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Water Application Rate Effect on Growth Performance of Hybrid Cocoa Seedlings in the Semi-deciduous Forest Zone of Ghana

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ABSTRACT: An experiment was conducted to determine the effectiveness of different watering application rates on leaf minerals and physical growth parameters of cocoa seedlings in the nursery. The treatments were arranged in a completely randomized design (CRD) with three replications. Results showed that watering regime I (0.06 l/pot) recorded low values in both macronutrients and micronutrients and also in physical growth parameters as compared to watering regimes II (0.18 l/pot) and watering regime III (0.36 l/pot) and were below the recommended values. The study showed that water application rate, watering regimes II (0.18 l/pot) and watering regime III (0.36 l/pot) were the most effective treatments in improving cocoa seedlings height, leaf area, plant stem girth, leaf number and tap - root length than watering regime I (0.06 l/pot). The study also revealed that application of 0.18 l/pot and 0.36 l/pot on hybrid cocoa seedlings gave a higher calcium, magnesium, potassium, phosphorous, nitrogen, iron, zinc, copper, manganese concentration in the leaves than the water application rate of 0.06 l/pot. The study indicating that hybrid cocoa seedlings required between 0.18 l/pot and 0.36 l/pot in the first five months in the nursery in semi-deciduous forest zone of Ghana in the absence of rain.

INDEX TERMS: Nursery, Watering regime, Growth parameters, Macronutrients, Cocoa seedlings, Application rate and Micronutrients.

1. INTRODUCTION

Cocoa (*Theobroma cacao L.)* is a major cash crop in many tropical countries and is produced within 10^{o}N and 10^{o}S of the equator where the climate is suitable for its growth. West Africa has been the center of cocoa cultivation for many decades, as two-thirds of the world's cocoa is produced in West Africa compared to the mere 17 %, Africa's share of the total world cocoa production in 1900 (Duguma *et al.*, 2001).

Currently, the six main world cocoa producers are Ivory Coast, Ghana, Indonesia, Nigeria, Brazil, and Cameroon in descending order. Ivory Coast is the largest cocoa producer with a 95 % increase in output over the 1980s and now holds more than 40 % of the world market. In Ghana, cocoa export accounts for about 60 % of the country's foreign earnings (ICCO, 2007). The most significant contribution to the rise in global output is expected from Africa where production is forecast to rise by about 9 %, followed by the Americas, whereas production in the Asia and Oceania is likely to remain static. Africa remains the major cocoa-producing region, accounting for 70 % of world cocoa production in 2002 and 2003, followed by Asia and Oceania (18 %) and the Americas (12 %) according to ICCO (2007). Compared to other agricultural activities, cocoa has been leading the subsector in the economic growth and development of several West African countries (*Duguma et al.*, 2001). Yields in 2001 were about 540 kg /ha in the Ivory Coast and between 230 and 280 kg /ha in Ghana (Hartemink, 2005). A considerable part of the cocoa in the world is produced by smallholders, and the International Cocoa Organization (ICCO) estimates that approximately 14 million people are directly involved in cocoa production. It is estimated that over 95 % of cocoa in Ghana are produced by smallholder cocoa farms (ICCO, 2007) and about 42 % of these cocoa farms are old and less productive (Asare, 2008).

Presently the establishment and rehabilitation of smallholder cocoa farms, aimed at replacing over 42 % ageing and non productive cocoa stock in the field is limited by scarcity of healthy hybrid cocoa seedlings and pods. Efforts to increase hybrid cocoa seedlings by smallholder cocoa farmers and seed production unit for planting and or replanting through the raising of hybrid cocoa seedlings in the nursery is associated with poor growth as a result of inadequate water application rate. Therefore it is necessary to investigate suitable water application rate required to raise vigorous hybrid cocoa seedlings in the nursery to replace the old and non-productive stock in the field for optimum and quality production of cocoa in Ghana.

2. MATERIALS AND METHODS

Study Area

Field experiments were conducted concurrently in November 2010 and repeated in February 2011 at Buako cocoa station (latitudes 6' 00" and 630"North and longitudes 2'15" and 2'45"West) in the rainforest zone of Ghana. The annual average precipitation in the area is 1400 mm with two maximum in July and September and a dry spell in August with an average monthly maximum temperature in the hottest months (Feb - March) of 31 - 33^{o}C and minimum in the coldest months (Dec - Jan) between 19^{o}C and 21^{o}C.

