# Growth Performance of Different Cacao Clones at Varying Rates of Sodium Chloride Fertilization

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***Abstract***- The increasing prices of commercial fertilizers lead to the utilization of natural products as source of plant nutrients. Relatively, several researches were conducted on the use of common salt (NaCl) as fertilizer and reported to have different effects on varying crop species. Hence, this study was conducted to 1) compare the growth of different cacao clones in response to varying NaCl rates, 2) assess the effects of NaCl on cacao growth and nutrient uptake and 3) determine the optimum NaCl rate that would hasten the growth of a certain cacao clone. The experiment was arranged in a 2x6 factorial in randomized complete block design (RCBD) with three replications. Cacao clones (BR 25 and UF 18) served as factor A and Factor B was composed of varying $K_2O$:NaCl ratios (control; 100% $K_2O$ + 0% NaCl; 75% $K_2O$ + 25% NaCl; 50% $K_2O$ + 50% NaCl; 75% $K_2O$ + 25% NaCl and 0% $K_2O$ + 100% NaCl). Other nutrients were applied in blanket to all treatment plants except for the control. Results show that BR 25 and UF 18 cacao clones have had comparable stem diameter (SD) and canopy spread (CS) at varying $K_2O$:NaCl ratios. On the other hand, varying $K_2O$:NaCl ratios failed to exhibit increment of SD and CS of two cacao clones. Moreover, no significant interaction effects were observed between clone and $K_2O$:NaCl ratios on cacao SD and CS. Lastly, although D-leaf tissue analysis showed no significant differences in nutrient (N, P, K, Ca, Mg and Na) uptake amongst cacao clone, $K_2O$:NaCl ratios and their treatment combinations, a Na uptake positive regression trend was observed.

***Index Terms***- salt fertilizer, sodium chloride, potassium, cacao growth, Theobroma cacao

## I. Introduction

Cacao (*Theobroma cacao* L.) is a tree crop highly suitable in different cropping systems. Demand for cocoa is expected to grow in coming decade between 2.5%-3.0% or around 100,000 MT's (Philippine Cacao Industry Roadmap, 2017), following growth pattern of worldwide GDP. Hence, local farmers have increased their interest in the cultivation of cacao due to the huge demand in the local and international markets, and with persistently favourable prices.

Cacao is a perennial crop which requires huge amount of nutrient. Like other crops, cacao plants absorb more potassium than any other mineral element except nitrogen. Cost of fertilizer inputs may be a burden to farmers who will venture on cacao production. Thus, alternative fertilizer program that is cheaper and effective would be essential. One of the possible alternatives is to use common salt or sodium chloride (NaCl) as component of the fertilizer program for cacao.

The use of common salt (NaCl) as fertilizer has little importance in crop production as huge amount of sodium (Na) and chlorine (Cl) were reported to be toxic to most crop species and these elements inevitably have an adverse effect on soil fertility. Contrary to these reports, NaCl was utilized as component of the fertilizer program for coconut (Margate and Magat, 1988) and sugar beet crops (Wakeel, 2008). It has been reported (Wakeel, 2008) that Na is more important nutrient than potassium for sugar beet although Na has still not been shown to be essential for most higher plants with a little exception on certain types of C4 plants (Subbarao et al., 2003). Although Na is not essential for many species, application of Na has been found to stimulate the growth of asparagus, barley, broccoli, caraway, carrot, cotton, millet, oat, sugar beet, red beet, and turnip (Harmer and Benne, 1945: Larson and Pierre, 1953; Lehr, 1953; Montasir et al., 1966). Moreover, Margate and Magat (1988) reported that the application of NaCl at 1.76-7.04 kg $tree^{-1}$ $year^{-1}$ in coconut palms resulted to high germination percentage of seednuts, better girth and leaf production of seedlings.

