



Mulching and Irrigation Practices on Cocoa Seedling Survival and Field Establishment

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Article History

Received: September 5, 2020

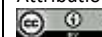
Revised: October 10, 2020

Accepted: October 18, 2020

Published: October 22, 2020

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Abstract

Irrigation experiments of cocoa tend to concentrate on yield of matured cocoa trees compared to field establishment of young seedlings. Seedling survival leading to optimum population density are fundamental to obtaining maximum yield of crops. The aim of this experiment was to determine the effect of mulching and irrigation on survival of hybrid cocoa clone raised in three different growing media during the establishment phase. The experimental design was a 2 x 2 x 3 factorial arranged in a split-split plot design, with irrigation as the main plot factor, mulching as the subplot factor and growing media as the sub-sub plot factor with three replications. Cocoa pod husk (CPH) was used as the mulching material and each plant received 5kg at a rate of 5.6 t/ha. Irrigation was done daily by applying 4L of water except when it rains. Data was collected on soil moisture, plant height, leaf number, stem girth and plant survival. Results indicated that irrigation and mulching significantly ($P < 0.01$) enhanced soil moisture. Cocoa seedlings raised in topsoil, mulched and irrigated significantly ($P < 0.05$) increased survival rate (94.5%) compared to seedlings raised in soil without irrigation and no mulching (47.1%). Similarly, the survival rate of seedlings raised in growing media M2, mulched and irrigated (93.0%) was significantly ($P < 0.05$) higher than similar seedlings without irrigation (73.4%). However, the survival rate of seedlings raised in M3 without mulching but irrigated was significantly ($P < 0.05$) higher 92.1% compared to seedlings raised in M3 mulched and irrigated 67.1%. Irrigation is very important in ensuring high survival rate during early field establishment. Mulching with cocoa pod husk without irrigation did not improve cocoa seedling survival.

Keywords: Cocoa; Irrigation; Mulching; Survival; Field establishment; Ghana.

1. Introduction

Cocoa has been the key export commodity and foreign exchange earner for the country's development, economic reforms and poverty reduction since independence of Ghana in 1957 [Kolavalli and Vigneri 1]. The economy of Ghana will continue to depend on cocoa cultivation as the primary contributor to GDP, sustaining growth and for achieving Middle Income Status (MIC) [2]. Ghana achieved its historic peak production of one million mt during the 2010/2011 season but could not maintain this achievement. The reduction in productivity of the cocoa sector in Ghana could jolt the livelihood of 800,000 to 1 million smallholder farmers [3].

Moreover, due to constant demand for cocoa, the production is being faced with a triple challenge of intensifying productivity on restricted land acreage, reduction of burden on forests ecosystems and intensifying resilience to climate change globally [4]. Again, in West Africa, improvement and replacement of existing trees are necessary due to aging tree stocks and pest-infected trees. It is estimated that 23% (368,000 hectares) of Ghana's area under cocoa cultivation is over 30 years old, and at least 17% (272,000 hectares) is damaged by cocoa swollen shoot virus disease (CSSVD) [5]. Most of the area with aging trees and every one of the CSSVD-affected area is in need of replanting. The Ghana government policies towards accelerated growth in cocoa production in the country is to ensure that Ghana continues to play an important role in the global cocoa economy [5].

Mulching conserves soil moisture by preventing evaporation from the soil surface and reduces erosion from runoff. Crop residues used as mulch might be loaded with organic matter, which is good enough for plant growth [6]. Mulumba and Lal [7], showed that mulch rate significantly affect available water capacity of the soil by 18-35%. Seedling survival and establishment of *E. trachycaulus* and *L. luwisii* was improved by 80% and 88% respectively when low straw and hay mulch was applied [8].

The use of irrigation increase soil moisture and provides an additional promising path towards improved establishment of plants [9]. Most irrigation experiments on cocoa focused on yields than field establishment, but

seedling survival leading to optimum population density is fundamental to obtaining maximum yield of crops. Famuwagun, *et al.* [10], pointed out that robust agronomic practices such as mulching and irrigation are needed to manage cocoa plantation establishment.