Experimental Setup

Plots were arranged and separated from each other by 1.5 m. In all, 9 plots containing eight hundred and ten hybrid cocoa seedlings planted in 11.5 cm x 18 cm and 15 cm x 20 cm poly bags with three different watering application rates (watering regimes) (0.06 l/pot, 0.18 l/pot and 0.36 l/pot) arranged in a completely randomized design (CRD) with three replications. Application of 0.06 l/pot used was the application rate currently being used by farmers while 0.18 l/pot are crop water requirement of cocoa seedlings suggested by Ogunrinde (2006) and Asare (2008). The application of 0.36 l/pot was the trial water application rate used for this experiment. Hybrid cocoa clones from Buako seed garden were planted. Planting was done on 6th December 2010 and 28th February 2011 for the first and second experiments respectively.

2.1 Crop water requirement and Water application

Crop water requirement of cocoa seedlings (liters /day) was determined using equation (1) below

$$CWR = \frac{f\ X\ E\ X\ A}{d}$$

(1)

Where:

f = Water loss factor (1.3)

E = Monthly Evapo-transpiration (m)

A= Area of pot/bags (m^2)

d = Number of days in months (Ogunrinde, 2006)

The Monthly Evapo-traspiration was estimated as 0.2 m in the area.

Asare and David (2010) suggested that cocoa seedling required 0.18 liter/seedling a day if there is no rain which is equivalent to the crop water requirement of cocoa seedlings (litres /day) suggested earlier by Ogunrinde in 2006.

The watering application was done every day (except rainy days) in the morning (7:00 am) with 0.06 l/pot for watering regime I and 0.18 l/pot for both watering regime II and III. In the evening (5:00 pm) 0.18 l/pot again for watering regime III only for the entire experimental period (20 weeks) using 13.5 liter watering can. Each 13.5 liter watering can full of water was used to water seventy-five hybrid cocoa seedlings on watering regime II only in the morning and watering regime III in both morning and evening while the same watering can full of water was used to water hundred and fifty hybrid seedlings under watering regime I only in the morning . A 6.5 m tall bamboo shed was provided to prevent excessive evapo-transpiration and scorching by sun.

2.2 Physical growth parameters

Growth parameters such as plant height, leaf area, number of leaves and stem girth were recorded from one month after planting (MAP) and continued to measure every two weeks until 20 weeks after planting. Six cocoa seedling plants were selected at random from each plot and tagged for growth measurements. Plant height and leaf area were measured using a measuring ruler. The plant height was taken from the soil surface to the apical tip of the plant. The leaf length and breadth were measured. The leaf area was estimated by multiplying the product of length and maximum width by 1.396 cocoa leaf calibration factor (Amanpongni, 2011). The plant stem girths were measured by put string around the stem and the length of the string then measured using measuring tape. At 3 MAP, root lengths were taken until at 5MAP in the nursery. This was done by carefully uprooting the seedling and put string along the tap root and then measured.

2.3 Soil and plant leaf analysis

Initial soil samples for the experiment were analyzed for N, P, K and Organic carbon. At 5 MAP leafsamples from various treatments were taken, dried at 60 ^{O}C for 48 hours and analyzed for N, P, K, Ca and Mg and micronutrients at Soil Research Institute (SRI), Kwadaso - Kumasi.

2.4 Data analysis

All data were subjected to statistical analysis using Statistical Package for Social Science (SPSS)

The treatments' means were separated and compared using Duncan Multiple Range Test (DMRT) and Least Significant Difference (LSD) both at 5 % level (Steel *et al.*,1997)

3.0 RESULTS AND DISCUSSION

Leaf Macronutrients Composition of Hybrid Cocoa Seedlings

Table 1: Effects of watering regimes on the macronutrients composition (%) of hybrid cocoa seedlings at 5 MAP

	Experiment I					Experiment II				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Watering regime I	2.1 c	0.1 c	0.6 c	0.1 b	0.4 c	2.4 b	0.2 b	0.8 b	0.2 b	0.4 b
Watering regime II	3.4 a	0.2 b	1.1 a	0.3 a	0.8 a	4.3 a	0.3 a	1.3 a	0.3 a	0.9 a
Watering regime III	3.1 b	0.3 a	0.9 b	0.3 a	0.7a	3.8 a	0.3 a	1.2 a	0.3 a	0.7 a
LSD(0.05)	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1

Treatment means having the same letters along the column are not significantly different from each other at 5 % level

Nitrogen content of cocoa leaves planted under watering regime II in both experiments had the highest average values of 3.4 % and 4.3% whiles watering regime I obtained the lowest average values of 2.0 % and 2.4 % in both experiments. The values obtained in watering regime II and III were higher than the deficiency level of 1.8 % (Paramananthan, 2006) which might have facilitated the green pigment of seedlings which is the primary absorber of light energy responsible for photosynthesis, helps in stimulation of rapid and vigorous vegetative growth, increasing seedlings height, leaf area and dark green color of seedling leaves (Ogunrinde, 2006)**.** These observations also confirm early study by Agbeniyi *et al* (2010) that high nitrogen concentration found in the leaves of hybrid cocoa seedlings stimulate rapid vegetative growth and give a bigger leaf area.