The ever increasing prices of commercial fertilizers especially sources of $K_2O$ give realization to cacao growers to formulate a cheaper and effective fertilizer program. One of the potential alternatives is to use NaCl as fertilizer. Gattward et al (2012) reported that Na can partially replace K in the nutrition of cacao, with significant beneficial effects on photosynthesis, water use efficiency and mineral nutrition of this crop. Hence, this study was conceptualized to 1) compare the growth of different cacao clones in response to varying NaCl rates, 2) assess the effects of NaCl on cacao growth and nutrient uptake and 3) determine the optimum NaCl rate that would hasten the growth of a certain cacao clone.

## MATERIALS AND METHODS

The study was conducted at Central Mindanao University, Musuan. Maramag, Bukidnon from November 2016 to October 2017. The existing one month-old cacao clonal garden under coconut plantation was utilized in this study. Prior to treatment application, soil sampling was done. Composite soil sample (0-30 cm and 31-60 cm depths) was brought to Soil and Plant Analysis Laboratory (SPAL) of Central Mindanao University

(CMU) to determine the nutrients available in the soil. The soil of the experiment area was classified as Adtuyon clay. Soil texture was clay loam based on feel method assessment. Soil pH was slightly acidic for cacao plants. Organic matter, extractable phosphorus (P), extractable Ca and Mg were below critical levels, whereas extractable K was at optimum level (Table 1).

'UF-18' and 'BR-25' cacao clones were provided by the Department of Agriculture-Bureau of Plant Industry in Davao City, Philippines. Three-month old "PBC-123" seedlings (rootstock) was grafted with "UF-18" and "BR-25" scions. The grafted 'UF-18' and 'BR-25' cacao clones with five to seven mature leaves and with uniform height were utilized as the test plants. Transplanting of cacao seedlings was done on November 2017. Each cacao plant was supplied with 100 grams 14-14-14 fertilizer, 50 grams dolomite and 500 grams vermicast through basal application. Prior to treatment application, baseline data of cacao plant growth parameter (stem diameter=7mm, number of leaves=7, number of branches=1.33, number of shoots=2.63, canopy spread= 15 cm) were gathered.

The experiment was laid-out in a 2x6 factorial in randomized complete block design (RCBD) with three replications. Cacao clone (BR-25 and UF-18) served as Factor A, whereas Factor B was composed of varying $K_2O$:NaCl ratios (control; 100% $K_2O$ + 0% NaCl; 75% $K_2O$ + 25% NaCl; 50% $K_2O$ + 50% NaCl; 25% K2O + 75% NaCl and 0% $K_2O$ + 100% NaCl) as shown on Table 2. Other nutrients were supplied based on the fertilizer recommendation of PCARRD (1989) as cited by Magat and Secretaria (2007) as shown on Table 3.

Ammonium sulphate (21-0-0-24S), solophos (0-20-0) and muriate of potash (0-0-60) were used as substitute to complete fertilizer to meet the desired $K_2O$:NaCl ratio without deviation of N and $P_2O_5$ requirements of the crop. The fertilizers were applied by digging four holes (10 cm depth) in the ground parallel to the cacao plant canopy. Each hole was then covered with soil after fertilizer application to prevent nutrient volatilization.

Table 1
*Soil physical and chemical characteristics of the experiment area*

| Soil Depth (cm) | pH | Organic matter (%) | Extractable P (%) | Exchangeable K (%) | Ca (%) | Mg (%) |
|---|---|---|---|---|---|---|
| 0-30 | 5.25 | 2.86 | 0.00027 | 0.0039 | 0.44 | 0.024 |
| 31-60 | 6.51 | 2.76 | 0.00017 | 0.0054 | 0.86 | 0.028 |
| Average | 5.88 | 2.81 | 0.00022 | 0.0046 | 0.65 | 0.026 |
| Critical level | 6.00* | 3.00* | 0.20000** | 2.0000** | 0.50** | 0.450** |

*- Wessel (1985)
**- Ling (1990)

Tip pruning was employed using a pruning shear at 4 months after transplanting (MAT), 7 MAT and 10 MAT. Chupons were removed at early detection. Recommended insecticide was applied as foliar spray at monthly interval to control insect pests. Manual weeding (round weeding and weed slashing) was employed to control weeds.