The aim of this experiment was to determine the effect of mulching and irrigation on growth and survival of cocoa seedlings during the dry season.

2. Methodology

2.1. Land Preparation and Planting

The site was slashed, cleared and stumps removed using pickaxe and the stumps packed at the edge of the field, and leaves were allowed to rot. The land was left for 3 weeks of which weeds blocks (replications) which were lined and pegged. Plantain suckers produced under plantain sucker multiplication in polybags were obtained at FOHCREC nursery planted one month before transplanting the cocoa seedlings.

2.2. Soil Sampling

Soil samples were collected at random at six different points in the field, using an auger, at a depth of 0 – 20cm and 20cm – 40cm which were analysed in the laboratory for chemical and physical properties.

2.3. Transplanting Cocoa Seedlings

Six-month-old cocoa seedlings were transported from University of Ghana farms to FOHCREC, the seedlings were hardened by reducing the nursery shade for 8 days before transplanting at the field. The cocoa seedlings were planted at a spacing of 3m x 3m to holes that were dug to 25cm deep.

A plot consisted of fifteen plants (5 x 3 planted in a rectangular fashion) and data was taken on the seedlings in the middle, bordered by 12 plants. Each plot size measured 45m x 45m and contiguous to other treatments plots and the distance between plots was 3m. The experiment was replicated three times with 180 plants per replicate making a total of 540 plants.

2.4. Experimental Design and Treatments

The experimental design was a 2 x 2 x 3 factorial arranged in a split-split plot design, with irrigation as the main plot factor, mulching as the subplot factor and growing media as the sub-sub plot factor with three replications. There were two levels of irrigation on the main plot (Irrigation and No Irrigation), (M-Mulching and NM-No Mulching).

2.5. Application of Mulch Treatment

Cocoa pod husk (CPH) was used as the mulching material obtained from the cocoa farm at FOHCREC, the CPH were collected from a heap that has been left on the farm for three months. The material was applied 5cm away from the plant stem to a radius of 60cm and thickness of 10cm, 5cm away from the plant stem. Each plant received 5kg of the mulch material at a rate of 5.6 t/ha.

2.6. Irrigation Treatment

Irrigation was done manually, which started on the 4th of January, when it has not rain for two weeks. Irrigation was done daily by applying 4L of water to each plant, except when it rains and if the crop evapotranspiration (ET_C) exceeds the deficit. The quantity of water applied was calculated using the following equation: $V_0 = A \times ET_C \times 1/AP \times Fw$ [11]. Reference evapotranspiration (ET_o) of the growing season were calculated following the FAO 56 paper (Penman-Monteith equation) approach using weather data accessed from an installed automatic weather station at the FOHCREC.

2.7. Data Collection and Analysis

Data was collected on plant survival, plant height, leaf number, stem girth and soil moisture was measured using Time Domain Reflectometry (TDR), on probes installed 5cm away at root zone of the plants early in the morning before the sun rises.

The data was analysed using GenStat Twelfth Edition statistical package PL 20.1 (VSN International Ltd), using ANOVA in a split-split plot model. Percentages reduction in survival between Irrigation and No - irrigation was calculated as follows: $MD = (I - NI) \times 100 / I$, where I is irrigation and NI is no-irrigation.

3. Results

The climatic data from January to June 2019 is presented in Table 1; the climatic condition showed that there was severe drought in January where there was no rainfall at all. In February there was some amount of rainfall which was <100 mm and it continued in March to April with slight increase in rainfall amounting to >100 mm. However, the rainfall figures doubled in May and June that is the peak period of rainfall in the experimental area.

Table-1. Climatic data from January to June 2019

Months	Mean Rainfall (mm)	Mean Temperature ($^{\circ}\text{C}$)		Mean RH (%)		Solar Radiation (MJ m^{-2})	Mean Wind Speed (m/s)
		Max	Min	Max (Night)	Min (Day)		
January	0.0	35.0	22.0	99.8	41.5	12.2	0.35
February	87.4	36.9	21.7	99.9	49.8	14.6	0.30
March	107.4	35.7	22.4	99.5	47.5	15.6	0.34
April	110.5	35.4	22.7	100.0	54.3	16.1	0.33
May	206.5	34.0	22.8	100.0	58.1	14.4	0.28
June	260.6	31.8	22.6	99.9	64.0	12.2	0.31