Watering regime III recorded the highest mean phosphorous concentration of 0.3 % in two experiments. Phosphorous concentration in cocoa leaves of watering regime II & III was above deficiency level of 0.13 % (Paramananthan, 2006; Aikpokpodion, 2010) which is essential for root development, flowering, pod formation and strengthen the stem girth of cocoa plant thereby preventing lodging during transplanting on the field (Ling, 1990). These observations also confirm early study by Ogunlade &Aikpokpodion (2006) that the phosphorous concentration in the leaf at specific growth stage is related to the performance of crop.

Watering regime II in both experiments recorded the highest potassium concentration of 1.1 % and 1.2 % for experiments I and II respectively which strengthens the stem girth of seedlings thereby aiding the plants to resist fungal and bacterial attacks as well as to resist lodging whiles watering regime I had least values of

metabolism, carbohydrate formation and translocation of starch to all parts of the seedlings (Teoh, 1980).

Magnesium content of cocoa leaves under watering regime II had highest values of 0.8 % and 0.9 % in experiments I and II respectively. Watering regime I resulted in the lowest content of 0.4 % and 0.5 %. The magnesium content of watering regimes

3.1 Leaf Micronutrients Composition of Hybrid Cocoa Seedlings

Table 2 presents results of micronutrients composition of leaf of cocoa seedlings

0.5 % and 0.8 % for experiments I and II respectively which may affect plant

II&III was above the critical level of 0.5 % which constitute an essential component of chlorophyll molecule without which photosynthesis cannot take place (Ogunrinde, 2006; Aikpokpodion, 2010). Also low magnesium concentration of seedlings under watering regime I may be responsible for chlorosis along the leaf veins and stunted growth observed in the growing period.

leaves under the influence of different watering application rates

Table 2: Effect of watering regimes on leaf micronutrients (ppm) of hybrid cocoa seedlings at 5MAP

	Experiment I				Experiment II			
	Fe	Cu	Zn	Mn	Fe	Cu	Zn	Mn
Watering regime I	13.3 c	25.0 c	35.3 c	23.0 c	17.6 c	25.0 c	37.6 c	27.3 c
Watering regime II	22.0 b	38.6 b	50.3 b	38.3 b	23.6 b	44.3 a	53.3 b	41.6 b
Watering regime III	89.0 a	48.3 a	71.6 a	49.6 a	91.3 a	46.0 a	74.0 a	54.6 a
LSD (0.05)	2.5	3.8	2.3	4.5	2.1	3.1	1.8	3.6

Treatment means having the same letters along the column are not significantly different from each other at 5 % level.

Watering regime III resulted in the highest iron concentration with values ranging from 89.0 ppm to 91.3 ppm in experiments I and II respectively and found within the normal range of 65.0 - 175.0 ppm for cocoa production (Paramananthan, 2006) responsible for the synthesis of proteins contained in the chloroplasts and also

The copper concentration obtained in all watering regimes in both experiments was

activates a number of respiratory enzymes in the cocoa plant. Watering regime I resulted in the lowest iron concentration in experiment I and II respectively (Table 2) which might have led to the chlorosis of leaves observed among the seedlings planted under watering regime I in the both experiments.

above deficiency level of 4.00 ppm (Paramananthan, 2006). This suggests that all the watering regimes were good for accumulation of copper in the leaves of cocoa seedlings which are associated with chlorophyll formation, as well as with protein and carbohydrate metabolism.

Watering regime II and III resulted in high zinc concentration compared to watering regime I (Table 2). The zinc concentration recorded under all the watering regimes was within the normal range between 30.0 - 65.0 ppm which is responsible for chlorophyll formation, stem elongation, normal root development, activator of cocoa plant enzymes and formation of growth hormones. Watering regime III in experiments I and II resulted in highest manganese concentration values of 54.6 ppm and 49.6 ppm respectively, which were above the critical level of 30.0 ppm which are essential for nitrogen transformations in cocoa plants. High manganese concentration in cocoa leaves increases the availability of magnesium, calcium and phosphorous in plant. High level of manganese concentration is also associated with activation of plant enzymes and formation of chlorophyll. Watering regime I resulted in the lowest manganese concentrations of 23.0 ppm and 27.3 ppm for experiment I and II (Table 2) which could lead to stunted growth, failure in reproduction process and mottled chlorosis of seedling leaves.

