth of fertigation water was calculated with CROPWAT model. Fertigation was applied only those days, when rainfall was less than 5.0 mm per day. Fertigation was started on March 20, 2004 and ended on July 20, 2005. Fertigation was applied for a period of 386 days during the pineapple growing period.

Prior to each destructive harvest, each leaf was analyzed using the chlorophyll meter (CM) values, which measured the leaf greenness using a chlorophyll meter (MINOLTA ^{TM} SPAD-502) (Takebe & Yoneyama, 1989). The CM value was recorded from 5 points/leaf. The actual leaf chlorophyll content was determined on the basis of proposed standard curve. Plant height, number of leaf, D-leaf (the longest & youngest leaf) length, D-leaf area, D-leaf dry weight and SPAD values were measured at 2, 4, 6, 8 and 10 month after planting (MAP). Eighteen (18) plants were tagged at random from each treatment for measuring the sequential increase in plant height and number of leaves. The fruits were harvested, when one-third was ripe and this was achieved 147 days after flower induction. Ninety fruits were collected at random from the middle of 18 rows and the average weight was recorded. Length and diameter were recorded with a measuring tape and scale. Fruits were cut longitudinally for the measurement core diameter with a scale.

The data of pineapple plants and fresh fruit harvest were analyzed using SPSS package. The data were analyzed using ANOVA procedure and comparison of means was done using LSD at 5% level of significance.

RESULTS AND DISCUSSION

Plant morphological traits were measured after every two month interval starting from two months after planting and continued until ten months of planting. Recorded data clearly indicated that seawater treatment could not affect the morphological features up to six months of planting. In consequence, data on only two stages (8 & 10 months) are being cited and discussed in this section.

Plant height: The maximum plant height was 75.7 cm for 100% K treatment and the lowest was 67.7 cm for 60% Na for K substitution from seawater after ten months of planting (Table I). The significant reduction in plant height was observed only in T4, where 60% K was replaced by Na from sea water source at later stage of growth (Fig. 1). The results are supported by Marschner (1995), where he reported that that Na for CAM crops like pineapple is not only essential for plant growth, but can also replace part of K's function, moreover it has an additional growth enhancement effect.

Table I: Morphological traits of pineapple at the age of 10 months under various substitution levels of sodium for potassium

Na for K substitution	*Plant height (cm)*	*No. of leaves/plant*	*Greenness of leaf (SPAD value)*
T1 (100% K from fert.)	75.7 a	57.9 a	59.5 a
T2 (85% K + 15% Na)	75.5 a	57.5 a	58.5 a
T3 (70% K + 30% Na)	75.6 a	57.8 a	58.3 a
T4 (40% K + 60% Na)	67.7 b	52.7 b	52.1 b
$LSD_{0.05}$ value	6.11	4.12	5.01

Table II: The D-leaf characters as affected by various substitution levels of sodium for potassium at 10 months age of pineapple plant

Na for K substitution	*Length of D-leaf (cm)*	*D-leaf area (cm²)*	*Dry weight of D-leaf (g)*
T1 (100% K from fert.)	68.8 a	215.5 a	2.81 a
T2 (85% K + 15% Na)	67.6 a	201.3 ab	2.70 a
T3 (70% K + 30% Na)	68.0 a	204.3 ab	2.79 a
T4 (40% K + 60% Na)	62.7 b	181.6 b	2.36 b
$LSD_{0.05}$ value	4.26	14.45	0.32

Table III: Effect of Na substitute for K from seawater on pineapple fruit

Na for K substitution	*Fruit length (cm)*	*Fruit diameter (cm)*	*Fruit weight (g)*
T1 (100% K from fert.)	15.33 a	11.83 a	980.60 a
T2 (85% K + 15% Na)	15.02 a	11.51 a	936.32 a
T3 (70% K + 30% Na)	15.10 a	11.63 a	969.89 a
T4 (40% K + 60% Na)	14.88 a	11.28 b	930.00 a
$LSD_{0.05}$ value	0.66	0.43	109.80

Number of leaves per plant: There was no significant effect of seawater application on the number of leaves per plant up to 0, 15 and 30% substitution of K by Na however, significant effect was observed at 60% K replacement (Table I, Fig. 2). It was also found by other studies (Yufdi, 2004) that increasing Na in the vacuoles replaced part of K function so that the amount of K in the vacuoles was insufficient to carry out other functions resulted in decreasing plant growth, which reflected with number and size of the leaves. The highest number of 57.9 leaves was produced with control treatment and this number was statistically similar to 15 and 30% substitution.

