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# THE IMPACT OF IRRIGATION ON THE REPRODUCTIVE GROWTH PARAMETERS OF MANGO IN A COASTAL SAVANNAH AGRO-ECOLOGICAL ZONE OF GHANA

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## ABSTRACT

*Weather patterns, rate of panicle emergence and flowering of mango trees are known to be directly related. The study was conducted to assess the impact of irrigation on the reproductive growth parameters of mango (Mangifera indica, L.) (Variety: Kent) in the coastal savannah belt of Ghana's agro-ecological zones. A randomised complete block design (RCBD) with three replications was used for the study. The water regimes administered were: T1 = 0%, T2 = 50%, T3 = 100% and T4 = 150% of estimated mango water requirement (CRW). On the average, T4 induced the highest response of panicle emergence indicating that prior to panicle formation and emergence, a considerable volume of moisture was required by the mango orchard. T2 and T3 recorded the highest number of malformed panicles with 29 % performance levels indicating that irrigation at those rates does not prevent formation of malformed panicles. T4 out-performed all other treatments in flowering and fruit set. At average fruit weights of 0.59 kg, 0.49 kg, 0.50 kg and 0.52 kg for T1, T2, T3 and T4 respectively, the mean fruit yield per hectare are 8.0 t/ha, 9.2 t/ha, 10.7 t/ha and 11.7 t/ha. The study reports high fruit retentions at the "pigeon-egg" and "golf ball" stages of mango fruit development for both T3 and T4, leading to higher fruit yields in the said scenarios. However, from economic point of view, irrigation treatment T3 (100% of CWR) is recommended to mango farmers.*

***Keywords:*** *Irrigated mango, fruit set, panicle emergence, malformed panicle and mango yield*

## INTRODUCTION

Ghana's mango export level, though steadily increasing is low compared to other producing countries (Zakari, 2012). Some of the reasons for this are that mango production in Ghana is rain-fed and cultivation of the crop is not widespread across various agro-ecological zones (Hatsu, 2006). In particular, mango production areas in Ghana include: Guinea savanna zone (Tolon-Kumbugu, Savelugu-Nanton, and Upper West), Coastal savanna zone (Yilo Krobo, Manya Krobo, Akwapim South, Asuogyaman, Dangme West, North and South Tongu, Ketu) and some parts of the Forest-transitional zone (Hohoe, Kpando, Ho, Techiman, Wenchi, Kintampo, Nkoranza, Atebubu, Ejura-Sekyere-Odumasi, and Sekyere West).

The annual rainfall amounts for these agro-ecological zones are 1000 mm, 800 mm, and 1300 mm for the Guinea savanna zone, Coastal savanna zone and Forest-transitional zone, respectively (FAO, 2005). Unreliable and unpredictable rainfall patterns experienced by these zones could possibly impact negatively on the reproductive parameters; thereby, adversely affecting fruit yield of mango.

The mango crop bears flowers either on its terminal panicles or on those panicles that arise from auxiliary buds. Soil moisture conditions that enhance the viability of these bearing panicles are crucial in promoting high fruit yield. Singh (1977) reports that weather patterns and period of emergence of panicles and/or flowering of mango are directly related. Hence, irrigation of the mango crop in the production areas where prolonged drought, high inter-annual variability and erratic rainfall distributions occur could help boost the yield of mango immensely.

According to Coelho *et al*., (2002) the amount of water required by mango depends on soil properties and climatic conditions within the vicinity of its orchard. This amount of water also differs during the crop's vegetative growth periods (non-productive or juvenile phase) as compared to its reproductive growth phase (i.e. from flowering to maturity). Due to this, mango irrigation system design requires the consideration of factors that are integral to the determination of the tree's water requirements. Such factors include rainfall pattern at the location of the orchard, size and age of the tree, cultivar type, and depth of soil, type of soil and density of plants per unit area (Shantha, 1989).

Two important factors considered when forecasting the yield of mango are type of cultivar and age of the tree. Between 10 and 20 years, a mango tree could yield 200 to 300 fruits annually with the possibility of doubling its yield level (not generally proportional) when the tree becomes twice the age stated above (Morton, 1987). Factors such as cultural practices carried out during cultivation of the tree, soil type, and the climatic conditions also play significant roles in yield determination. How prolific a mango tree becomes, depends heavily on the extent of dryness of the cultivated regions especially during its reproduction period (Griesbach, 2003). Hence, there is need to determine how irrigation technology could be used to improve yield of mango plantations towards making it the "cocoa" of the transition and savannah agro-ecological zones of Ghana. This study, therefore, assessed the impact of irrigation on some selected reproductive parameters (counts of emerged panicles, malformed panicles, flower count, fruit set and yield) of mango in the Coastal savannah agro-ecological zone of Ghana. The objective is to determine the set of water regimes that could be adopted by mango farmers as an alternative measure in place of the current practice of rain-fed mango production.

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## RESEARCH METHODS

The experimental site was the research farm of the Biotechnology and Nuclear Agriculture Research Institute (BNARI) of Ghana Atomic Energy Commission (GAEC), Kwabenya, located on latitude $05^0$ 40N and longitude: $0^0$ 13W. The experimental site is about 76 m above the sea level and lies in the Coastal savanna zone of Ghana which receives between 700 mm and 1000 mm of rainfall annually (FAO, 2005). A micro-electronic meteorological station (µMETOS), installed within a proximity of about 50 m from the experimental site, recorded the mean monthly weather variables (Table 1).