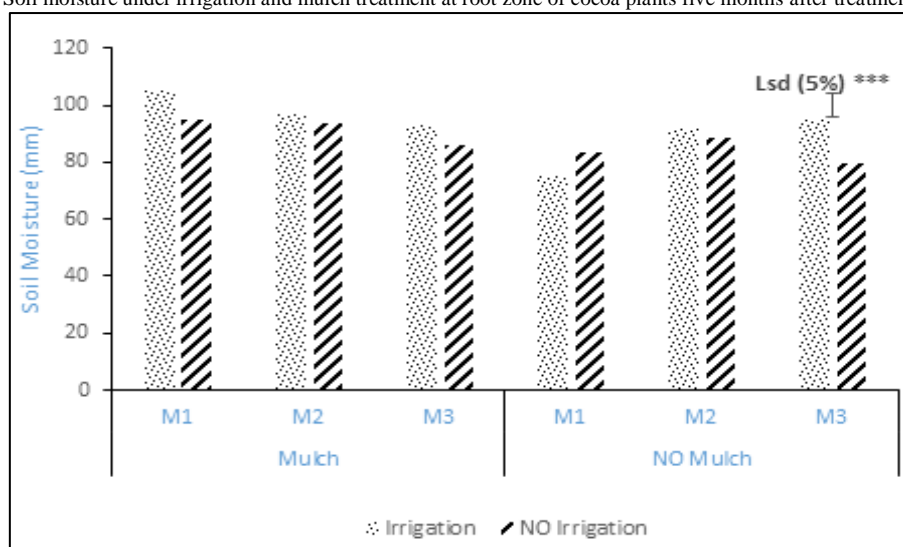
Source: FOHCREC Weather station, Kade

3.1. Soil Moisture under Irrigation and Mulch Treatment at Root Zone of Cocoa Plants

Figure one shows the result of the interaction between irrigation, mulching and growing media effect on soil moisture content at the root zone of the plants. The interactive effect was highly significant ($P < 0.01$), soil moisture content under irrigation x mulch x M3 was significantly higher (105.4 mm) compared to irrigation x no mulch x M3 (75mm).

No irrigation x mulch x M1 (95.1 mm) was significantly higher compared to no irrigation x no mulch x M1 (83.6 mm). However, there was no significant difference in soil moisture content for irrigation x mulch x M2 (96.9 mm) and irrigation x no mulch x M2 (91.9 mm).

Figure-1. Soil moisture under irrigation and mulch treatment at root zone of cocoa plants five months after treatment application



3.2. Effect of Irrigation and Mulching on Cocoa Seedling Survival and Establishment During the Dry Season

Seedling survival under irrigation was significantly ($P < 0.05$) high (89.6%) while no irrigation recorded (65.6%) the least based on the main effect. Mulching, on the other hand, did not significantly ($P > 0.05$) affect cocoa seedling survival. The type of growing media significantly ($P < 0.01$) affected survival with M2 recording significantly higher survival percentage (83.9%) compared to M1 (73.4%) and M3 (75.5 %) respectively (Table 2a).

The interactive effect of irrigation and growing media significantly ($P < 0.05$) affected plant survival, the higher number of surviving plants were recorded under irrigation x M1 (90.5 %) while no irrigation x M1 recorded (56.4%). Survival under irrigation x M3 was significantly higher (89.0%) compared to no irrigation x M3 (62.0%) (Table 2a).

The interactive effect of irrigation x mulch x growing media significantly ($P < 0.05$) influenced survival. Seedlings transplanted from M1 had a higher number of surviving plants (94.4%) under irrigation and mulching compared to survival under no irrigation x mulch x M1 (47.1%). M3 x irrigation x mulch interaction effect was significantly higher on the number of surviving (86.0%) plants than M3 x no irrigation x mulching (67.1%). However, the interaction between irrigation x mulching did not significantly affect M2 treated plants. Nevertheless, a significantly higher number of surviving plants were recorded under irrigation x no mulch x M3 (92.1%) compared to no irrigation x no mulch x M3 (56.8%) treatment (Table 2a).