D-leaf sampling for plant tissue analysis was done at 12.5 MAT. This was done by collecting 18 leaves (3rd leaf from the tip, mature in plants half-shade) per plot based on the recommended guidelines of de Mello Prado and Caione (2012). Collected leaf samples were brought to SPAL at Central Mindanao University for nutrient analysis.

**Data Gathered**

Vital growth parameters of cacao clones measured in this study include stem diameter and canopy spread.

1. Stem diameter was gathered at bimonthly interval starting at four months after transplanting (MAT). This was done by measuring the stem diameter (2.54 cm above the graft union) using a pre-calibrated vernier caliper.
2. Canopy spread was measured using a pre-calibrated measuring stick. This growth parameter was taken at 12.5 MAT.
3. D-leaf nutrient (N, P, K, Ca, Mg, Na) uptake was determined through plant tissue laboratory analysis conducted by SPAL staff at Central Mindanao University.

**Statistical Analysis**

Data were analyzed using the MStatC software 1998 version.

Table 2
*Treatments of the study*

| Cacao clone (Factor A) | $K_2O$:NaCl rates (Factor B) | | |
|---|---|---|---|
| | $K_2O$ (%) | NaCl (%) | Other nutrients (%) |
| BR 25 | 0 | 0 | 0 |
| | 100 | 0 | 100 |
| | 75 | 25 | 100 |
| | 50 | 50 | 100 |

| | | | |
|---|---|---|---|
| | 25 | 75 | 100 |
| | 0 | 100 | 100 |
| UF 18 | 0 | 0 | 0 |
| | 100 | 0 | 100 |
| | 75 | 25 | 100 |
| | 50 | 50 | 100 |
| | 25 | 75 | 100 |
| | 0 | 100 | 100 |

Table 3
*Fertilizer recommendation for juvenile cacao plants (PCARRD, 1989 as cited by Magat and Secretaria, 2007)*

| MONTHS AFTER TRANSPLANTING | AMOUNT OF 14-14-14 FERTILIZER | |
|---|---|---|
| | *kg $ha^{-1}$ | grams $tree^{-1}$ |
| 1 | 50.80 | 46.0 |
| 4 | 67.43 | 60.7 |
| 8 | 67.43 | 60.7 |
| 12 | 101.57 | 91.4 |

*amount is based on 1,111 plants $ha^{-1}$

## II. RESULTS AND DISCUSSION

**Stem Diameter**

Stem diameter of cacao regardless of clone was similar in response to varying $K_2O$:NaCl (Figure 1) ratios across different ages after transplanting. Both BR 25 and UF 18 clones have comparable stem diameter although BR 25 tend to be wider at latter growth stages. Moreover, cacao clones applied with varying rates of $K_2O$:NaCl ratios have had comparable stem diameter to cacao clones with no $K_2O$ and NaCl (Figure 2) application. Furthermore, the interaction of cacao clones and the varying levels of $K_2O$:NaCl ratios have had no significant influenced on the stem diameter of cacao plants at varying growth stages (Figure 3). Results indicate that the stem diameter of young BR 25 and UF 18 cacao clones in the field is not affected by the application of varying $K_2O$:NaCl ratios employed in this study. NaCl at the rate of 40.21 kg $ha^{-1}$ in four split applications to newly established cacao plantation have no negative effects on stem diameter. In the Philippines, NaCl is utilized as component of fertilizer program in coconut plantations (Margate and Magat, 1988) of which cacao is being planted as intercrop. In fact, Gattward et al (2012) reported that Na can partially replace K in the nutrition of cacao, with significant beneficial effects on photosynthesis, water use efficiency and mineral nutrition of this crop. However, in this study the effects of NaCl on the stem diameter of one year old cacao seedlings was not displayed.