3.2 Growth Performance of Hybrid Cocoa Planting Seedlings

Plant height of hybrid cocoa seedlings nursed under all the water application rate (watering regime) gradually increased with time and followed the normal growth curve of tree crops (Figure 1). The results showed that the monthly plant height was influenced by different watering regimes. Both watering regime II (0.18 l/pot) and III (0.36 l/pot) produced vigorous monthly mean plant height higher than watering regime I (0.06 l/pot) in both experiments. However, the heights of cocoa seedlings produced by watering regime II and III in both experiments were found above the optimum value of 35 cm (Shepherd, 1978) and that could be attributed to higher nitrogen concentrations obtained in the two experiments under watering regime II and III.

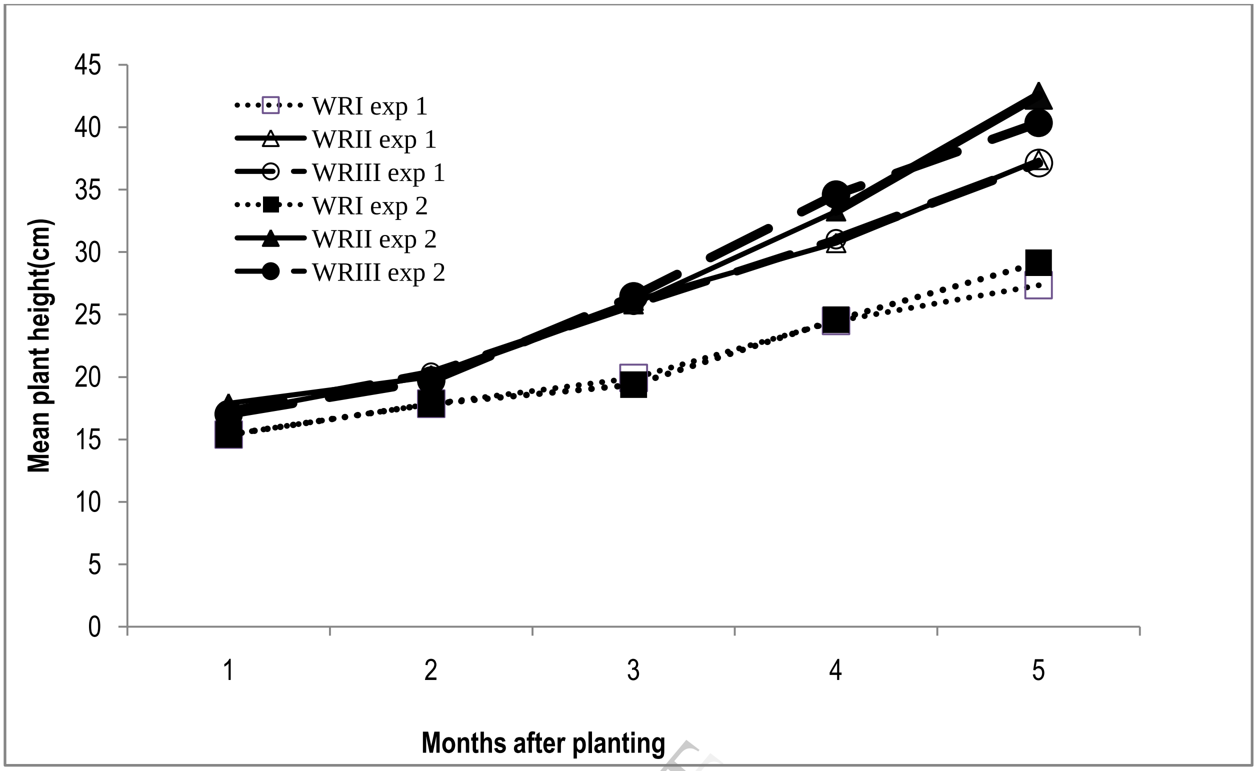

Figure 1: Effects of watering regimes on the height of hybrid cocoa seedling

Plant leaf area of hybrid cocoa seedlings under all the watering regimes steadily increased with time (Figure 2). The results indicated that the monthly plant leaf areas were influenced by all the watering regimes. Hybrid cocoa seedlings planted under watering regime II (0.18 l/pot) and III (0.36 l/pot) produced higher monthly mean leaf area during the study period than watering regime I (0.06 l/pot) in both experiments which could be attributed to high concentration of potassium, phosphorous and magnesium obtained for watering regime II and III in both experiments.

