EFFECT OF COIR MULCH AND KAOLIN ON EVAPOTRANSPIRATION AND YIELD OF PWANI HYBRID 4 MAIZE UNDER RAIN-FED AND ADEQUATE SOIL MOISTURE CONDITIONS IN COASTAL KENYA

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DECLARATION AND RECOMMENDATION

DECLARATION

I declare that this thesis is my original work and has not been presented for a degree in any other University.

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RECOMMENDATION

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DEDICATION

The works of this study is dedicated to my late brother, Mathias Mbuvi, to my late father Paul Mbuvi, who tirelessly gave me moral support but never lived to see the final product. To my mum, Theresia Kavete for shouldering the family's burden, and all my family members for their patience and support.

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ABSTRACT

Adverse soil moisture deficit as a result of high ambient temperatures and high velocity June winds at critical stages of maize growth had been singled out as the most important factor limiting maize yield in Coastal Kenya during long rain season. This study was carried out to study the effect of foliar applied kaolin and coir dust mulch on evapotranspiration and yield of Pwani hybrid 4 maize. A 2x2x4x3 split-split plot design experiment, replicated thrice was set at Pwani University Farm, in 2007 and 2008 seasons, with coir dust mulch as the main plot treatments; irrigation as the sub-plot treatments, and kaolin at sub-subplot levels. Parameters measured included plant height, periodic above ground biomass and grain yield, soil moisture content, soil and air temperatures, % relative humidity and wind run at 31, 49, 66, 83 and 100 days after sowing. Energy and water balance equations were used to determine crop evapotranspiration. Genstat 14th Edition was used in data analysis and the means obtained used to develop ET-Yield production functions for predicting Pwani hybrid 4 maize yield in Coastal Kenya. Coir mulching resulted in reduced evapotranspiration early in the seasons, contributed to highest (9-15 %) soil moisture conservation, availing it at later stages of growth, up to 49th DAS. Beyond this period irrigation provided superior soil moisture conditions, especially at critical stages of maize growth. Coir mulching early in the season could substitute supplementary irrigation without significant losses in grain yield. Coir mulching was more beneficial in biomass and grain production during the relatively drier season II than during wetter season I. Coir mulch alone treatment resulted in highest grain yield ($p \leq 0.05$) in both seasons, of 6.7 and 4.9 tons ha^{-1}. Interactions of coir mulch and irrigation offered the best option in ameliorating June winds effects. Although irrigation resulted in highest biomass, it did not result in highest grain yield. Application of kaolin alone depressed final biomass and grain yield. However, its interactions with coir mulch and irrigation resulted in increased yield during a wetter season except when applied at floral stages, while its application during a relatively drier season resulted in depressed yield. Its application during wetter conditions in coir mulched or irrigated maize crop resulted in significant ($p \leq 0.05$) increases in biomass and grain yield of 20-31 % and 41.9 % respectively. Kaolin had “short and long term” effect on levels of soil moisture, seasonal evapotranspiration and biomass. The response of Pwani hybrid 4 maize yield to kaolin was highest at floral stages, and under stress conditions. Multiple linear regressions indicated that coir mulching was the most important factor in determining the level of grain yield.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	Agro-Ecological Zones
AGFP	Actual Grain Filling Period
AGFP	Actual Grain Filling Period
CEC	Cation exchange capacity
CSMD	Critical Soil Moisture Deficit
CMSW	Composted municipal solid waste
DAP	Di-ammonium phosphate
DAS	Days After Sowing
DM	Dry matter
ENSO	El Niño Southern Oscillation
ET	Evapotranspiration
ET_O	Potential evapotranspiration
FAO	Food and Agricultural Organization
FURP	Fertilizer Use Recommendation Project
GDSA	Mono-glyceryl n-decenylsuccinic acid
GLM	General linear models
HI	harvest Index
HQS	8-Hydroxyquinoline sulfate (8-HQS),
ICARDA	International Centre for Agricultural Research in Dry Areas
KARI	Kenya Agricultural Research Institute
KIWASAP	Kilifi Water and sanitation
LAI	Leaf area index
MDSA	Mono-methyl n-decenylsuccinic acid
NIR	Near infrared radiation
PAR	Photosynthetically Active Radiation
PH4	Pwani hybrid 4
PIDA	Participatory integrated development action
PMA	Phenyl mercuric acetate
PRAs	Participatory Rural Appraisals

PVC	Poly-vinyl carbon
QBO	Quasi-biennial Oscillations
RAG	Radiation above ground
RBG	Radiation below ground
R.H	Relative Humidity
SAS	Statistical Analysis System
VPD	Vapor pressure deficit
WUE	Water use efficiency

CHAPTERONE

INTRODUCTION

1.1 Background information

Maize (*Zea mays* var. L) is globally the third most important cereal grain after wheat and rice. It is the most important staple food in most African countries including Kenya (FAO, 2010). Kenya, with an area of about 1.5million hectares under maize and annual production of 2.3million tons is a net importer of maize. This is due to the low maize production and productivity with average yield of 1.1-1.3 tons ha^{-1} in most farmers' fields (Mulaa *et al.* 2005). In the coastal region of Kenya, maize is ranked as the primary staple food (Wekesa *et al*. 2003; Mulaa *et al.* 2005).

The Coastal region of Kenya has over 2.5 million people, an enormous agricultural arable land potential of about 34317 km^2, good soils and ample annual rainfall of 1000 mm to 1200 mm, making the region suitable for both food and horticultural crops production (Jazold and Schmidt, 1983). Despite this high agricultural potential, the region is highly food deficit (Nicholson *et al*. 2004; Mulaa *et al.* 2005). The region's annual local food production is less than 20 % of its food requirement due to poor maize yield of less than 0.4 tons ha^{-1}, which is far below the potential for the region (Wekesa *et al.* 2003).

High evapotranspirative demand occasioned by high ambient temperatures and high velocity (June) winds have been singled out as the most important variables limiting maize yield during the long rains season in the coastal region of Kenya (KIWASAP-Chakama PRA, 1994; Muti and Kibe, 2009). Indeed only two months in a year, namely April and May, experience positive moisture regime. This annual weather phenomenon has for long frustrated the efforts of farmers in the region, with bulk of the population heavily dependent on relief food (Republic of Kenya, 2003). The main effects of the winds can be summed up as limiting the amounts and distribution of rainfall in the areas they traverse, with consequent decline in rates of crop growth and yield (Muti and Nge'tich 2009).