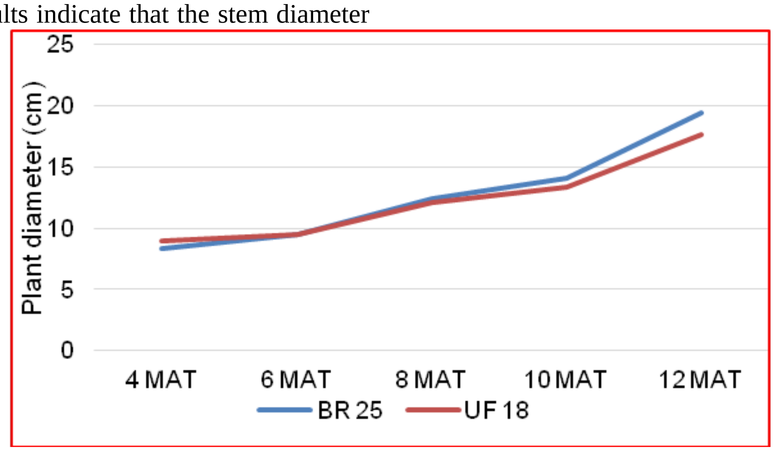


***Figure 1*. Stem diameter of two cacao clones in response to varying $K_2O$:NaCl ratios**

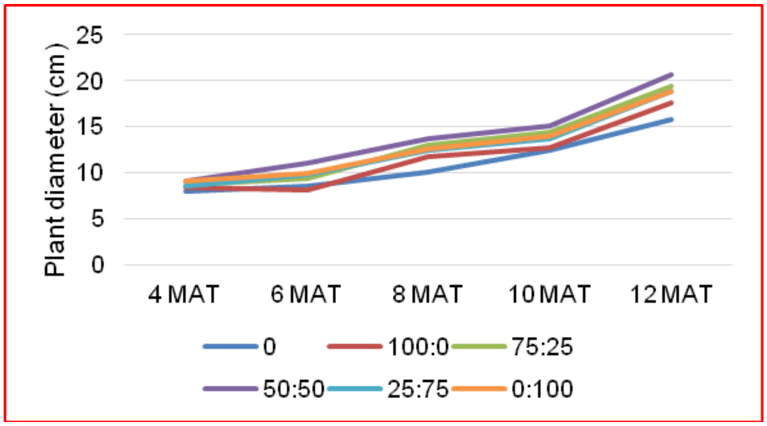


***Figure 2*. Effects of $K_2O$:NaCl ratio on the stem diameter of cacao**

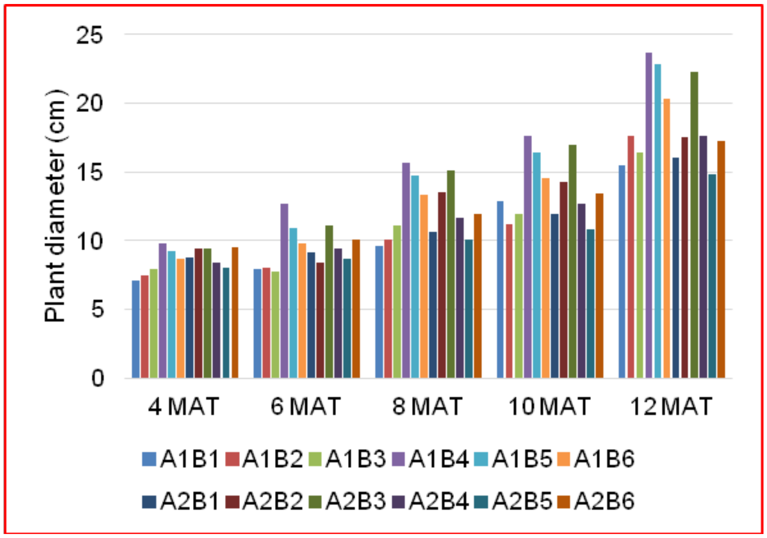


***Figure 3*. Effects of the different treatment combinations on the stem diameter of cacao**

## Canopy Spread

The data on canopy spread of two cacao clones subjected to varying $K_2O$:NaCl ratios are shown in figures 4, 5, and 6. Canopy spread of BR 25 and UF 18 cones were statistically comparable (Figure 4). However, it was noted that numerically BR 25 cacao clone have wider canopy spread compared to UF 18. Moreover, the varying levels of $K_2O$:NaCl ratios have no effects on the canopy spread of BR 25 and UF 18 cacao clones (Figure 5). However it was noted that numerically the application of 50:50 $K_2O$:NaCl ratio resulted to plants with wider canopy spread compared to different $K_2O$:NaCl ratios. Further, in terms of numerical value, no application of $K_2O$ and NaCl produced the narrowest cacao canopy spread. Furthermore, interaction of clones and varying ratios of $K_2O$ and NaCl have no significant influence on the canopy spread (Figure 6) of cacao.