Table-2a. Effect of irrigation x mulching x growing media interaction on cocoa seedling survival (percentage) under establishment

Irrigation		Growing Media			Mean	Mean
		M1	M2	M3		
Irrigation	Mulch	94.4	93.0	86.0	91.1	89.6
	No mulch	86.5	85.9	92.1	88.1	
	Mean	90.4	89.4	89.0		
No irrigation	Mulch	47.1	73.4	67.1	62.5	65.6
	No mulch	65.7	83.2	56.8	68.6	
	Mean	56.4	78.3	61.9		
	Mean	73.4	83.9	75.5		

Lsd (5%) - Irrigation = 17.3, Mulching = 13.6, Growing media = 8.3, irrigation x mulch = 15.6, irrigation x media = 13.8, irrigation x mulch x media = 19.0

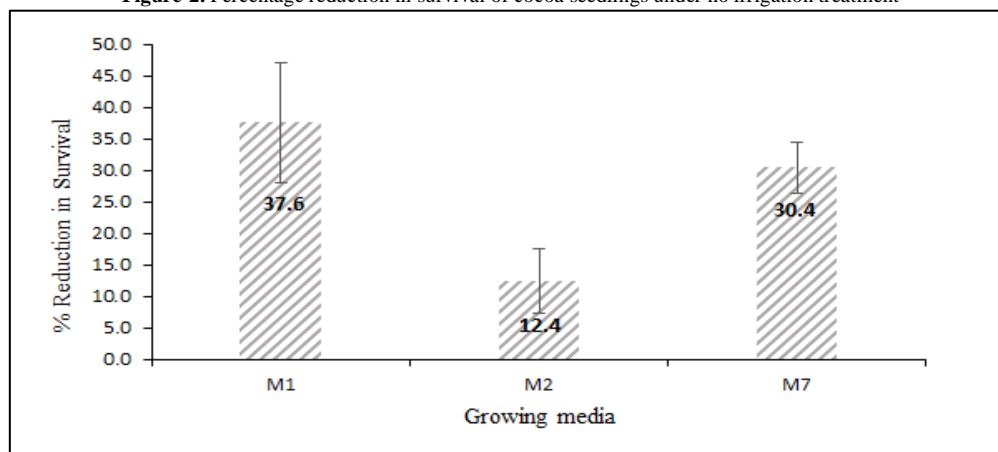
Table-2b. Effect of mulching x growing media interaction on cocoa seedling survival (percentage) under establishment during the dry season

Mulch	Growing Media			
	M1	M2	M3	Mean
Mulch	70.8	83.2	76.2	76.8
No mulch	76.1	84.5	74.4	78.4

Lsd (5%) - Mulch x growing media = 14.6

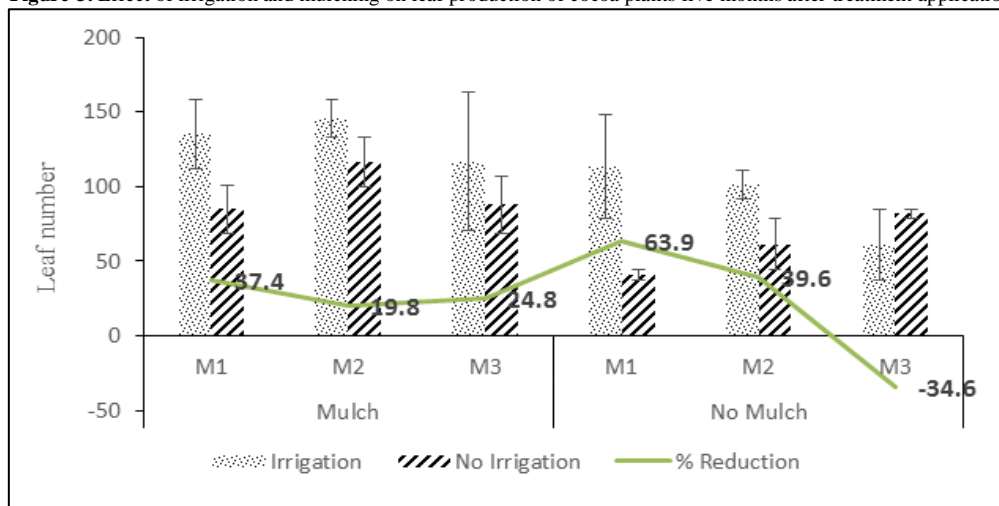
3.3. Percentage Reduction in Survival of Cocoa Seedlings under no Irrigation Treatment