*Table 1.Weather variables recorded at the experimental site during the study period.*

| Months | $T_{max}$ ($^oC$) | $T_{min}$($^oC$) | R.H. $_{average}$ (%) | S $_{radiation}$ ($M.J.m^{-2}.day^{-1}$) | Wind $_{speed}$ ($m.s^{-1}$) | $ET_o$ ($mm.day^{-1}$) |
|---|---|---|---|---|---|---|
| January | 33.5 | 21.6 | 79.1 | 17.8 | 14.5 | 6.8 |
| February | 33.4 | 25.1 | 77.2 | 19.5 | 15.6 | 6.2 |
| March | 33.6 | 24.8 | 77 | 21.8 | 17.7 | 6.5 |
| April | 32.3 | 25.2 | 80.3 | 20.5 | 16.5 | 5.9 |
| May | 31.6 | 23.7 | 82.7 | 20.1 | 16.0 | 5.6 |
| June | 23.7 | 21.2 | 85.3 | 16.3 | 14.1 | 4.5 |
| July | 28.7 | 23.1 | 85 | 17.1 | 12.8 | 4.2 |
| August | 29.8 | 22.3 | 83.2 | 18.6 | 11.5 | 4.6 |
| September | 32.3 | 23.9 | 82.4 | 20.1 | 16.4 | 5.5 |
| October | 32.1 | 23.7 | 83 | 19.8 | 15.8 | 6.1 |
| November | 23.6 | 23.4 | 80 | 16.6 | 14.1 | 6.2 |
| December | 28.9 | 23.2 | 79 | 17.2 | 13.2 | 6.4 |
| Average | 30.3 | 23.4 | 81.2 | 18.8 | 14.9 | 5.7 |

The soil at the experimental site is the Haatso series, a well-drained savannah ochrosol derived from quartzite schist, described as a Ferric Acrisol (FAO/UNESCO, 1994). Some chemical and physical properties are as shown in Table 2.

*Table2. Chemical and physical properties of the soil at the experimental site*

| Soil Layer (cm) | pH ($H_2O$) (1:2) | Org. C (%) | Total N (%) | Avail. P (mg $kgX^1$) | K (cmol+kg $X^1$) | Sand (%) | Silt (%) | Clay (%) | Bulk density ($g/cm^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 0-20 | 7.33 | 1.06 | 0.36 | 11.07 | 0.41 | 41.4 | 43.2 | 15.4 | 1.34 |
| 20-40 | 7.39 | 0.50 | 0.34 | 6.79 | 0.30 | 40.4 | 44.7 | 14.9 | 1.22 |
| 40-60 | 7.83 | 0.50 | 0.31 | 4.28 | 0.25 | 45.3 | 43.8 | 10.9 | 1.41 |
| 60-80 | 7.99 | 0.39 | 1.26 | 3.89 | 0.19 | 48.0 | 41.1 | 11.1 | 1.33 |
| 80-100 | 7.79 | 0.36 | 0.42 | 2.40 | 0.21 | 46.3 | 43.0 | 10.7 | 1.47 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 100-120 | 7.85 | 0.23 | 1.13 | 2.10 | 0.22 | 55.8 | 36.4 | 7.8 | 1.38 |
| Average | 7.70 | 0.51 | 0.64 | 5.09 | 0.26 | 46.20 | 42.03 | 11.80 | 1.36 |

***Experimental Plot Design***

The experiment was setup by employing the randomised complete block design with three replications on an existing mango (variety: Kent) orchard that was eight (8) years old. The orchard had an inter-row distance of 10.0 m and within-row distance of 10.0 m (Figure 1). The cultivated area per irrigation treatment/lateral was 0.05 ha (500 $m^2$) and occupied by 5 mango trees.

The irrigation system used on this orchard was an improvised drip system with laterals (12.7 mm diameter) and sub-mains (19.05 mm internal diameter) made from "pvc" pipes joined together using T-joints were necessary. A 19.05 mm diameter "pvc" pipe served as the mainline which was connected to the water reservoir. The irrigation water flows were controlled using valves. The laterals had end caps to stop spillage of water and also help pressure build-up within the system. Four irrigation treatments (T1, T2, T3 and T4) were imposed and replicated three times. These irrigation treatments are defined as follows:

- T1 - No irrigation requirement
- T2 - Irrigation at 50 % of estimated crop water requirement (CWR)
- T3 - Irrigation at 100 % of estimated CWR
- T4 - Irrigation at 150 % of estimated CWR

A 63.5 mm diameter hole was augured at three selected tree locations within each of the four irrigation treatments and a 130 cm long, end-capped access tubes (pvc pipes) were installed at a soil depth of 120 cm. to monitor soil moisture dynamics throughout the season, using a neutron probe, in the root-zone of the selected mango trees.

The volumetric soil water content at each access tube location (i), depth (k) and time (j), were calculated from the device’s counting rate CR (i,j,k), of slow neutron, using BNARI's pre-determined calibration curves as given in Equation 1:

$$\theta_{v(i;j;k)} = 0.236_{(i)}\, CR_{(i:j;k)} - 0.015_{(i)} \quad [1]$$

where:

$0.236_{(i)}$ and $0.015_{(i)}$ = calibration constants (i.e. slope and intercept, respectively) at site (i).