## D-Leaf Nutrient Uptake

All treatment plants have had comparable nutrient uptake as revealed by the D-leaf tissue analysis (Table 3). N and P surpassed the critical levels, whereas K, Ca and Mg were below the critical levels. In terms of Na uptake, UF 18 had higher accumulated Na than BR 25 cacao clone although not significant. It was observed further that there is an increasing Na accumulation of cacao plant as higher rate of NaCl was applied in UF 18 cacao clone. On the other hand, Na was absent in BR 25 cacao clone in all ratios of $K_2O$ and NaCl.

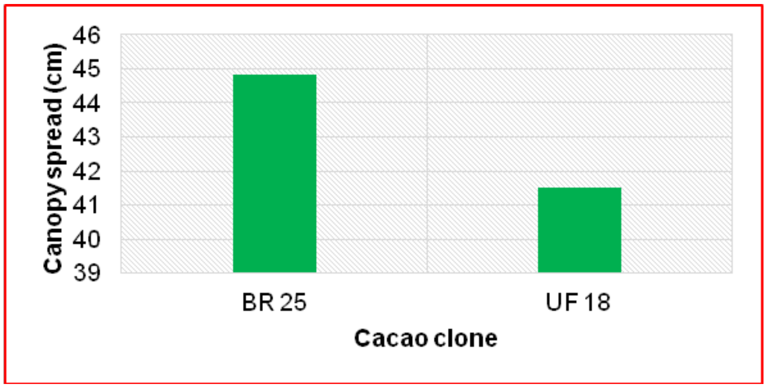


*Figure 4*. Canopy spread of two cacao clones in response to varying $K_2O$:NaCl ratio

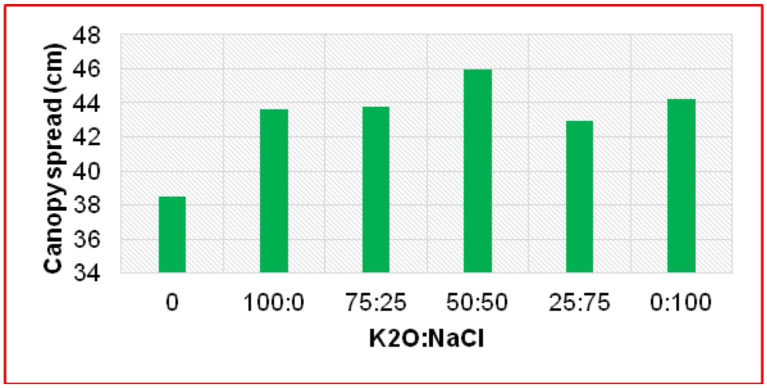


***Figure 5*. Effect of $K_2O$:NaCl ratio on the canopy spread of cacao**

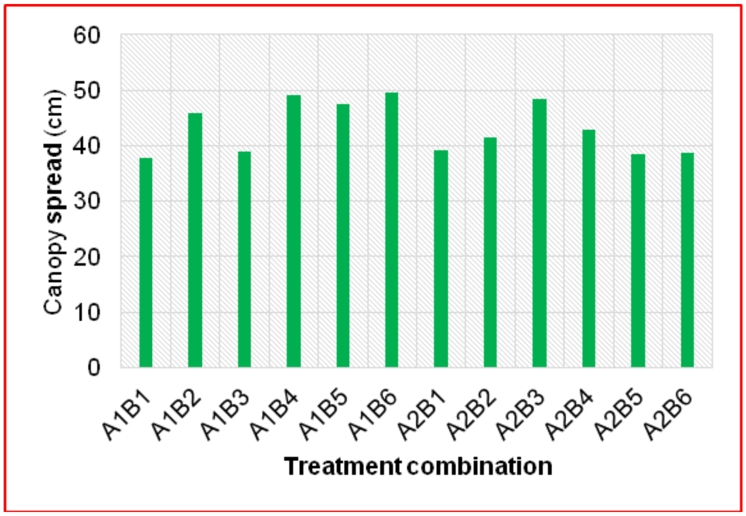


***Figure 6*. Effects of the different treatment combinations on the canopy spread of cacao**

The result indicates that BR 25 cacao clone inevitably has more exclusion property to Na. Further, this result shows that different cacao clones could have different response to Na application.