SPAD values: The highest SPAD value was found using of 100% K from KCl, which was not significantly different to the treatment of up to 30% substitution. But, significant effect of seawater was evident on the leaf greenness at 60% substitution (Table I). Results revealed that SPAD value was decreased with increasing percent Na concentration in irrigation water. In the previous experience it was found that chlorophyll concentration in Annona leaves was positively linearly correlated with the SPAD readings (Schaper & Chacko, 1991). The SPAD values were recorded 59.5, 58.5, 58.3 and 52.1 at T1, T2, T3 and T4 treatments, respectively. The decrease of SPAD values in 60% replacement is presented in Fig. 3. SPAD values have been reported to be used extensively to determine leaf colour that varies from

Fig. 1: Effect of Na substitute for K from seawater on plant height

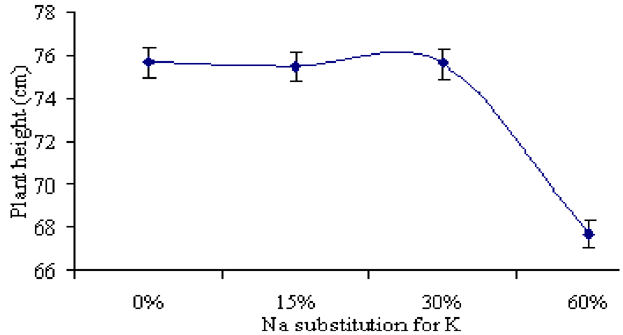


Fig. 2: Effect of Na substitute for K from seawater on number of leaves per plant

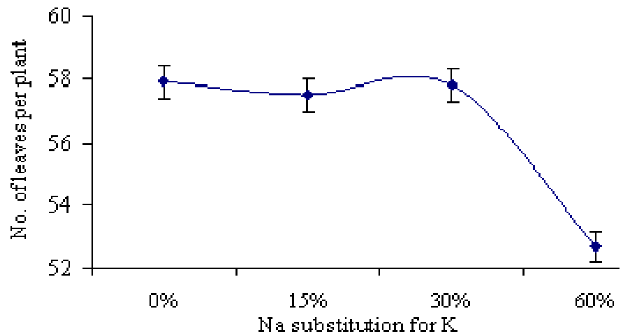
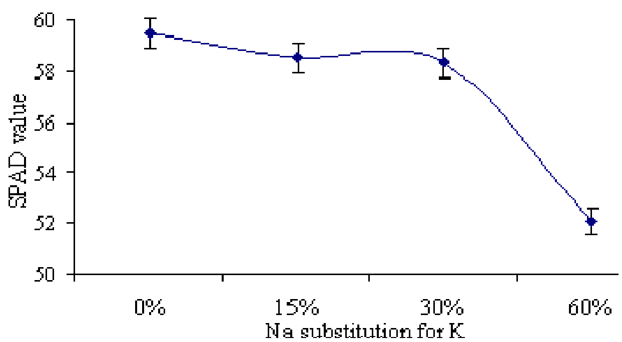


Fig. 3: Effect of Na substitute for K from seawater on pineapple leaf greenness



pale yellow to dark bluish-green, depending on ecological, climatic and nutritional conditions. A reddish-yellow color can appear, accompanied by loss of turgidity if the water supply decreases, particularly when soil water drops or the root system is inadequate (Py *et al.*, 1987).