The depth of stored soil water, expressed in cm, within the measured soil profile "S" was computed using the Equation 2.

$$S_{L_i} = \theta_{Avg} \sum \Delta z \quad [2]$$

where:

$\Delta z$ = soil layers of thickness

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***Estimation of the depth of irrigation water supplied***

The neutron probe measurements (soil moisture data) were used in a model (Mango Plus Software) developed by the authors for the estimation of the project's irrigation water required for a hectare of mango orchard. The duration of the reproductive period is 120 days. The net depth of irrigation applied (mm) and the volume of irrigation water supplied were estimated using as 425.27 mm and 5320 $m^2$/ha/reproductive period of 120 days, as shown in Figures 2 and 3 respectively.

The depth of irrigation water supplied per tree per period was hence estimated based on the following assumptions:

- Irrigation is localized due to the use of the improvised drip irrigation scheme
- Wetted/evaporative surface area per tree was assumed to be 1 $m^2$.

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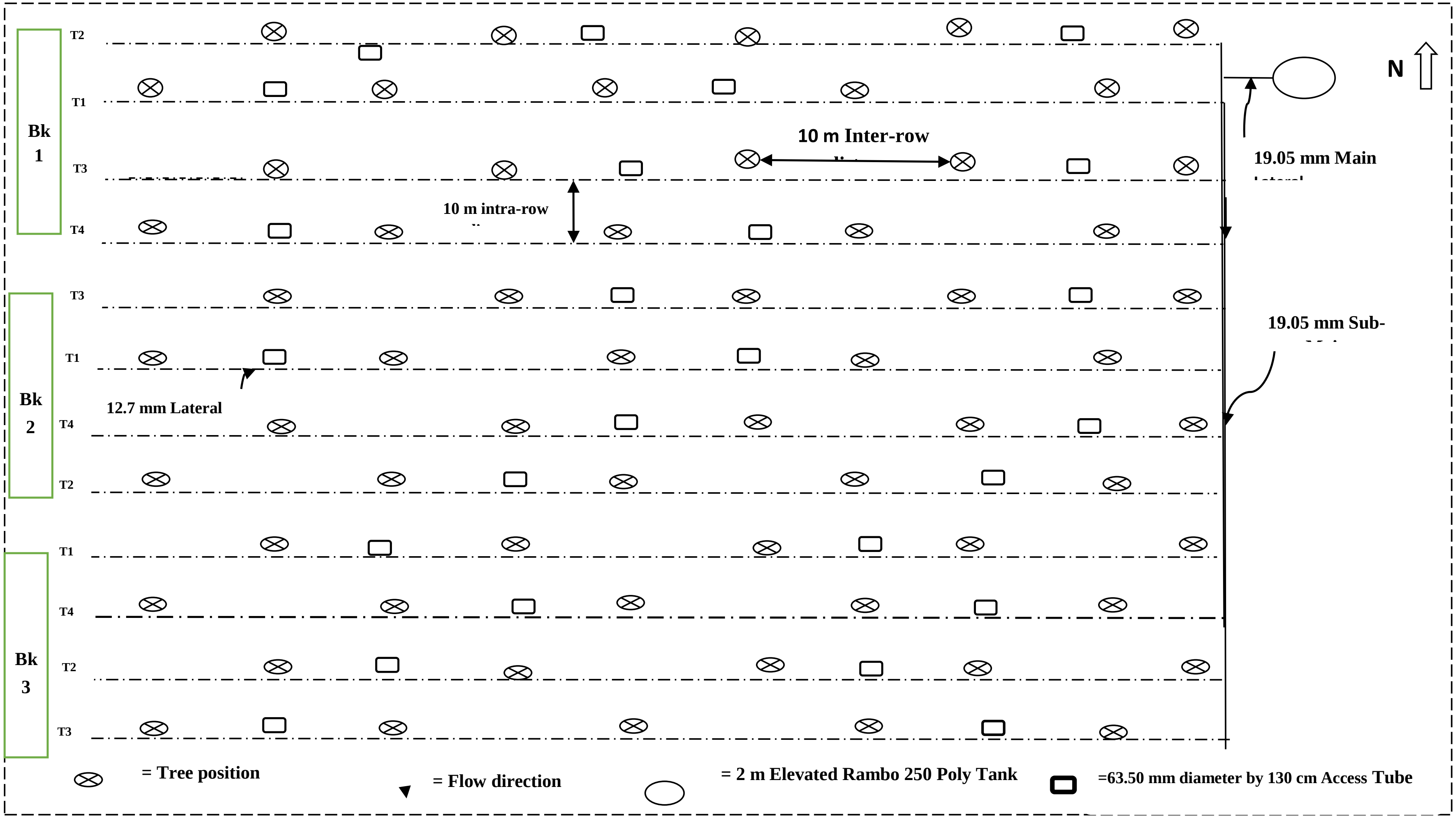
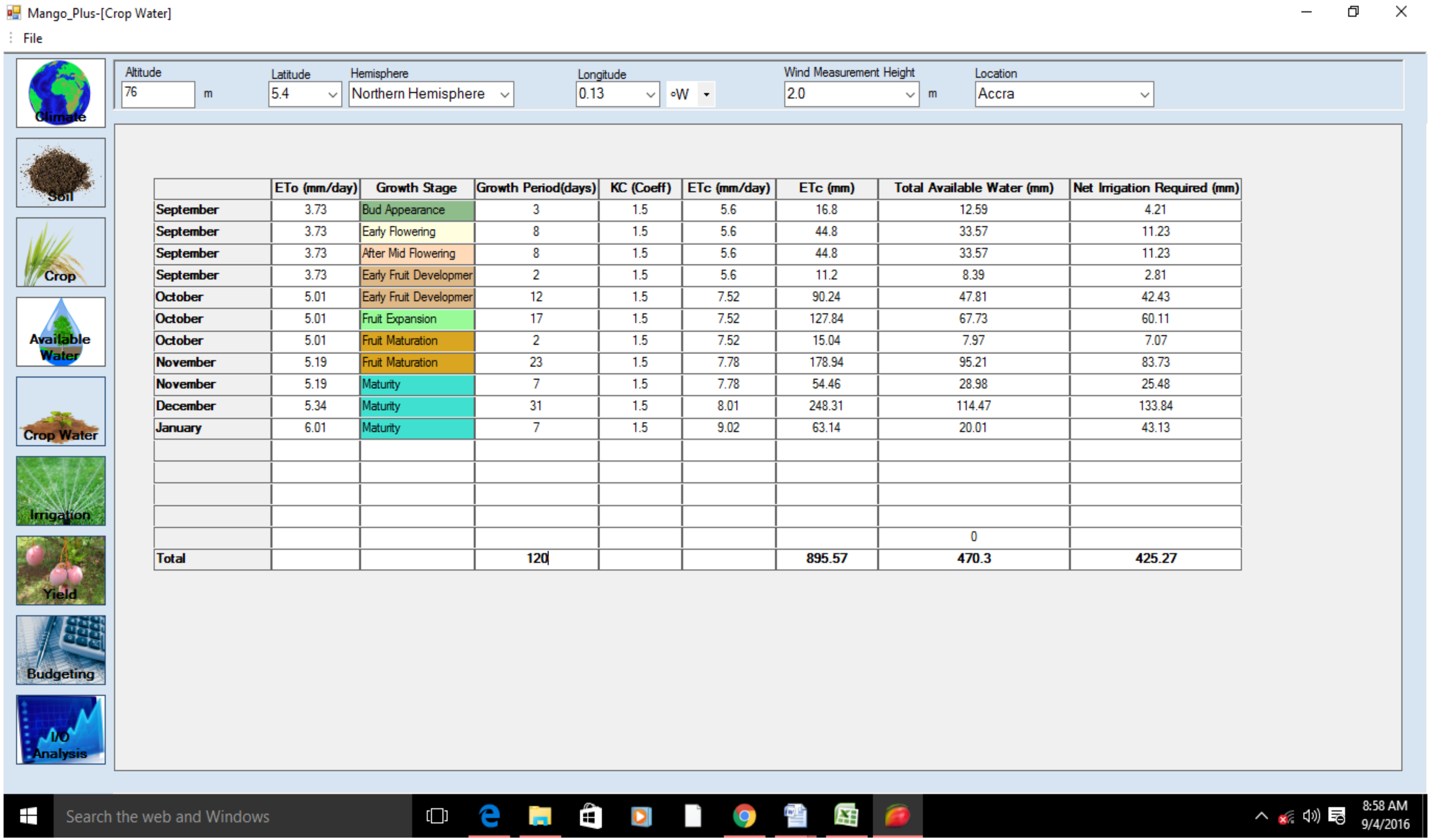