Percentage reduction in survival accountable to moisture stress was significantly ($P < 0.05$) lower for M2 (12.4%) treated plants compared to the M1 (37.6%) and M7 (30.4%). Treatment difference between M1 and M3 was not significant ($P > 0.05$) (Figure 2).

Figure-2. Percentage reduction in survival of cocoa seedlings under no irrigation treatment

3.4. Effect of Irrigation and Mulching on Leaf Number

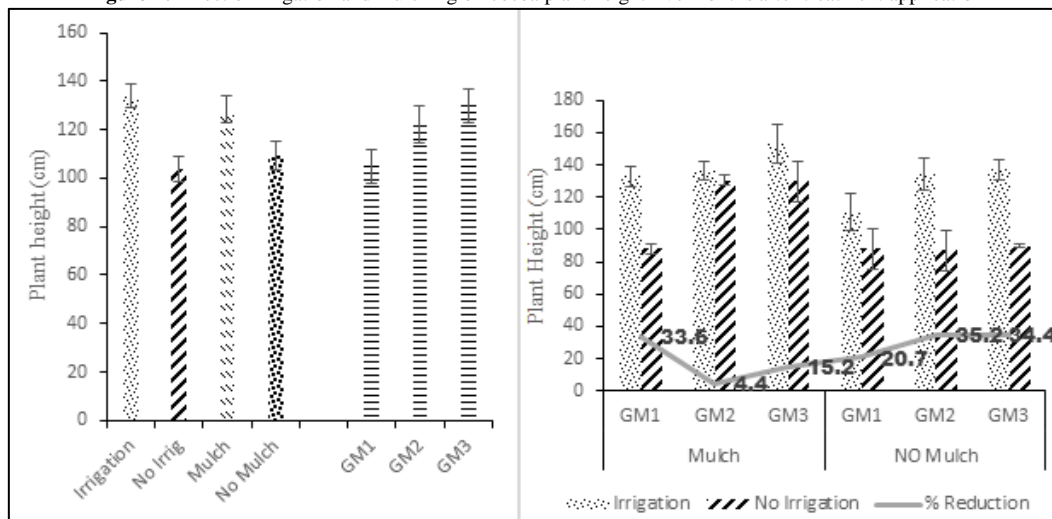
The interaction between irrigation, mulching and growing did not significantly ($P < 0.05$) affect the leaf number produced per plants five months after treatment application, however, the leaf number produced reduced by 63.9% in the M1 treated plants under no irrigation and no mulching. Interestingly, when plants were irrigated but not mulched, leaf number reduced by 34.6% in M3 treated plants.

Figure-3. Effect of irrigation and mulching on leaf production of cocoa plants five months after treatment application

3.5. Effect of Irrigation and Mulching on Cocoa Plant Height

Five months after treatment application, the main effect for irrigation treatment was significant ($P < 0.05$) on plant height. Plants under irrigation were significantly taller (133.9 cm) than those under no irrigation (108.3 cm) treatment (Figure 4). Similarly mulching had significant ($P < 0.05$) effect on plant height, the mean plant height under mulching treatment was significantly higher (128.3 cm) compared to those under no mulching (109.4 cm). Plant height was significantly affected by the type of growth media and it was higher for M3 (129.8 cm) compared to M1 (104.8 cm) and M2 (122.0 cm) respectively. However, no significant ($P > 0.05$) interactive treatment effect was observed. The percentage reduction in plant height under no irrigation but mulched treatment was 33.5%, 4.4% and 15.2% for GM1, GM2 and GM3, while under no mulching and no irrigation, plant height was reduced by 20.7%, 35.2% and 34.4% for GM1, GM2 and GM3 respectively.