The June winds also enhance high evapotranspiration rates, thereby aggravating soil water deficit, especially when maize plant is at developmental stages most sensitive to water stress

(McGregor and Nieuwolt, 1998; Cakir, 2004; Muti and Nge'tich 2009). Steduto and Hsiao, (1998) and Li *et al.* (2004) reported that gradual onset of soil moisture stress induced early senesce in maize, leading to reduction in leaf area index (LAI), PAR utilization, canopy conductance, CO_2 assimilation, and evapotranspiration, with consequent decline in biomass accumulation and low final yield.

In view of the increasing demand for limited water resource, the possibility of reducing crop transpiration without significantly affecting yield, particularly in areas with high evaporative demand and in irrigated agriculture is advantageous (Bittelli *et al*. 2001). Available literature proposes use of modern technologies in moderating adverse effects of high evaporative demand, wind effects and soil moisture stress on crop yield. Such are use of mulches, shelters and shelterbelts, application of yield stabilizing agents like foliar antitranspirants such as kaolin and plant hormones (Vaidyanathan *et al.* 1999; Campbell-clause, 1998; Cleugh *et al.* 2002).

Bittelli *et al*. (2001) and Lee *et al.* (1999) demonstrated the possibility of reducing crop transpiration by use of foliar applied chitosan and Abscicic acid (ABA) analogs, without significantly affecting yield in pepper, wheat, barley and tomatoes. The use of foliar applied Kaolin, magnesium carbonate, and sodium salicylate was observed to significantly increased biomass, yield and yield components of barley under water stress compared to control (Bergmann *et al.,* 1994; El-Kholy *et al.* 2005).

Application of soil surface mulches in dry-land conditions increased available water in the root zone by reducing evaporation, preventing soil seal formation, and almost doubled yield (Dee Raymer, 1998; Agassi *et al.* 2004; Shumavo, 2010; Michael, 2013). However, limited literature exist on the use of kaolin and surface mulch in moderating wind induced high evaporative demand and their effects on growth and yield of maize. Acording to Campbell-Clause, (1998); Steduto and Hsiao, (1998); Cleugh *et al.* (2002) and Zhang *et al.* (2004), the magnitude of wind effect on evapotranspiration of most crops is not known and more research is required.

Thus, this study was carried out to evaluate the effect of foliar applied kaolin and coir dust mulch in ameliorating high evapotranspirative demand and high ambient temperatures on yield of Pwani hybrid 4 maize at the coastal region of Kenya. The purpose of this study was to determine whether water can be conserved or plant-soil water relations could be favorably altered in water-limited agricultural environments by use of soil surface mulch and Kaolin respectively.

1.2 Statement of the problem

Yield of major food crops in Coastal region of Kenya have been low due to occurrence of deficit soil moisture conditions especially at critical stages of maize growth during long rain seasons, thereby increasing food insecurity in the region (Wekesa *et al.* 2003; Zhang *et al.* 2004; Mulaa *et al.* 2005). The deficit moisture conditions have been as a result of high evapotranspirative demand occasioned occurrence of high velocity June winds and by high ambient temperatures (McGregor and Nieuwolt, 1998; Muti and Kibe, 2009).

1.3 Justification of the study

The Coastal and Eastern regions of Kenya consume over 70 % of the ksh. 5 billion worth of annual relief food imports, yet the region with its enormous arable land potential received substantial rainfall in years when other regions were experiencing drought (Indeje *et al.* 2000; Republic of Kenya, 2003). Adoption of findings in this study will in the long term help improve maize yield in the region to save not only local currency but foreign exchange spent on relief food imports. Social economic studies in the region by KARI (2005) indicated that farmers' own maize production resulted in savings of over ksh. 36,000 per acre compared to purchases from the shops. More than one-third of the children in the region suffer from moderate to severe chronic malnutrition (Nicholson *et al.* 2004). Therefore improved maize production would lead to improved calorie intake, thereby reducing malnutrition levels and improving child's survival rates. Increased knowledge on moisture deficit mitigation measures from this study would lead to high maize yield for both subsistence and cash. The income from maize sales would no doubt increase the purchasing power of the coastal people, hence increased standards of living.

1.4 Objectives of the study

The main objective of the research was to study the effect of kaolin and coir dust mulch, on increasing crop yield in coastal region of Kenya.

1.5 Specific objectives

To determine the:-

1. Effect of coir dust mulch on evapotranspiration and yield of Pwani hybrid 4 maize.
2. Effect of foliar applied Kaolin at different stages of maize growth on evapotranspiration and yield of Pwani hybrid 4 maize.
3. Interaction effect of coir mulch and irrigation on evapotranspiration and yield of Pwani hybrid 4 maize.
4. Interaction effect of coir mulch, irrigation and Kaolin on evapotranspiration and yield of Pwani hybrid 4 maize.
5. Develop ET-Yield production functions for Pwani hybrid 4 maize

1.6 Hypothesis

1. Coir dust mulch does not affect evapotranspiration and yield of Pwani hybrid 4 maize
2. Foliar applied kaolin does not affect evapotranspiration and yield of Pwani hybrid 4 maize
3. Interactions of coir dust mulch and irrigation does not affect evapotranspiration and yield of Pwani hybrid 4 maize
4. Interactions of coir dust mulch, irrigation and kaolin have no effect on evapotranspiration and yield of Pwani hybrid 4 maize

CHAPTER TWO

LITERATURE REVIEW

2.1 The role of transpiration and evaporation in plants

Plant transpiration maintains transpiration stream necessary for absorption of plant nutrients from the soil, cooling of the plant, among other physiological functions (Zhang *et al.* 2004; Li *et al.* (2004). The transpiration process is dictated by weather factors that determine the level of atmospheric evaporative demand, while soil factors determine the availability of water to the plants (Steduto and Hsiao, 1998; Li *et al.* 2004). Evaporation mainly occurs on the exposed bare soil surfaces and contributes in depletion of available soil moisture especially with increased soil heat load and high wind speed of more than 5 ms^{-1}.