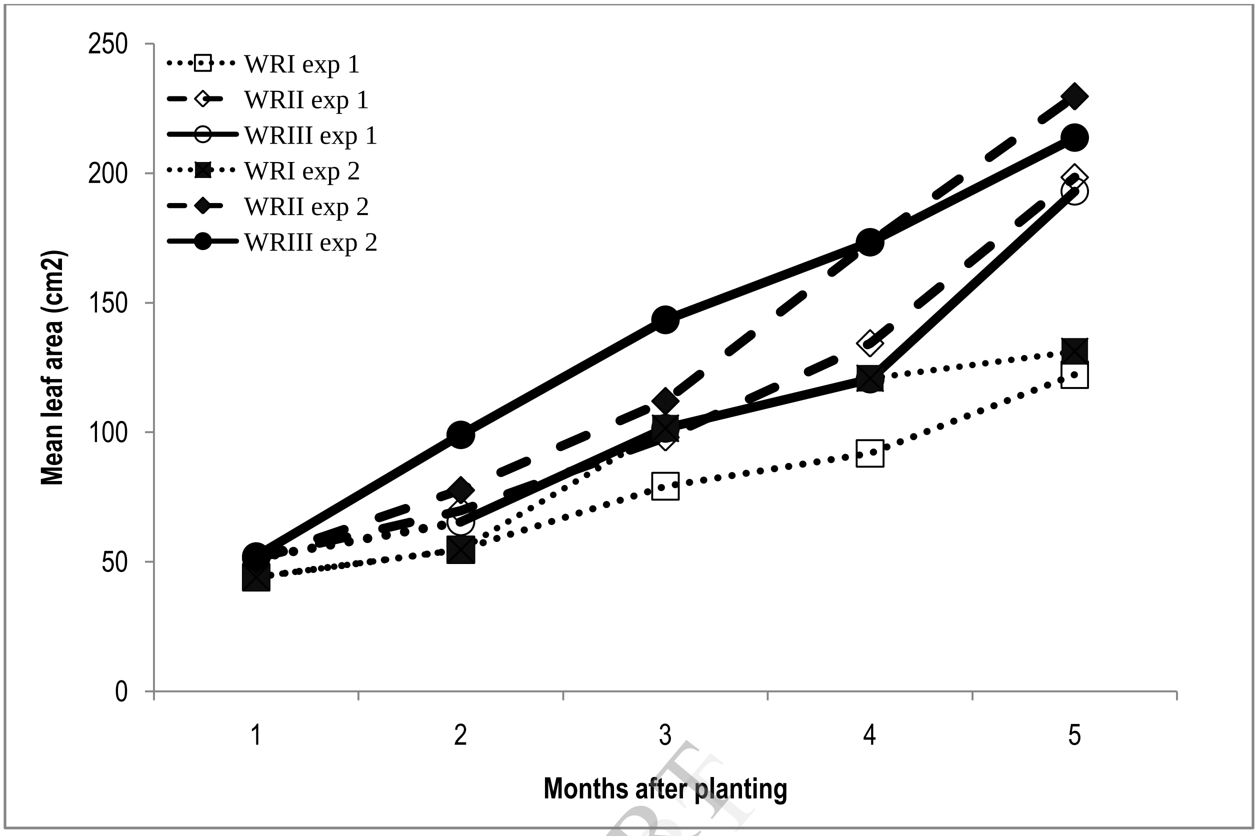

Figure 2: The effects of watering regimes on leaf area of hybrid cocoa seedlings.

Plant stem girth of hybrid cocoa seedlings increased with time under the three watering regimes in the two experiments. The stem girth showed differences among the treatments mean in both experiments, except at 1MAP. The monthly mean stem girths recorded during the growing period under watering regime II and III in both experiments were found to be higher than maximum value of 2.5cm (Shepherd, 1978) and this is attributed to the higher potassium and magnesium concentrations recorded in both experiments under watering regime II and watering regime III. This gives credence to the work done by Agbeniyi *et al* (2010) that increasing the levels of potassium and magnesium concentrations in cocoa leaves tends to produce bigger stem diameter that prevent hybrid cocoa seedlings from logging during transporting of cocoa plant.