D-leaf length: The D-leaf can be used as an index leaf for plant growth up to the time of forcing (artificial flower induction) for qualitative studies. The length of D-leaf was influenced significantly by the application of seawater treatments. However, difference in length of D-leaf was observed only after 10 months of planting. The longest leaf (68.8 cm) had been produced with the application of 100% K treatment and comparable lengths were also produced with 15 and 30% K substitution. The overall growth of D-

Fig. 4: Effect of Na substitute for K from seawater on D-leaf length

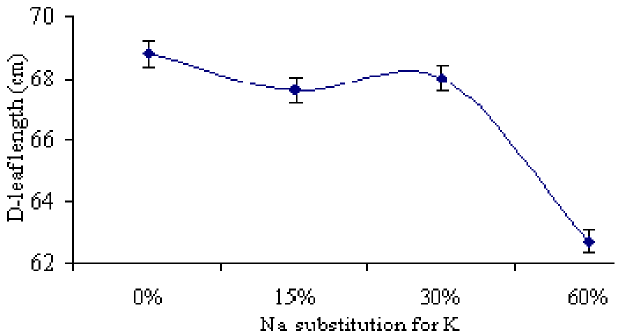


Fig. 5: Effect of Na substitute for K from seawater on D-leaf area

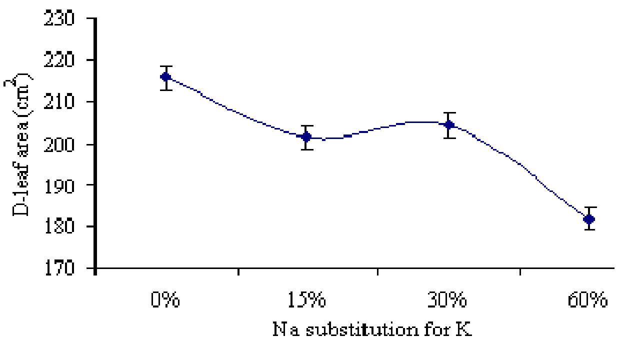
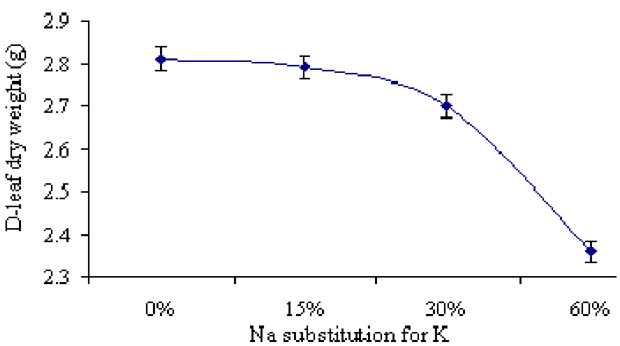


Fig. 6: Effect of Na substitute for K from seawater on D-leaf dry weight



leaves indicated that application of seawater in BRIS soil resulted in the significant reduction in leaf length (Table II). Here it is clear that a too little adverse effect was recorded from sea water application (Fig. 4). In general, the leaf length was in increasing trend with the advancement of plant age. The K uptake in D-leaf was higher than that in the old leaf (Yufdy, 2004) and a low concentration gradient decreased the plant's ability to absorb K. It was reflected by the increase in Na uptake in D-leaf, which has significant effects on plant growth and development.

D-leaf area: There was no significant difference in D-leaf area at 100% K from KCl and 30% Na and 15% Na for K substitution from seawater (Table II). Longest leaf did not always maintained highest leaf area. This might due to the narrowing of the leaves at latter stages of growth. At that time of forcing the plant attains the maximum canopy cover and the interplant competition for space and nutrition is high, which might have forced the plant to expand the leave longitudinally. The highest D-leaf area of 215.46 cm^2 was achieved with 100% K from KCl and the least of 181.6 cm^2 was from substitution of K with Na by 60% from seawater (Fig. 5).

Membranes are the special organs of the plants for regulating the ion content that can control active and passive solute fluxes (Reddy & Lyengar, 1999). Decreasing membrane stability might cause cation leakage from the root of mung bean resulting in decrease of root elongation that affects plant growth and development (Nakamura *et al*., 1990; Rashid *et al*., 2004). The increasing Na uptake in D-leaf may be related to the role of Na as preferential vacuolar osmoticum and in turgor generation that has been observed in certain plant species (Jones, 1981). The small amount of Na uptake is probably useful to partially alleviate the requirement of the stomata for K. Excessive amount of Na may lead to nutritional disorders and the plant becomes susceptible to osmotic and specific-ion injury.