The challenges posed on maize production in the Coastal region of Kenya by the high evapotranspirative demand occasioned by June winds and high ambient temperatures, at critical maize growth stages implies that among the options for mitigating their effects, one would have to consider either (I) cutting down the high evapotranspirative demand and (ii) conserving as much soil moisture as possible and directing it mainly for transpiration formation or (iii) do supplementary irrigation to reduce the water stress, ultimately improving yield.

2.2 Effect of soil surface mulches on available soil moisture

The major causes of loss of rainwater in semi arid regions are runoff due to seal formation by raindrop impact, and evaporation from the wet soil surface (Agassi *et al.* 2004). Application of soil surface mulches have been found to be an effective way to prevent seal formation and significantly reduced water loss (Agassi *et al.* 2004; David *et al.* 2005; Michael, 2013). By reducing evaporation from the soil, this increased available water in the root zone, and therefore increased transpiration with consequent increase in yield since biomass production in cereals is strongly correlated with amount of transpired water (Njoka *ET al.*2004; Shumavo, 2010).

Mulching has also been known to smoother weeds by depriving them of light energy resulting in reduced or no growth, and cutting down the cost of production by over 40 % (Ossom *et al.*

2001). Besides weeds consume large amounts of soil moisture at early stages of growth, and their smothering implies conserving more moisture in the root zone (Dee Raymer, 1998; Teasdale and Mohler, (2000).

2.3 Wind velocity on stomatal resistance and yield

Wind is a big management problem in Australian agriculture resulting in setting up of National Wind program (Campbell-clause, 1998; Cleugh *et al.* 2002). Kobriger (1984) found that stomatal resistance increased and transpiration rate decreased in response to moderate wind speed of 6 ms^{-1}, and to strong winds of 10-13 ms^{-1}, respectively. Thus one of the effects of June winds, whose average velocities ranged 5-30 ms^{-1}, is to increase the magnitude of evapotranspiration (McGregor and Nieuwolt, 1998). According to Campbell-Clause (1998) the increase in stomatal resistance with increase in wind speed reduced daily evapotranspiration and therefore evapotranspiration in grapes by 17 %.

Wind speed affected stomatal aperture size, amount of transpiration and also influenced evaporation from the soil surface (Campbell-Clause, 1998; Cleugh *et al.* 2002). Thus the effect of wind on evapotranspiration has implications for water requirements in crops. At moderate wind speeds, much of the evaporation due to wind is from moist soil surface (Campbell-clause, 1998).

2.4 Effect of wind velocity on vapor pressure deficit

Steduto and Hsiao, (1998) and Villalobos *et al.* (2004), reported thatbefore onset of senesce, surface resistance increased linearly with increase in vapor pressure deficit (VPD) and wind velocity beyond 5 ms^{-1}. Allen *et al.* (1998) showed that atmospheric vapour pressure deficit (VPD) increased exponentially with increasing temperature.According to Jiyane and Gonzalez, (2003) and Villalobos *et al.* (2004) increase in VPD increases evapotranspiration. Plants respond to high VPD by reducing stomatal conductance which effectively saves soil moisture for periods with less evaporative demand, at the cost of reduced carbon assimilation (Lobell *et al*. 2013). Strong winds increases aerodynamic resistance, convective and sensible heat fluxes, and turbulence mixing of air, thereby increasing VPD.

2.5 Effect of wind on soil moisture and evapotranspiration

Wind plays an important role in the transpiration process (Jiyane and Gonzalez, 2003). It affects temperature, relative humidity, evaporation, transpiration, plant mechanical stress, and stomatal closure (Easterling *et al.* 1997; Cleugh *et al.* 2002). Strong winds increase turbulence thereby reducing the boundary layer resistance, improving the transport of water vapour towards the dry atmosphere. Increases or decreases of evapotranspiration as wind speed increases will depend on the conditions of the atmosphere and the surface (Jiyane and Gonzalez, 2003).

Reducing or sheltering against wind speed achieved the greatest reduction in evaporation when canopy cover was minimal, the atmosphere was dry and soil was wet, but decreased as canopy close-up (Cleugh *et al.* 2002). At peak wind speed of more than 5 ms^{-1}, soils dried more rapidly after rainfall events, but at decreasing rates with depth. Soil evaporation rates were observed to be 1.5-3.0 times greater in windy conditions when volumetric water content were above 20 % saturation. These soils reached air-dry limits when those in non-windy conditions had over 30 % available moisture. This conserved available moisture was utilized by plants and resulted in increased transpiration and therefore more biomass fixation.

Cleugh *et al.* (2002) and Zhang *et al.* (2004) observed that while overall seasonal evapotranspiration was unchanged, the benefit of increased water availability for crop growth (as a result of sheltering wind) conferred advantages in terms of final yield. However, soil evaporation forms a small component of overall seasonal evapotranspiration, while transpiration constitutes the largest proportion (Cleugh *et al.* 2002). For most plant canopies with limited water availability, canopy transpiration tends to be insensitive to wind speed, and that increased wind speed will favor convective heat transfer that may reduce canopy transpiration. Also when canopy resistance is low, reducing wind speed does not reduce evaporation (Allen *et al.* 1998).

2.6 Wind speed and CO_2assimilation

Loss of water vapor in plants occurs through cuticular transpiration and stomata, while CO_2 uptake into leaf is via stomata (Campbell-clause, 1998; Cleugh *et al.* 2002). If the stomatal resistance is increased by increase in wind velocity, the uptake of CO_2 is markedly reduced. Therefore yield improvement can be achieved if wind speed is restricted to levels that do not increase stomatal resistance nor result in water stress.

2.7 Kaolin properties and its mode of action

Kaolin is a soft white fine powder and chemically, is a hydrated aluminum silicate known as China clay of the formula: $H_2Al_2Si_2O_8\ H_2O$ and molecular mass of about 258 (Grim, 1968; Chamchaiyaporn *et al.* 2013). Kaolin and the clay mineral kaolinite are natural components of the soil and occur widely in ambient air as floating dust. It has a density of 2.1 to 2.6 gm cm^{-3}. The cation exchange capacity of soils with kaolinite clay is considerably less than that of montmorillonite, of the order 2 to10 meq per 100 gm, depending on the particle size. However, the rate of the exchange reaction is quite rapid, and almost instantaneous (Grim, 1968). Kaolin has excellent adsorbent, reflective and cell membrane stabilizing properties. (Schiffenbauer and Stotzky, 1982; El-kholy *et al*. 2005). It is locally available and is used as a remedy for diarrhea (dysentery), and cholera in livestock (CIREP, 2003).