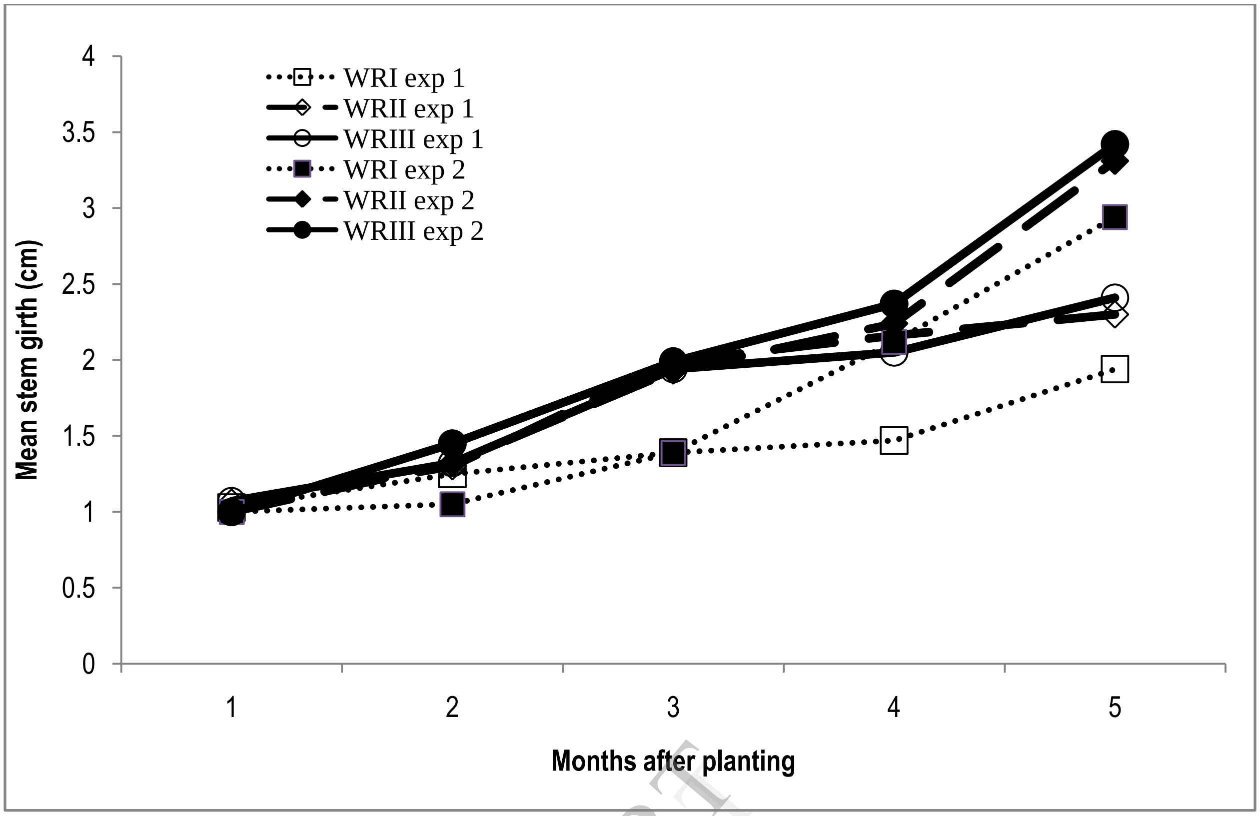

Figure 3: The effect of watering regimes on the plant stems girth of hybrid cocoa seedlings.

The number of hybrid cocoa seedlings leaves planted under all the watering regimes gradually increased with time throughout the entire experimental period as indicated in Figure 3. The results showed that monthly plant leaf number was influenced by watering regimes. Both watering regime II (0.18 l/ pot) and III (0.36 l/ pot) produced monthly mean numbers of leaves which were higher than watering regime I (0.06 l/pot) in the two experiments. An increase in the number of leaves of hybrid cocoa seedlings under the watering regime II and III positively affect the photosynthetic activity of the plant since leaf number is a growth index that could enhance crop yield.