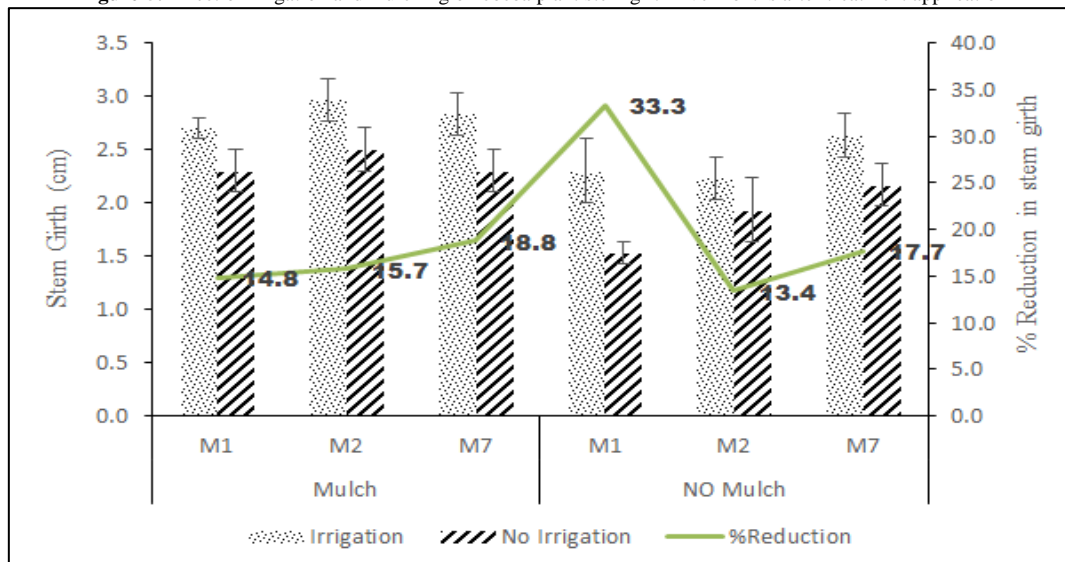
Figure-4. Effect of irrigation and mulching on cocoa plant height five months after treatment application



3.6. Effect of Irrigation and Mulching on Cocoa Plant Stem Girth

Irrigation on the main effect significantly ($P < 0.05$) induced thicker stem girth (2.6 cm) than those under no irrigation (2.1 cm). The interactive effect of irrigation x mulching x growing media did not significantly ($P > 0.05$) affect stem girth. However, stem girth was reduced by 33.3%, 13.4%, and 17.7% for GM1, GM2 and GM3 treated plants respectively under no irrigation and no mulching treatments. When plants were not irrigated but mulched, stem girth reduced by 14.8%, 15.7% and 18.8% for GM1, GM2 and GM3 treated plants.

Figure-5. Effect of irrigation and mulching on cocoa plant stem girth five months after treatment application



4. Discussion

4.1. The Role of Mulching and Irrigation on Cocoa Seedling Survival and Establishment

The high survival percentage observed for M1 (90.4%) under irrigation might be attributed to increased soil moisture when plants were watered than no watering treatment. This survival percentage observed was higher than those reported by Acheampong, *et al.* [9] who studied field establishment of cocoa under irrigation, mulching plus shading regime and reported 82% survival rate of PA 150 cocoa genotype under a shade and watering treatment. Moisture availability in soil enhances nutrient uptake by crops and results in good growth and survival. On the other

hand, survival for M1 under no irrigation was low (56.4%) and this corroborated with [Oppong \[12\]](#) who recorded 57% survival of cocoa in marginal cocoa growing areas of Ghana with a prolonged dry season and uneven rainfall conditions.

Survival of seedlings under cocoa pod husk mulch including irrigation x mulching interaction effects did not differ significantly from the no mulch treatment though a significant increase in height, stem girth and leaf number along with high soil moisture content was recorded under the mulch treatment. Similar lack of significant seedling survival under mulching and watering treatment was found by [Singer and Martin \[13\]](#). [Singer and Martin \[13\]](#) They studied the effect of landscape mulches and drip irrigation on transplant establishment and growth of three North American desert native plants, and reported that the application of mulch was detrimental to growth and survival of brittlebush and four-wing saltbush.