Recent studies have shown that kaolin is a good antitranspirant due to its reflective properties. These reflective properties have made it find its new uses in crop production where it is ideal for ameliorating the effects of high insolation on field crops (El-Kholy *et al*. 2005; Glenn, 2013). Heat stress is a major limiting factor in plant productivity, since it increases leaf and canopy temperatures and VPD (Lobell *et al*. (2013). Combination of high leaf temperatures and high levels of PAR greater than 1600 µmol m^{-2} s^{-1} leads to reduction in size of stomata opening (Glenn, 2009), despite favorable soil moisture conditions. This leads to decline rates of transpiration and also reduction in CO_2 concentration in the intercellular spaces of the mesophyll cells, resulting in reduced rates of photosynthesis (midday depression in photosynthesis) and therefore low biomass(Glenn, 2009; Chamchaiyaporn *et al*. 2013).

Studies on foliar use of kaolin in hot and drier environments characterized by high VPD and high levels of PAR showed that the reflective nature of the resulting plant surfaces resulted in reduced leaf temperatures and therefore low heat load in the leaf canopy. This resulted in reduced transpiration rates, but low temperatures that were conducive for continued opening of stomata.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

The research was conducted in two seasons, the long rains of 2007 and the long rains of 2008. It should be noted that the April 26th to 3rd August 2007 season and the April 26 to 3rd August 2008 season of the study are also referred to as, “the relatively wetter season I”, and “the relatively drier season II”, respectively. Cumulative crop evapotranspiration during the growing period shall herein be referred to as “seasonal evapotranspiration”, or “evapotranspiration”. From the onset, it is important to point out that the region’s long rains are under constant modulation by the quasi-biennial oscillation, where one year of higher rainfall is followed by a year of lower rainfall (Muti and Nge’tich, 2009).

3.2 The study site

The study was carried out at Pwani University Crop Science farm, located at an altitude of 10-15m,above sea level (ASL) and at latitude $3^{o}49'S$ and longitude $39^{o}80'E$, in the Coconut/cassava Agro-ecological zone $CL_{3,}$ in Kilifi district. Annual maximum and minimum temperature range was28-30^{o}C, and 20-23^{o}C, respectively (Jaezold and Schmidt, 1983). Annual rainfall was 1100mm. Soils were mainly sandy loam with pockets of clay loam, with a pH of 5.5, but poor in organic matter (Wekesa *et al*. 2003).

3.3 Materials

Pwani hybrid 4 maize variety was bought from local stockiest and planted in all experimental plots. It was of medium maturity period of 120 days and yield potential of 4.5 to 6.5 tons ha^{-1}. It had a tendency to give 2 cobs per plant in optimal conditions and good grain filling characteristics (Wekesa *et al.* 2003). Kaolin powder was sourced locally, in packages of 100 gm and was prepared to a suspension of 6 % concentration by mixing 60 gm in a litre of clean water. Coir mulch dust, a by-product of coconut industry was sourced from Cocos factory in Kilifi. It is locally and readily available in coastal region of Kenya. It has low bulk density, and spongy. It is mainly used as a potting media in horticulture industry.

3.4 Experimental layout and design

A 2x2x4x3 split-split plot design with three replications was used (Fig 3.1). Allocation of treatments in blocks (replications), main plots, subplots and sub-subplots was completely randomized. Plot sizes were 6.0 m x 4.0 m. Paths between plots and sub-plots were 1m wide and between blocks 1.5 m.