*Figure 1: Schematic layout of an improvised drip irrigation scheme in the model Mango orchard*




| | ETo (mm/day) | Growth Stage | Growth Period(days) | KC (Coeff) | ETc (mm/day) | ETc (mm) | Total Available Water (mm) | Net Irrigation Required (mm) |
|---|---|---|---|---|---|---|---|---|
| September | 3.73 | Bud Appearance | 3 | 1.5 | 5.6 | 16.8 | 12.59 | 4.21 |
| September | 3.73 | Early Flowering | 8 | 1.5 | 5.6 | 44.8 | 33.57 | 11.23 |
| September | 3.73 | After Mid Flowering | 8 | 1.5 | 5.6 | 44.8 | 33.57 | 11.23 |
| September | 3.73 | Early Fruit Developmer | 2 | 1.5 | 5.6 | 11.2 | 8.39 | 2.81 |
| October | 5.01 | Early Fruit Developmer | 12 | 1.5 | 7.52 | 90.24 | 47.81 | 42.43 |
| October | 5.01 | Fruit Expansion | 17 | 1.5 | 7.52 | 127.84 | 67.73 | 60.11 |
| October | 5.01 | Fruit Maturation | 2 | 1.5 | 7.52 | 15.04 | 7.97 | 7.07 |
| November | 5.19 | Fruit Maturation | 23 | 1.5 | 7.78 | 178.94 | 95.21 | 83.73 |
| November | 5.19 | Maturity | 7 | 1.5 | 7.78 | 54.46 | 28.98 | 25.48 |
| December | 5.34 | Maturity | 31 | 1.5 | 8.01 | 248.31 | 114.47 | 133.84 |
| January | 6.01 | Maturity | 7 | 1.5 | 9.02 | 63.14 | 20.01 | 43.13 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | 0 | |
| Total | | | 120 | | | 895.57 | 470.3 | 425.27 |