The significant percentage survival observed for M2 (83.9%) compared to that of M1 and M3 might be due to the bigger seedling size at transplanting [\[14\]](#), and the ability to grow faster and establish before the dry seasons' sets in. Once this was achieved the plant is able to survive under adverse environmental conditions. This finding agrees with [Padi, et al. \[15\]](#) who conducted an experiment on the differential response of cocoa families to field establishment stress and concluded that seedling size at transplanting might have a positive influence on seedling survival during the dry seasons.

On the other hand, the observation that mulch x growing media interaction did not have a significant effect on seedling survival might relate to the fact that the mulch material used seemed not to improve seedling survival without irrigation. In the soil medium treated plants, survival reduced by 47.1% under no irrigation x mulching treatment compared to no irrigation x no mulching which was 65.7%. [Engelbrecht and Kursar \[16\]](#), pointed out that seedling mortality might be high even under short dry spells.

Similar irrigation x mulching x plant species interactive discrepancies were reported by [Silva and Vieira \[17\]](#) who observed that mulching did not have any significant effect on survival of *C. langsdorfii*, that only 9% of the seedlings survived when mulched while *Eugenia disenterica* recorded 99% survival under no mulching. There is a need to further research into the suitability of cocoa pod materials for mulching cocoa seedlings during the establishment phase.

We would accept the null hypothesis that cocoa pod husk mulching without irrigation did not improve cocoa seedling survival when seedlings were transplanted from soil medium under this condition of study. The low survival rate observed might be attributed to the mulch thickness, which could reduce aeration and lower oxygen diffusion thereby causing root damage. [Cushman, et al. \[18\]](#), indicated aeration difficulty accompanying thick and plastic mulch materials.

Adverse effect of mulch materials on soil are also associated with sudden increased in pH that might get to alkaline medium and reduce obtainability of micronutrients by plants [\[19\]](#).

Soil moisture at 40 cm depth was significantly higher for mulch treated plants that also resulted in taller plants with thicker stems than those under no mulch treatment. It is generally agreed upon that mulching boost soil moisture by lowering evaporation from the soil surface and accelerating water infiltration into the soil. [Singer and Martin \[13\]](#), was of the view that mulches would only conserve soil moisture if rainfall amount was enough to penetrate the mulch layer or if irrigation was used.

Further research is required to survey potential cocoa growing areas and identification of water sources that do not dry during the dry season to enable farmers to irrigate the young cocoa during establishment. Limited water sources and inaccessibility to water sources might make irrigation practices difficult to the subsistent cocoa farmer and even on large-scale plantations. Investment in irrigation facilities for the cocoa plantation during the establishment phase may go a long way to benefit fully-grown plantations as watering during flowering and fruiting might improve the yield of cocoa beans. [Carr and Lockwood \[20\]](#), were of a similar view that water relations of cocoa should also have been the topic of most cocoa research programs since the crop is susceptible to drought and is grown in parts of the world that dry season alternates the rainy season.

5. Conclusion

Mulching increased soil moisture as usual which reflected positively on seedling growth parameters but did not improve seedling survival. The experiment showed that if cocoa seedlings are raised in soilless media seedling survival could be improved during the dry season. If seedlings are transplanted from the soil, irrigation is essential to improve survival above 90% for well-established plantations. The study showed that mulching with cocoa pod husk should be done in combination with irrigation to improve seedling survival at the field. Transplanting seedlings from both soil and soilless media, irrigation is essential during the dry season. This require further research to survey potential cocoa growing areas and identification of water sources that do not dry during the dry season and digging of wells to enable farmers to irrigate the young cocoa during the dry season.

Recommendation

Further research is required to look at the suitability of cocoa pod husk for mulching cocoa seedlings during the establishment phase. The quantity of water to apply and irrigation interval would depend on the prevailing climatic condition of the area. Where watering becomes almost impossible, the soilless medium comprising of SD+PM+RHB (70:25:5) could be used to raise cocoa seedlings for improved survival at the field. There is a need to invest in irrigation facilities in other to boost cocoa establishment and production in the country.

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