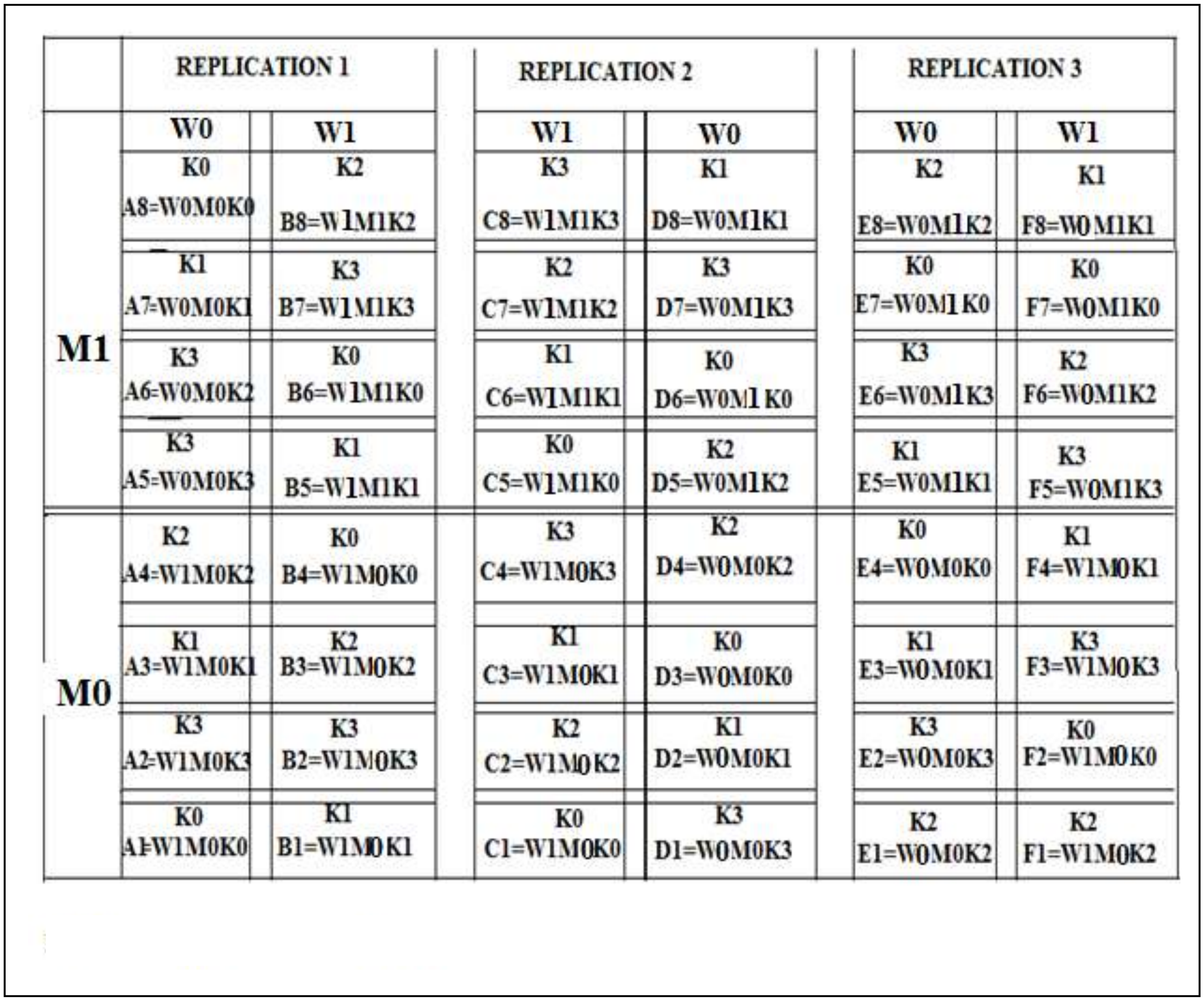
3.5 Treatments

3.5.1 Main plots: Coir dust mulch treatment was allocated to main plots. The coir dust mulch was applied at 2 levels; i) with coir dust mulch (M1) and ii) without coir mulch (M0). For the plots receiving mulch treatment, a layer of 0.1 m (based on El-kholy, 2004) coir dust mulch was applied within and between the plant rows 7 days after germination (to allow plant height of 10-15 cm and relatively stronger stem).

3.5.2 Sub-plots: soil moisture level (irrigation) treatment was allocated at sub-plot level.
The soil moisture treatment was at two levels; rain-fed (W0) and W1, where supplementary irrigation was applied when the soil moisture content in the treatment plots fell below 75 % saturation (or 37.5 mm ha^{-1}) using KARI drip kit system, with emitters at every 0.3 m along the row.

3.5.3 Sub-sub-plot: kaolin treatment (time of application)

A kaolin suspension at 6 % concentration was applied at 4 levels, based on time of kaolin application (K) in relation to stages of maize growth, in days after sowing (DAS). The kaolin is sprayed using a hand held knapsack sprayer on maize foliage (twice at every stage of maize growth, at 5 day interval), when the maize crop was at 25-35, 40-50 and 50-65 days after sowing (DAS). The control treatment was not applied kaolin.



	REPLICATION 1		REPLICATION 2		REPLICATION 3	
	W0	W1	W1	W0	W0	W1
M1	K0 A8=W0M0K0	K2 B8=W1M1K2	K3 C8=W1M1K3	K1 D8=W0M1K1	K2 E8=W0M1K2	K1 F8=W0 M1K1
	K1 A7=W0M0K1	K3 B7=W1M1K3	K2 C7=W1M1K2	K3 D7=W0M1K3	K0 E7=W0M1 K0	K0 F7=W0M1K0
	K3 A6=W0M0K2	K0 B6=W1M1K0	K1 C6=W1M1K1	K0 D6=W0M1 K0	K3 E6=W0M1K3	K2 F6=W0M1K2
	K3 A5=W0M0K3	K1 B5=W1M1K1	K0 C5=W1M1K0	K2 D5=W0M1K2	K1 E5=W0M1K1	K3 F5=W0M1K3
	K2 A4=W1M0K2	K0 B4=W1M0K0	K3 C4=W1M0K3	K2 D4=W0M0K2	K0 E4=W0M0K0	K1 F4=W1M0K1
M0	K1 A3=W1M0K1	K2 B3=W1M0K2	K1 C3=W1M0K1	K0 D3=W0M0K0	K1 E3=W0M0K1	K3 F3=W1M0K3
	K3 A2=W1M0K3	K3 B2=W1M0K3	K2 C2=W1M0K2	K1 D2=W0M0K1	K3 E2=W0M0K3	K0 F2=W1M0K0
	K0 A1=W1M0K0	K1 B1=W1M0K1	K0 C1=W1M0K0	K3 D1=W0M0K3	K2 E1=W0M0K2	K2 F1=W1M0K2

Figure 3.1: Split-Split-Plot Layout and Design

Key:

A1, A2, A3…; B1, B2 ……. Denotes plot numbers within a given sub-plot

Treatments:

M0= No mulch applied; M1= Coir dust mulch applied (at 0.1 m layer); W0= No irrigation applied; W1=Irrigation applied; K0=No Kaolin applied; K1= Foliar applied Kaolin at 25-35 DAS (Days after sowing maize = vegetative stage); K2= Foliar applied Kaolin at 40-50 DAP = Floral initiation/ taseling stage; K3= Foliar applied Kaolin at 50-65 DAP= Grain-set/grain-filling stage

3.6 Sowing and agronomic practices

Pwani hybrid 4 maize was sown at a spacing of 0.75 m by 0.3m, two seeds per hill (Wekesa *et al.* 2003). DAP and CAN fertilizers were used at a rate of 109 kg ha^{-1} as basal and 306 kg ha^{-1} as top dress fertilizers respectively (FURP, 1998). Three manual weeding was carried out, at 15, 45 and 65 DAS. Weeding in coir mulched plots was done by picking out emerging weeds. Bulldock (carbo-furan) granules were used to control maize stalk borer at a rate of 10 kg ha^{-1} at 45 DAS, and at 75 DAS. All other agronomic practices were carried out as recommended by KARI (Mulaa *et al*. 2004).

3.7 Sampling

Sampling was done fortnightly, with irrigated plots being sampled just before and 24hrs after irrigation (Zhang *et al*. 2004). The following parameters were measured at intervals of 17 days to allow for sufficient growth differences: Plant height, above ground dry matter, stomatal conductance, transpiration and solar radiation interception. For above ground biomass determination, destructive sampling of three randomly selected plants per plot was carried, starting from 15 days after sowing (DAS).