*Figure 2: Computed depth of net irrigation water requirement*

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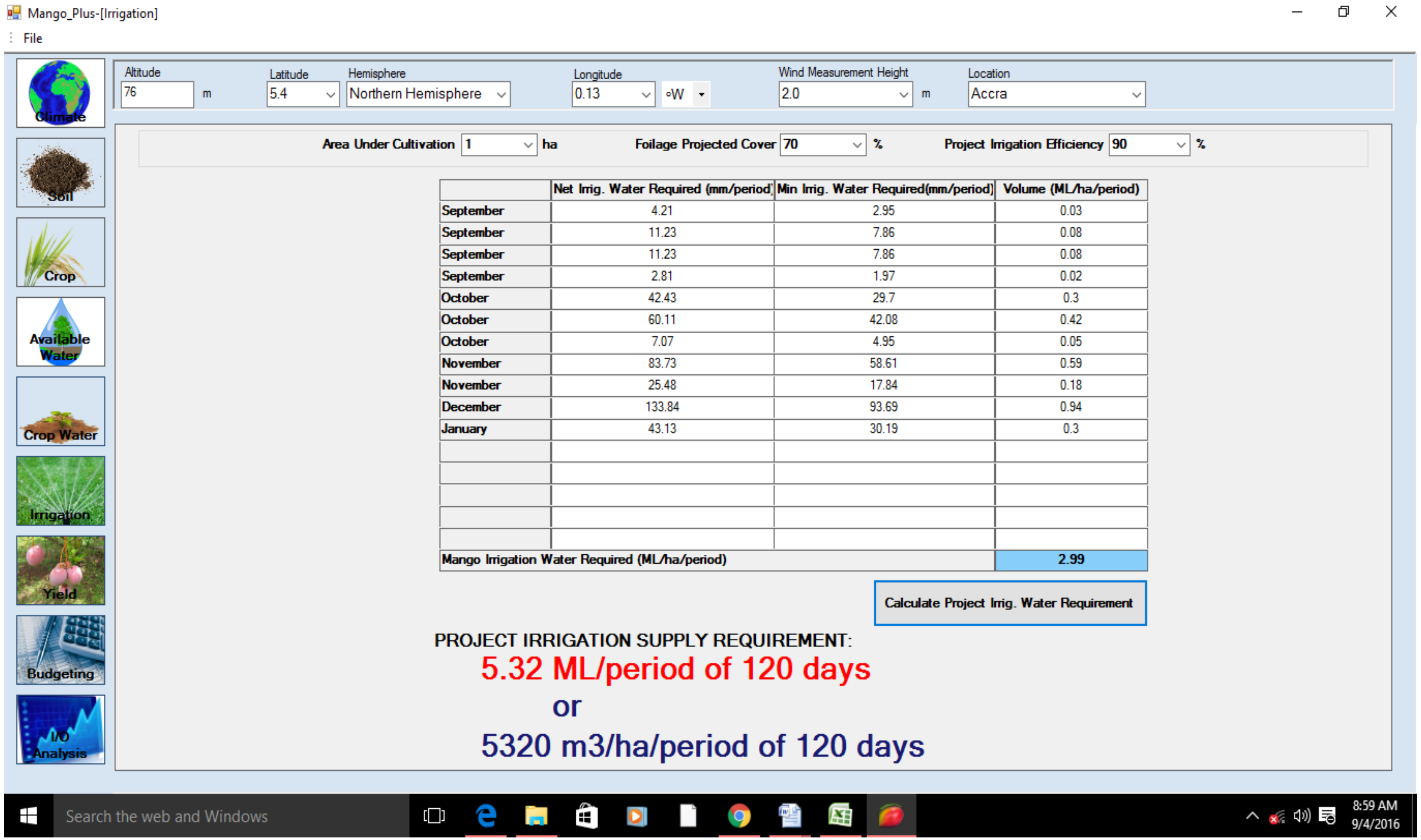


*Figure 3. Computed volume of irrigation water required*

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*Table 3: Computation of project's depths of irrigation water supplied per reproductive period.*

| Irrigation Treatment | No. of Trees/Trt. | Area (ha) | Net Irrigation Applied (mm) | Gross Irrigation Applied (mm) |
|---|---|---|---|---|
| T1 | 15 | 0.15 | 0 | 0 |
| T2 | 15 | 0.15 | 212.6 | 266 |
| T3 | 15 | 0.15 | 425.3 | 532 |
| T4 | 15 | 0.15 | 637.9 | 798 |
| Total | 60 | 0.60 | - | - |

This study employed the use of water management scheme where irrigation commenced prior to initiation of flowers until two weeks before the mangoes were harvested. All irrigation applications were done early in the day. The reproductive growth cycle was initiated in the third week of August by spraying 4% solution of potassium and calcium nitrate to induce flowering.

***Analytical Procedure***

The effect of irrigation on a mango orchard was investigated by studying the trend of response of the selected reproductive growth parameters of the tree when subjected to the four different irrigation treatments. These were computed using the relationships given below:

**a. Count of Emerged Panicles**

Panicle emergence is the first stage of reproductive growth in mango. Panicles emerge predominantly on the rachis but on very few occasions they also emerge at other portions. Healthy panicles are noted to produce viable inflorescence for fruiting. The cumulative count of panicles per selected branch from each of the non-identical irrigation treatment was recorded weekly, starting from the first day of visible panicle emergence. After periods of data collection, the mean of the cumulative panicle count per irrigation treatment was recorded and computed using Equation 3.

$$\text{Panicle Count} = \frac{\sum_{T_i=1}^{T_i=m} P_i}{n} \quad \text{[3]}$$

where:

Pi = cumulative count of panicles at the last count,
Ti = treatment,
m = number of treatments and
n = the number of replications.