**Table 3**

***D-leaf nutrient accumulation of one year old cacao plants. UF 18 $R^2$ value for Na=0.5689***

| TREATMENT | Nutrient (%) | | | | | |
|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | Na |
| Cacao clone (A) | | | | | | |
| BR 25 (A1) | 2.33 | 0.68 | 1.02 | 0.40 | 0.40 | 0.0000 |
| UF 18 (A2) | 2.20 | 0.60 | 1.01 | 0.34 | 0.37 | 0.0142 |
| Significance | ns | ns | ns | ns | ns | ns |
| $K_2O$:NaCl (B) | | | | | | |
| 0 (B1) | 2.41 | 0.61 | 1.14 | 0.38 | 0.37 | 0.0000 |
| 100:0 (B2) | 2.30 | 0.52 | 0.93 | 0.39 | 0.41 | 0.0000 |
| 75:25 (B3) | 2.00 | 0.83 | 1.16 | 0.31 | 0.34 | 0.0008 |
| 50:50 (B4) | 2.40 | 0.59 | 1.01 | 0.34 | 0.39 | 0.0023 |
| 25:75 (B5) | 2.26 | 0.53 | 0.95 | 0.38 | 0.40 | 0.0056 |
| 0:100 (B6) | 2.22 | 0.63 | 0.92 | 0.42 | 0.42 | 0.0341 |
| Significance | ns | ns | ns | ns | ns | ns |
| A x B | | | | | | |
| A1B1 | 2.37 | 0.74 | 1.28 | 0.36 | 0.33 | 0.0000 |
| A1B2 | 2.31 | 0.45 | 0.79 | 0.49 | 0.45 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| A1B3 | 2.15 | 1.05 | 1.11 | 0.34 | 0.36 | 0.0000 |
| A1B4 | 2.51 | 0.61 | 1.08 | 0.35 | 0.41 | 0.0000 |
| A1B5 | 2.40 | 0.55 | 0.85 | 0.38 | 0.46 | 0.0000 |
| A1B6 | 2.24 | 0.66 | 1.03 | 0.48 | 0.42 | 0.0000 |
| A2B1 | 2.45 | 0.48 | 0.99 | 0.40 | 0.40 | 0.0000 |
| A2B2 | 2.28 | 0.59 | 1.08 | 0.29 | 0.38 | 0.0000 |
| A2B3 | 1.84 | 0.61 | 1.22 | 0.28 | 0.32 | 0.0016 |
| A2B4 | 2.28 | 0.56 | 0.93 | 0.33 | 0.37 | 0.0046 |
| A2B5 | 2.13 | 0.50 | 1.05 | 0.38 | 0.36 | 0.0112 |
| A2B6 | 2.21 | 0.60 | 0.82 | 0.36 | 0.41 | 0.0681 |
| Significance | ns | ns | ns | ns | ns | ns |
| Critical level[1/] | 2.00 | 0.20 | 2.00 | 0.50 | 0.45 | NA |
| CV (%) | 5.96 | 16.33 | 39.36 | 90.95 | 9.67 | 18.42 |

ns- not significantly different at 0.05 level of DMRT
[1/]- Prado and Caione (2012)

## III. CONCLUSION AND RECOMMENDATION

Although there were trends observed in this study on the growth of BR 25 and UF 18 cacao clones at varying $K_2O$ and NaCl ratios, results are found not significant and thus inconclusive. Hence, further study would be essential. Flowering and pod development of BR 25 and UF 18 cacao clones at varying $K_2O$:NaCl ratios is also recommended to be monitored.

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