3.8 Parameters measured and their determination

3.8.1 Above ground biomass

This was determined by weighing oven dried harvested samples (at 70^{0}C to a constant weight) as described by Steduto and Hsiao, (1998). Three plants per plot were sampled at 31, 49, 66, 83 and at 100 DAS.

3.8.2 Net radiation (Rn), soil temperatures and daily bright sunshine

Net solar radiation was measured using pyranometer (decagon devices) located 1.5m above the soil surface from 7:00 am up to 6:00 pm (Villalobos *et al.* 2004). Soil temperatures were measured at 0.05 m and 0.1 m depths in three different places per plot, at 09:00 hrs; 14:00 hrs and 17:00 hrs using soil thermometer.

3.8.3 Air temperatures and % Relative humidity

Maximum and minimum temperatures were measured using air thermometer while % relative humidity was measured using dry and wet bulb thermometers. These instruments were placed at standard height of 1.5 m above soil surface, and when the crop height approached 1.5 m, the instruments were placed at a height of 2 m.

3.8.4 Wind speed and rainfall

This was measured using wind anemometer placed at standard height of 2 m above ground, and at least 60 cm above maize canopy. Rainfall amounts were obtained from Pwani University weather station.

3.8.5 Determination of water balance

Change in available soil water content was related to evapotranspiration using equations(1) and (2) from which either of them was estimated (Allen *et al*. 1998)

$\Delta S = (P+I+C)-(R+D+E+T)$---(1)

where: Gains-Losses = Change in storage. Since E+T = ETc, then

$ETc = I+P+C-D-R-\Delta S$--(2)

Where ETc = actual evapotranspiration; ΔS=change in soil moisture content of the root zone, P= rainfall; I = irrigation input, R = run off from the field, D = downward drainage out of the root zone, E = evaporation from the soil, T = transpiration from plant canopy, C = capillary contribution from the water table. Assumptions made were that i) upward movement of soil moisture from deeper layers through capillarity was negligible, ii) surface run-off was negligible due to high porosity of the soils iii) deep drainage was negligible.

3.8.6 Soil parameters and moisture content

Soil porosity, bulk density, texture, nitrogen, phosphorus, potassium, CEC, Electrical and hydraulic conductivity were determined as described by Tandon, (2001).Soil moisture contentwas measured at intervals of 20 cm up to a depth of 1.0 m. The 0-20 cm depth soil moisture content was determined using gravimetric method, while soil moisture content for depths beyond 20 cm was determined using neutron probe as described by Greacen (1981). For

the irrigated plots, it was measured before and 24 hours after each watering; at emergence and at physiological maturity (d' Andria *et al.* 1997). The neutron probe was first calibrated in situ using undisturbed core samples. Thereafter, it was inserted in pre-drilled holes in which PVC access pipes were inserted to respective depths and counter readings taken. The upper soil surface 0-0.15 m depth moisture content was measured by gravimetric, since use of neutron probe at this depth would result in stray high speed neutrons in the air and being absorbed by organic matter at the top soil leading to erroneous readings.
method as per the equation given by Socias and Medrano, (1994):

SWC % = 100(SFW-SDW)/SDW---(3)

Where SFW were soil fresh weight samples and SDW were dry weight soil samples.

3.9 Yield production functions

Crop evapotranspiration-Yield production functions were developed using the model equations outlined by Singh *et al.* (1987), Kumar *et al.* (1997) and Allen *et al.* (1998) and were used to estimate seasonal yield response factor (Ky) for Pwani hybrid 4 maize.

$Y=a+b\,[1-(1-ET/ET_m)^2]$……………………………………………………………(4)

$[1-(Y_a/Y_m)]=K_y[1-(ET_a/ET_m)]$…………………………………………………………(5)

Where Y is crop yield due to seasonal evapotranspiration for various growth sub-periods; a and b are empirical constants; ET_m is the maximum evapotranspiration corresponding to maximum crop yield; ET is actual evapotranspiration for a given growth sub-period; Y_a, is actual yield; Y_m is maximum yield obtained in well irrigated, non-stress conditions; K_y, is the yield response factor, which describes the reduction in relative yield due to reduction in seasonal evapotranspiration as a result of increased soil moisture deficit (Allen *et al*. 1998; Kumar *et al*. 1997).

The relationship between the dependable variable, Yield (Y), to independent variables, Kaolin, mulches, time of Kaolin application and evapotranspiration were investigated using multiple regression analysis model equation:

$Y=\alpha+\beta X_1+\beta_2X_1{}^2+\beta_3X_2+\beta_4X^2{}_2+\ldots\ldots\ldots.+\beta_\kappa X_\kappa, +\epsilon_{ijk}$,--(6)

Where X_1, $X_{2,}\ldots\ldots X_k$ are single k independent variables i.e. Kaolin application time, coir dust mulch, and soil moisture levels, βs=the partial regression coefficients associated with each independent variable X, ϵ_{ijk} is the error term for unaccounted variables, α is the Y-intercept when all Xs have zero values.

3.10 Data analysis

General linear models (GLM) procedure of Genstat Discovery 14th Edition (2011) Program and was used in the analysis of the data. Analysis of variance (ANOVA) tables of means, for the treatments were generated and thereafter, regression analysis over the treatments was done. Comparison of means of maize yield, crop evapotranspiration, and other parameters for the different treatments were done using protected (LSD) and New Duncan's multiple range test. The ET-yield production functions were developed using the means.

CHAPTER FOUR

RESULTS

4.1 Rainfall characteristics during long rains in seasons I and II

The long rain of season II (2008), namely April –July, had lower rainfall amounts than the long rains of season I (April – July of 2007) by 11 % (Table 4.1). Season I (2007) long rains’ period received 28.8 % of the total rainfall. For the same time period, season II (2008) long rain season received 23 % of the total rainfall. The rainfall distribution was slightly better in season II than in season I where over 57.8 % of the growing season’s rainfall was received in May alone (Table 4.1).

The monthly rainfall and potential evapotranspiration during the study period showed that in a whole year, only two months experienced positive moisture regime for crop growth, namely April and May which fall within the long rains season. In all other months, the potential evaporation exceeded received rainfall (Table 4.1).