**b. Mean of malformed panicles**

Panicle malformation, also known as floral malformation, is characterized by short, thickened and enlarged rachises. Severity of panicle malformation could vary from

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light to medium or heavy and it could be on the same shoot. Panicles become greener and may continue to bear fruits after fertilization although majority of malformed panicles die off before the end of the growing season.

Midway in the experiment (when fruits had developed beyond the golf ball stage), the malformed panicles were counted and the results were evaluated using Equation 4:

$$\%\ \text{MFP} = \left(\frac{\text{Number of Malformed Panicles}}{\text{Total Emerged Panicle Counted}}\right)100 \ldots\ldots\ldots\ldots\ldots\ldots \text{[4]}$$

where:

% MFP = percentage malformed panicle

### c. Flower Count

Mango inflorescence production is enhanced primarily by high temperatures and low humidity. The selected branches per irrigation treatment were monitored every other day during the month of September to record the appearance of first flower per panicle and the average flower counts were estimated using the Equation 5:

$$\text{Flower Count} = \frac{\sum_{T_{i=1}}^{T_{i=m}} X_i}{n} \ldots\ldots\ldots\ldots\ldots\ldots \text{[5]}$$

where:

Xi = cumulative count of flowers at the last count,
Ti = treatment,
m = number of treatments and
n = the number of replications.

The mean number of flowers counted within the period of data collection was determined using Equation 5.

### d. Count of Fruit Set

The mango fruit passes through different developmental stages before it attains maturity. These include: tiny stage, pigeon egg stage, golf ball stage of fruit and maturation stage of development (fruit maturity).The number of fruits set/retained was counted for each developmental stage. For this purpose, only selected/tagged branches in each irrigation treatment were considered. The mean count of fruit set was calculated using the Equation 6.

$$\text{Count of Friut Set} = \frac{\sum_{T_{i=1}}^{T_{i=m}} FS_i}{n} \ldots\ldots\ldots\ldots\ldots\ldots \text{[6]}$$

where:

$FS_i$ = Count of fruit set at a particular stage of fruit development

Fruit maturity is the last stage of fruit development and it is normally within the range of 3 and 4 months after flowering.

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**e. Yield Performance**

At harvest, the wholesome fruits were counted for every irrigation treatment and the mean value determined.

***Statistical Analysis***

Each of the data set collected during the various reproductive growth stages of the mango crop was analysed based on the experimental design used. The data sets were subjected to the Analysis of Variance (ANOVA) using the GenStat Discovery (Edition 12). Means were separated using the Least Significance Difference (LSD) test whenever the statistical analysis indicated the presence of significant differences in treatment means.

## RESULTS AND DISCUSSION

**Weather Conditions:**Within the locality of the experimental site, the mean monthly air temperatures were generally lower during the major cropping season (April– July) compared to values recorded for the minor cropping season (September – December). In particular, the maximum and minimum air temperatures for the minor cropping seasonwere 29.3$^{o}$C and 23.6$^{o}$C, respectively, as against 29.1$^{o}$C and 23.3$^{o}$C for the major cropping season. During the major cropping season, the mean relative humidity was 83.3% while that for the minor cropping season was 81.1%. Additionally, the mean solar radiation for the major and minor cropping seasons were 18.5MJm$^{-2}$day$^{-1}$ and 18.4MJm$^{-2}$day$^{-1}$,respectively. Though erratic and unreliable, the rainfall amounts recorded during the major and minor cropping seasons of the study were 512.5 mm and 294.8 mm, respectively. According to Coelho *et al*. (2002), the amount of water required by mango depends on climatic conditions within the vicinity of its orchard. Mango is said to thrive well at locations with the following ranges of the following climatic parameter: temperature range of 26.66 °C and 36 °C (NDA, 2000), annual rainfall range of 250 to 2500 mm (NABARD, 2007) and relative humidity of 45% and 80% (NDA, 2000). These indicate that Ghana's coastal savannah zone has the requisite weather conditions for mango cultivation.

**Panicle Emergence:** Results obtained (Table 4) indicate that there were significant differences ($p \leq 0.05$) in the number of panicles that emerged within the irrigation treatments. Mango irrigation at 150 % of crop water requirement (T4) showed the highest response with a mean of 37 panicles which is statistically different ($p \leq 0.05$) from 23 and 16 panicles recorded for T2 and T1, respectively. However the mean number of panicles in T4 was not significantly different from the 31 panicles recorded for T3.This indicates that prior to panicle formation and emergence, a considerable volume of moisture was required by the orchard. The increase in the number of emerged panicles for irrigation treatments as compared to the control treatment is in agreement with the findings of Sarker and Rahim **(**2013) who reported a considerable increment in number of secondary panicles in a mango orchard that was subjected to double irrigation regimes as against single irrigation and no irrigation regimes.