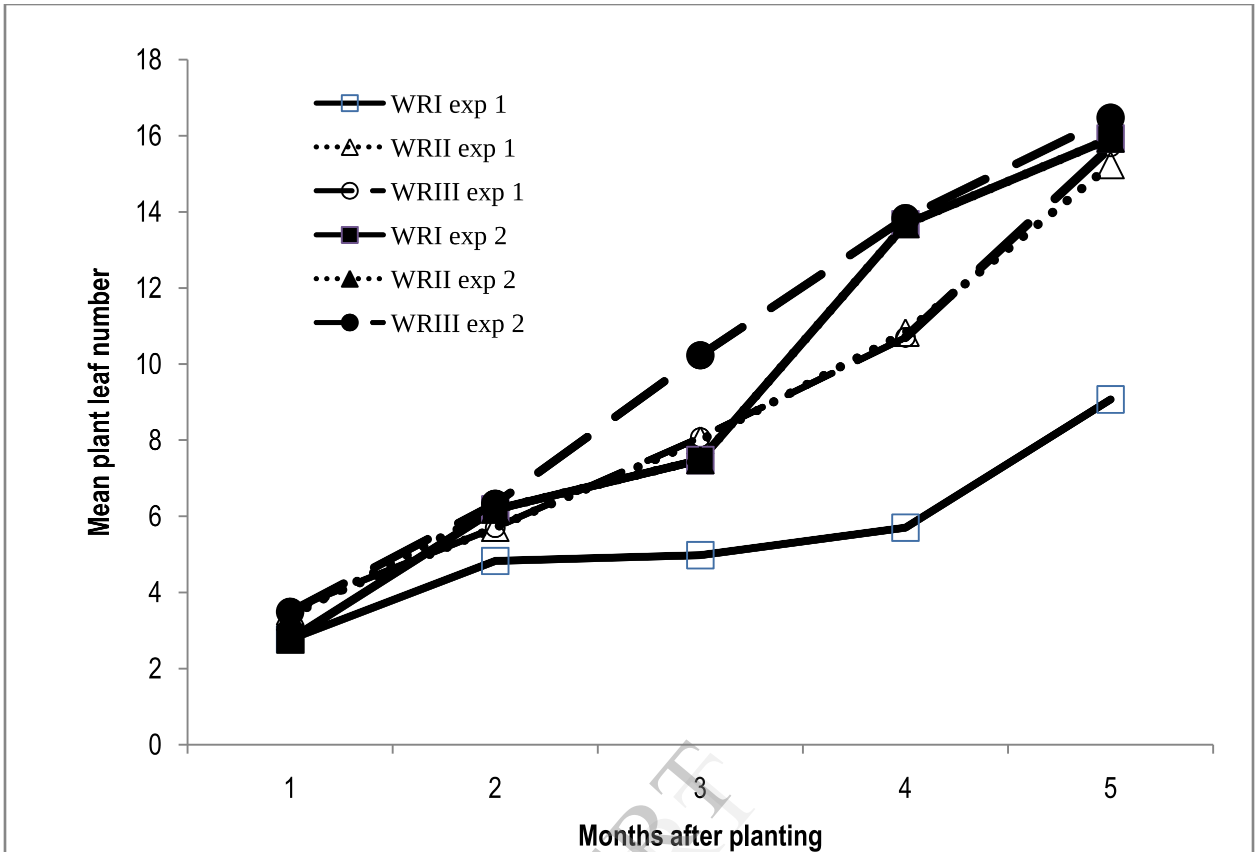

Figure 4: The effect of watering regimes on the leaf number of hybrid cocoa seedlings.

Root length also increased with time for all hybrid cocoa seedlings nursed under watering regime I, II and III. Again, both watering regime II (0.18 l/pot) and III (0.36 l/pot) produced fibrous mean root length higher than watering regime I and that could be attributed to phosphorous and nitrogen concentrations obtained in both experiments under watering regime II and III. It was observed that watering regime I in the first experiment recorded the lowest seedling root length and may be due to the watered efficiency.

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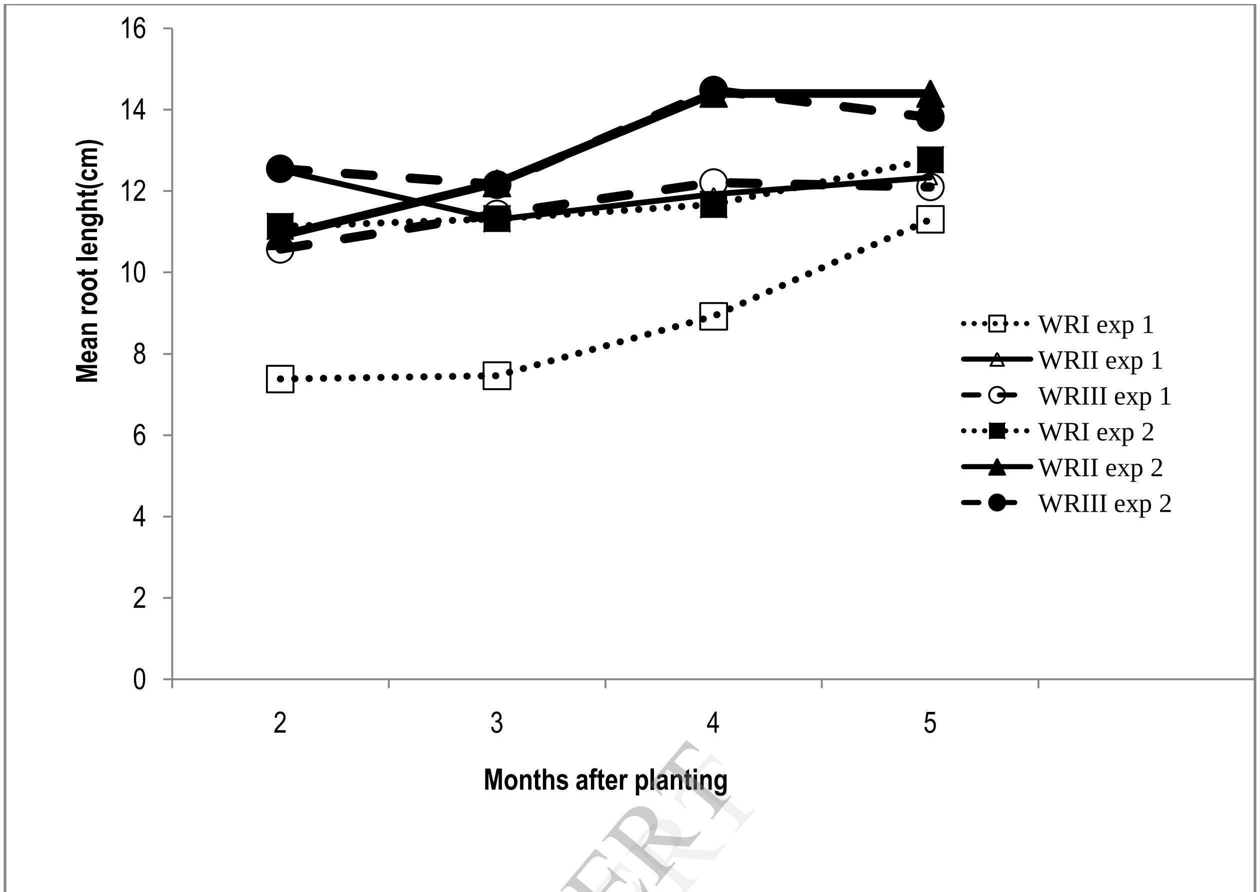