Table 4.1 Monthly rainfall, potential evaporation and net moisture regime in Kilifi during study period

	2007				2008			
Season	Rainfall	% of L/Rain's rainfall	Potential evaporation	Net moisture	Rainfall	% of L/Rain's	potential evaporation	Net moisture
Month								
January	1.5	0.1	210	-208.5	28.5	2.9	220.5	-192
February	0.5	0	197	-196.5	2	0.2	216.85	-214.85
March	15.5	1.4	215	-199.5	127	12.9	230.8	-103.8
April	184	16.6	186	-2	74	7.5	195.3	-121.3
May	640.5	57.8	171	**469.5**	463.5	46.9	179.55	**283.95**
June	198	17.9	156	**42**	188	19	150.6	**37.4**
July	67.5	6.1	156	-88.5	104.5	10.6	163.8	-59.3
L/R Totals	1107.5	100	1291	-183.5	987.5	100	1357.4	-369.9
August	148		175	-27	50.5		190	-139.5
September	121.5		191	-69.5	43		205.4	-162.4
October	60.5		202	-141.5	34		212.1	-178.1
November	25		195	-170	160		204.75	-44.75
December	93.5		205	-111.5	8		215.25	-207.25
Year totals	1556		2259	-703	1283		3742.3	-2459.3

4.2 Effect of coir dust mulch on evapotranspiration of Pwani hybrid 4 maize

During the relatively wetter and drier seasons I and II, seasonal evapotranspiration in coir mulched and non-mulched maize crops (Plates 1 and 2) increased as the maize crop advanced in age, as illustrated by the production functions shown in Figure 4.1.The Pwani hybrid 4 maize seasonal evapotranspiration increased at an average rate of 157.5 mm ha^{-1} and 151.3 mm ha^{-1} per phasic growth stage during the relatively wetter season I, and 156.3 mm ha^{-1} and 151.0 mm ha^{-1}during the relatively drier season II in coir mulched and non-mulched maize crops, respectively.

The basal evaporation was 534.2 mm ha^{-1}and 549.6 mm ha^{-1}in coir mulched and non-mulched maize crop, respectively, during the relatively wetter season I (Fig 4.1).However, season II had lower basal evaporation of 167.7 mm ha^{-1} and 190.1 mm ha^{-1}, in coir mulched and non-mulched maize crops, respectively. In season I the maize crop lost 13.36 % more water than during the relatively drier season II. The coir mulched treatments resulted in conservation of 9.2 %more moisture in season I and 11.8 % in season II than the non-mulched treatments. The relatively wetter season I had higher ($p \leq 0.05$) evapotranspiration than the relatively drier season II (Table 4.2). In both seasons, significant differences in seasonal evapotranspiration between coir mulched and non-mulched maize crops, were only notable at 0-31DAS. Thus, during the wetter season I, coir mulched maize crop lost 2 % more water ($p \leq 0.05$) than non-mulched crop.

During the relatively drier season II, non-mulched maize crop lost a significant 310.8 mm ha^{-1} of water at 0-31 DAS than coir mulched maize crop with 291.4 mm ha^{-1} (Table 4.2). Although there were no significant differences in seasonal evapotranspiration beyond 31 DAS in both seasons, non-mulched maize crop lost more soil water than coir mulched maize crops between the 31-49 DAS and 49-66 DAS phasic growth periods (Table 4.2). By the end of the season at 100 DAS, coir mulched treatments had final evapotranspiration of 1362.7 mm ha^{-1} in season I and 952.9 mm ha^{-1} in season II. The maize crop in non-mulched control (M0W0 treatment) had final seasonal evapotranspiration of 1333.5 mm ha^{-1} and 950.8 mm ha^{-1} in seasons I and II respectively. The coir mulched treatments maintained significantly higher levels of soil moisture that were 10.6 %; 6.8 % 12.1 % and 17.9 % more than those of non-mulched treatments at 31-49; 49-66; 66-88 and 83-100 DAS.

Table 4.2 Effect of coir mulch treatments on evapotranspiration and 100 cm crop available soil moisture under Pwani hybrid 4 maize in seasons I and II in Kilifi.

Seasons	**Season I (Apr 26th – 3rd Aug 2007)**						**Season II (Apr 26th – 3rd Aug 2008)**					
Date (DAS)	0	31	49	66	83	100	0	31	49	66	83	100
Treatments	Evapotranspiration in mm ha^{-1}											
M0		661.5b	246.1a	130.9a	38.5b	256.5b		310.8	206a	174.2	56.6a	203.2a
M1		675.4a	207.7b	146.2a	54.8a	278.6a		291.4	216.1a	176.8	63.7a	204.9a
Mean		668.5	226.9	138.6	46.7	267.6		301.1	211.1	175.5	60.2	204.1
LSD (5%)		4.8	24.2	23.9	5.2	8.6		3.5	16.3	2.0	18.7	1.4
Sed		1.1	5.6	5.6	1.2	2.0		0.8	3.8	0.5	4.3	0.3
	Seasonal evapotranspiration in mm ha^{-1}											
M0		661.5b	907.6	1038.5	1077	1333.5		310.8	516.8	691	747.6	950.8
M1		675.4a	883.1	1029.3	1084.1	1362.7		291.4	507.5	684.3	748	952.9
Mean		668.5	895.4	1034	1080.7	1348.3		301.1	512.15	687.6	747.8	951.85
LSD (5%)		4.8	29	52.9	58.1	66.7		3.5	19.8	21.8	40.5	41.9
Sed		1.1	6.7	12.3	13.5	15.5		0.8	4.6	5.1	9.4	9.7
			NS	NS	NS	NS			NS	NS	NS	NS
	100 cm -soil Profile moisture content in mm ha^{-1}											
M0	326.2a	260.7a	249.0b	161.4b	225.2b	29.0b	119.7b	213.9b	131.4	128.8	126.3b	26.6
M1	328.0a	248.6b	275.4a	172.4a	252.5a	34.2a	121.6a	235.2a	142.6	137.5	128.0a	26.6
Mean	327.1	254.6	262.2	166.9	238.9	31.6	120.6	224.5	137.0	133.1	127.2	26.6
LSD (5%)	2.52	3.94	14.87	6.73	8.02	0.02	0.79	2.62	15.12	15.37	1.33	0.02
Sed	0.586	0.915	3.460	1.560	1.860	0.005	0.183	0.609	3.514	3.572	0.310	0.004
	NS								NS	NS		NS

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

However, these amounts declined as the maize crop advanced in age towards maturity (Table 4.2 and Fig 4.19a). Between the period 49-66 DAS and 66-83 DAS, there was a decline in the amounts of evapotranspired water in both seasons (Fig 4.1 and 4.19b).