**Panicle Malformation:** Panicle malformation, also known as floral malformation, is characterized by short, thickened and enlarged rachises. The severity of floral malformation could vary from light to medium or heavy and it could be on the same shoot. Panicles become greener and may continue to bear fruits after fertilization although majority of malformed panicles die off before the end of the growing season. The mango variety used for the study

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(Kent) is a late blooming variety and therefore is less susceptible to malformation. Table 4 shows details of the mean numbers of malformed panicles. The highest number of malformed panicles (28.6 %) occurred in T2 and T3followed by 23.8 % and 19% of malformed panicles in T4and T1, respectively. No significant differences (p> 0.05) were observed in the percentage of malformed panicles among treatments. However, the no irrigation treatment scenario helped reduce the occurrence of malformation of panicles. This was found to be in agreement with the findings of Tahir, *et al*. (2003) who reported that 4.51 % of malformed mango panicles among completely stressed trees, compared to7.32 % occurring among those that were partially stressed and again, and 10.20 % of such panicles among non-stressed trees.

**Mean Flower Count:** Inflorescence production is enhanced primarily by high temperatures and low humidity (Roemer, 2011). In the model mango orchards, both Staminate and hermaphroditic flowers were observed, in an uneven proportion. Staminate flowers die off after fertilization while the hermaphroditic flowers bear the fruits. Among all the irrigation treatments considered under this study, inflorescence development as shown in Table 4, was at its peak in T4 where the average number of flowers was determined to be 1721.Irrigation at 100 % of crop water requirement (T3) followed with 1529 average number of flowers, and then came T2 with 1222 average number of flowers.

*Table 0. Mean number of panicle emerged, malfunctioned pinnacle and number of flowers under varying irrigation regimes.*

| Irrigation Treatment | Date of Appearance of 1st Panicle | Av. No. of Panicles Emerged/Limb/Tree | Av. No. of Malfunctioned Panicle/Limb/Tree | Av. No. of Flowers/Limb/Tree |
|---|---|---|---|---|
| T1 | 5th September | 16 | 4 | 1126 |
| T2 | 8th September | 23 | 6 | 1222 |
| T3 | 7th September | 31 | 6 | 1529 |
| T4 | 11th September | 37 | 5 | 1721 |
| CV (%) | - | 12.7 | 19.0 | 5.6 |
| LSD (0.05) | - | 6.431 | 1.88 | 146.8 |

The no irrigation treatment (T1), which was the control, produced 1126 flowers. With these results, except for T1 and T2, statistical differences ($p \leq 0.05$) were observed in flower count in the remaining irrigation treatments. Significant differences in the average number of flowers among treatments imposed were very high, indicating that the starting of the irrigation schedule just before flowering could be a prerequisite for enhancing the production of flowers in a mango orchard. Similarly, Sarker and Rahim (2013) reported that irrigation promotes flowering in a mango orchard.

**Percentile Fruit Set**: Fruit set in mango is a process controlled by availability of pollen, viability of the available pollen, number of pollinators and on self- and cross-pollination compatibility. Water availability is not critical during the pollination stages but just after the appearance of the fruit.During the early stage of fruit development (tiny stage) the highest number of fruit set was recorded for the 150 % irrigation treatment (T4) as compared to the other irrigation treatments. Records of mean fruit set (tiny stage) (Table 5)indicate that at the

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beginning of fruit set, irrigation was not a prime requirement as there were no significant differences ($p \leq 0.05$) in mean fruit set among the irrigation treatments imposed.

*Table 5. Mean number of fruit set and/or retained per limb per tree during fruit developmental stages.*

| Irrigation Treatment | Av. No. of Fruits/Limb/Tree | | | | Performance at Harvest |
|---|---|---|---|---|---|
| | Tiny Stage | Pigeon-egg Stage | Golf ball Stage | Fruit Maturation | Av. No. of fruits/Tree |
| T1 | 381 | 170 | 78 | 66 | 135 |
| T2 | 375 | 183 | 92 | 68 | 187 |
| T3 | 390 | 201 | 122 | 91 | 214 |
| T4 | 416 | 231 | 155 | 138 | 225 |
| CV (%) | 5.2 | 6.6 | 19.7 | 31.8 | 38.1 |
| LSD (0.05) | 38.33 | 24.23 | 41.43 | 54.45 | 56.31 |

At the pigeon-egg stage of fruit development the number of fruits retained increased gradually from 170 for T1 to 231 for T4. There were significant differences ($p \leq 0.05$) in the mean number of fruits retained on the mango trees among the irrigation treatments, indicating that irrigation was a prime requirement for enhancing reproductive parameters of mango. Specifically, significant differences ($p \leq 0.05$) in retained fruits existed between T2 and T4, T1 and both T3 and T4 and finally between T3 and T4.

The mean number of fruits that were retained on the mango trees as at the 'golf ball stage' of fruit development for the different irrigation treatments are in Table 5 and follow the same trend as observed for the pigeon egg stage. Statistically, there were significant differences ($p \leq 0.05$) among irrigation treatments for the number of retained fruits during the 'golf ball stage' of fruit development. Lastly, the mean number of fruits retained per selected limb during the maturation stage of fruit development, generally showed great variation and were significantly different ($p \leq 0.05$)among the irrigation treatments. The irrigation treatment T4 had the highest number of 138 fruits retained per selected limbs during the maturation stage, followed by 91 fruits for T3, 68 fruits for T2 and 66 fruits for T1.

Generally, the mean number of fruits retained during the various phases of fruit development increased with increasing levels of irrigation treatments. However, there were wide differences in the mean numbers of fruits retained within the varying developmental stages. Sarker and Rahim **(**2013) reported similar results for a mango orchard in Bangladesh.