Figure 5: The effect of watering regimes on the plant height of hybrid cocoa seedlings.

4.0 CONCLUSION

It was evident that application of 0.18 l/pot and 0.36 l/pot on hybrid cocoa seedlings significantly gave a higher leaf calcium, magnesium, potassium, phosphorous, nitrogen, iron, zinc, copper, manganese concentration than 0.06 l/pot in field experiments. The study also revealed that application of 0.18 l/pot and 0.36 l/pot on hybrid cocoa planting seedlings produced vigorous seedlings that are taller, larger leaf area, a bigger stem girth, and more number of leaves and longer root length than 0.06 l /pot. It could therefore be inferred that hybrid cocoa seedlings required 0.18 l/pot and more water per day during the first five months in the nursery in semi-deciduous forest zone of Ghana if there is no rain.

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REFERENCES

Agbeniyi SO, Ogunlade MO, and Oluyole KA, 2010. Fertilizer Use and Cocoa Production in Cross River state, Nigeria. ARPN Journal of Agricultural and Biological Science.5 (3):10-13.

Aikpokpodion PE, 2010. Nutrients Dynamics in Cocoa Soils, leafs and beans in Ondo State, Nigeria.

Asare RA, 2008. A Participatory Approach for Tree Diversification in Cocoa Farms: Ghanaian Farmers' Experience. STCP Working Paper Series 9.International Institute of Tropical Agriculture, Accra, Ghana.

Amanpongni A, 2011. An experiment to estimate cocoa leaf index in Ghana, Unpublished Paper

Asare R, David S, 2010. Planting, replanting and tree diversification in cocoa systems. Learning about sustainable cocoa production: a guide for participatory farmer training. Manual No. 2. Development and Environment Series 13-2010. Forest & Landscape Denmark.

Duguma B, Gochowski J, Bakala J, 2001. Smallholder cacao (*Theobroma cacao* L.) cultivation in agro-forestry systems of West and Central Africa: Challenges and Opportunities. *Agrofor Syst*, 51:177–188.

ICCO, 2007. *Assessment of the movements of global supply and demand.* Available at: <http://www.icco.org/statistics/other.aspx>.

Ling AH, 1990. Cocoa nutrition and manuring in Malaysia. In: *Proceedings of MCGC - Malaysian Cocoa Board Workshop on Cocoa Agricultural Research 1989, Kuala Lumpur*. Malaysian Cocoa Growers Council, Kuala Lumpur, pp. 131-142.

Ogunlade MO, and Aikpokpodion PO, 2006. Available Phosphorus and Some Micro-Nutrient Development, Contents of Cocoa Soils in Three Cocoa Growing Ecological.Zones of Nigeria Proceedings of 15th International Cocoa Research Conference 2006. Costa Rica (In press).

Ogunrinde S, 2006. Permanent Crops Production (ACP). National Open University of Nigeria, Nigeria.

Paramananthan S, 2006. Soil management for smallholder cocoa farmers in Vietnam, Ho Chi Minh City, Vietnam.

Shepherd R, 1978. Establishment and maintenance of cocoa seedling nurseries. *Cocoa Growers Bulletin* 25: 11-15.

Teoh CH, 980. Cocoa nursery manuring investigations. The Incorporated Society of Planters: Kuala Lumpur, 21-24 June 1978. p 193-207.