D-leaf dry weight: No significant variation in D-leaf dry weight resulted from seawater treatment up to 30% K substitution by Na from seawater (Table II). Leaf functions both as the source and sink for photoassimilate and higher accumulation of dry matter indicates the ability of the plants to intercept more solar radiation and produce assimilates for the growth and development of the plant. The D-leaf dry matter was recorded 2.81 g for T1; 2.70 g for T2; 2.79 g for T3 and 2.36 g for T4 treatments (Table II). Only the T4 had imposed adverse effect on dry weight (Fig. 6). The D-leaf dry matter increased significantly with the advancement of plant age and was remarkable at every stages of growth.

The highest accumulation of leaf dry matter resulted at ten months after planting in the control treatment. This happened in accordance with the growth of D-leaf length, thickness and water content. There is more than 85% of water content in the pineapple leaves. Water-storage tissues are located in the adaxial part of the leaf consisting of large palisade cells and filled with very watery mucilage (Py *et al.,* 1987). This water is used during starvation of water from these tissues, but quickly regain its original volume, when conditions return to normal condition. High amount of Na in the soil can decrease osmotic potential in the soil causing inhibition of water uptake. These conditions encourage the plant to take up more water causing thicker water storage tissue, which induces succulence. High Na concentration can increase K^+ leakage and decrease root elongation (Nakamura *et al.,* 1990), which affects on D-leaf growth and development. The negative effect of substantial amount of Na in the soil from 60% Na for K substitution treatment resulted in decreasing plant dry weight. Nutritional imbalance might be the reason for this result, which is influenced by nutrient availability, competitive uptake and transport or partitioning within the plant. It may also happen due to physiological inactivation of K resulting in an increase in plant's internal requirement for this essential element.

Fruit size and yield: There was no significant effect of seawater on fruit length of pineapple. Fruit length was not influenced by the application of Na to substitute K from seawater (Table III). The longest fruit of 15.35 cm was recorded with control treatment, but this fruit length was statistically similar to those produced with 15, 30 and 60% substitution. In a field trial, Selamat and Ramlah (1993) did not find any change in fruit length of pineapple 'Gandul' with potassium on peat soil. The highest percentage of Na sorbed was 92.58% obtained for 30% seawater, 67.84 and 54.75% for 40% seawater for Mg and K, respectively (Yufdy, 2004). This also suggested that Na could be sorbed more at 30% seawater compared to the other treatments.

Fruit diameter was influenced significantly with the application of highest dose of seawater. However, there was no significant effect with application of 0, 15, 30% Na to substitute K from seawater (Table III). The largest diameter (11.83 cm) was recorded with 0% Na for K substitution and the smallest diameter (11.28 cm) was resulted from 60% replacement. From the result it was observed that the fruit diameter of pineapple tended to decline with high rate of percent Na in irrigation water. Water supply has more influence on the concentration of free acids (Green, 1963), which is low in the case of water deficit (Py & Tisseau, 1965) and can be increased by irrigation (Combres, 1980). Potassium has a beneficial effect on fruit quality. The fact was that the water supply has such a marked influence on CAM in pineapple and consequently on the metabolism of organic acids may indicate the source of its influence on fruit quality and size (Py *et al.,* 1987).

There was no significant effect of seawater application on the fruit weight of pineapple production in BRIS soil (Table III). The mean fruit weights were 980.60 g (for 0% Na); 936.32 g (for 15% Na); 969.89 g (for 30% Na) and 930.0 g (for 60% Na), respectively. Obviously, there was a declining trend in fruit weight with increased application of percent Na; however, decreasing rate did not touch significant level. An increase in the concentration of one cation species in the nutrient medium may be depressed the uptake of another. The uptake rate depends on the concentration of the individual cation species in the soil solution and also on the uptake mechanism (Kirkby, 1979). A satisfactory supply of water plays also an important role in the filling and the weight of the fruit. In the current experiment, seawater with irrigation water application resulted in no significant adverse effect in fresh fruit weight. There is a possibility to replace Na up to 60% of K requirement on pineapple.

CONCLUSION

Replacement of K doses up to 30% with Na from sea water did influence at all the growth, development or fruit yield of pineapple in BRIS soil environment. Plant height, number of leaves per plant, D-leaf length and area and dry weight, fruit diameter were significantly reduced in case of 60% replacement. However, finally the fruit yield was not trimmed down at significance level. Therefore, sea water irrigation can easily substitute up to 60% dose of potassium fertilizer by sodium ions for the production of pineapple in BRIS soil area.

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