**Yield Performance:** The mean number of fruits harvested per tree for the treatments are as shown in Table 5. T1 produced an average of 135 fruits per tree which was the least when compared to the rest of the irrigation treatments (T2 = 187, T3 = 214 and T4 = 225 fruits). Statistically, there were significant differences ($p \leq 0.05$) among T1 and T3 and also T1 and T4. In general, these differences in fruit yield were high and they were due to the direct effect of the varying moisture regimes that were created at the root zones of the mango trees. Fruit yields were slightly lower than those reported by Morton, (1987) who reported a mean yield of between 200 and 300 fruits per tree.

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With mean weights per fruit estimated as: 0.59 kg, 0.49 kg, 0.5 kg and 0.52 kg for T1, T2, T3 and T4 respectively, the mean the yield performance per treatment were as follows; 8 t/ha, 9.2 t/ha, 10.7t/ha and 11.7t/ha. The size code (in grams) for accepting mango fruits on the international markets is 200-350 g for class A, 351-550 g for class B and 551-800 g for class C at a maximum permissible difference of 75, 100 and 125 g, respectively (TFNet,2016). This indicates that the irrigated mango orchard in this study produced class B and C fruit types which are suitable for the export market.

## CONCLUSION AND RECOMMENDATION

The study suggests that irrigation may be used for enhancing fruit retention at the “pigeon-egg‟ and “golf ball” stages of mango fruit development. The study also recorded higher fruit yield for the irrigated mango scenarios. Specifically, irrigation treatments T4 and T3 had significantly more positive impact on the reproductive parameters of mango compared to T2 and T1. However, from economic point of view, irrigation treatment T3 (100% of CWR) is recommended to mango farmers instead of T4 (150% of CWR) which out-performed T3.

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## REFERENCES

Coelho, E.F., A.S. de Oliveira, A.O.A. Netto, A.H. de C. Teixeira, E.C.E. Araújo, and L.H. Bassoi. (2002). "Irrigation". p. 166-189. *In*: P.J.C. Genu, and A.C. de Q. Pinto (ed.) A Cultura da Mangueira. Embrapa Informação Tecnológica, Brasília.

FAO (2005), Fact Sheet on Ghana from - Food and Agricultural Organization (FAO). Retrieved from: http://www.fao.org/fileadmin/user_upload/aquastat/pdf_files/ GHA_tables.pdf. Accessed date: 20/6/2013

FAO (2005): "Crop Evapo-transpiration - Guidelines for computing crop water requirements". Chapter 8 - $ET_c$ under soil water stress conditions. Retrieved from: http://www.fao.org/docrep/x0490e/x0490e0e.htm. Accessed date: 18/11/14

FAO/UNESCO (1994), "Soil Map of the World". Revised Legend, World Resources Report 60. FAO, Rome, Italy.

Griesbach J. (2003), Mango Growing in Kenya. Retrieved from; https://www.google. com.gh/webhp?sourceid=chromeinstant&ion=1&espv=2&ie=UTF8#q=mango+tree+depends +on+the+extent+of+dryness+for+prolific. Access date: 10/10/2015.

Hatsu, I. E. (2006), “Mango - The Next Big Export Earner for Ghana‟. Retrieved from: http://allafrica.com/search/?string=Mango%2CThe+Next+Big+Export+Earner+ for+ Ghana & Search=SEARCH. Accessed date: 24/8/2014.
Morton, J. F (1987); Papaya. In J. F. Morton (ed), "Fruits of Warm Climates". pp 336-346. Miami FL.

NABARD, (2007),” Model Bankable Scheme for Organic Cultivation of Mango in Tamil Nadu”. Retrieved from: http://www.nabard.org/modelbankprojects/mango.asp. Accessed date: 28/8/11

NDA (2000); Report from National Department of Agriculture, South Africa. Retrieved from;

ISSN: 2408-7920

http://www.nda.agric.za/docs/Infopaks/mango.htm. Accessed date: 28/8/11

Sarker. C., and Rahim M. A., (2013) Effect of Irrigation on Harvesting Time and Yield in Mango (*Mangiferaindica*L.) *Bangladesh Journal of Agricultural Research*. 38(1), 127-136

Shantha (1989): "Tree Management Systems for Profitable Mango Production" Retrieved from: http://shanthap.tripod.com/mb1.htm. Accessed date: 19/8/12

Singh, L. B. (1977), "Eco-physiology of Tropical Crops". Academic Press, New York. p. 479. Leonard Hill Ltd, London

Tahir F. M., Ibrahim M. and Hamid K (2003), Effect of Drought Stress on Vegetative and Reproductive Behaviour of Mango (*Mangifera indica L.,).* Asian Journal of Plant Science 2 (1): 116-118. 2003 ISSN 1682-3974

TFNet (2016), "Mango - Market and International Trade". Retrieved from: http://www.itfnet.org/v1/2016/05/mango-market-and-international-trade/ Accessed date: 29/12/15

Roemer, M. G. (2011), "Premature Fruit Drop in Mango (Mangifera indica L.) in Northern Vietnam". Retrieved from: https://opus.uni-hohenheim.de/volltexte/2011/657/ pdf/Roemer_2011_Premature_Fruit_Drop_in_Mango.pdf Accessed date: 29/12/15

Zakari A. K (2012), "National Mango Study - Ghana" Retrieved from; http://www.intracen.org/uploadedFiles/intracenorg/Content/About_ITC/Where_are_we_working/Multicountry_programmes/Pact_II/National%20mango%20study%20-%20Ghana.pdf. Accessed date: 21/1/14