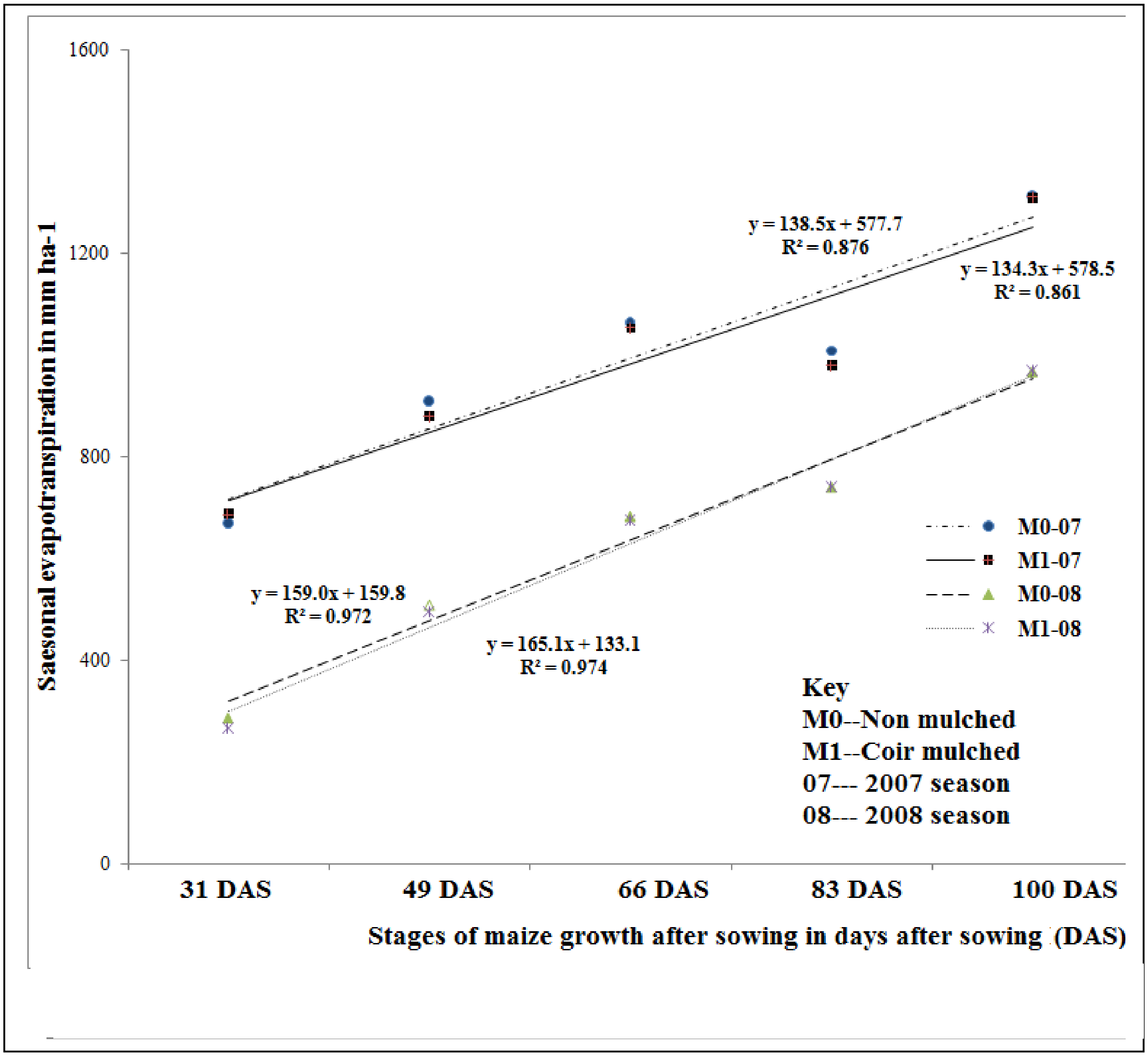


Figure 4.1: Effect of coir dust mulch on seasonal evapotranspiration of Pwani hybrid 4 during the wetter and drier seasons I and II in Kilifi

Plate 1: Temporary water logging observed early in the relatively wetter season I resulted in reduced growth rates of Pwani Hybrid 4 Maize

Plate 2: Coir mulched maize.
Note the 10.0cm layer of coir mulch was able to cut off solar radiation resulting in reduced soil head load and therefore lower rates of evapotranspiration

4.3 Effect of coir dust mulching on above ground biomass yield of Pwani Hybrid 4maize

Biomass of Pwani hybrid 4 maize in coir mulched and non-coir mulched treatments increased as the maize crop advanced in age towards maturity in both seasons (Fig 4.2). The best fit regression functions indicated that daily rates of biomass accumulation during the relatively wetter and drier seasons I and II increased in a parabolic pattern (Fig 4.3). In season I, coir mulched and non-mulched maize crops had a longer period of biomass accumulation with the rates of growth increasing to a peak plateau at 90 DAS, and yielding final biomass of 14.2 and 14.9 tons ha^{-1} respectively (Fig 4.3). However, beyond this period, the growth rates started declining. Beyond 49 DAS, non-mulched maize crop maintained higher growth rates compared to coir mulched maize crop (Fig 4.3). During early stages of growth between the period 31-49 DAS in season II, the coir mulched and non-mulched maize crop had significant ($p \leq 0.05$) 45.7 % higher rates of growth compared season I which resulted in significantly ($p \leq 0.05$) 44.9 % higher biomass of 4.9 tons ha^{-1} in season II, compared to 2.7 tons ha^{-1} of season I. The maize crop during season II had a relatively shorter period of biomass accumulation compared to season I.

The non-mulched maize crop during season II maintained higher rates of growth, than coir mulched crop. However, this non-mulched maize crop attained peak maximum growth rates relatively much earlier and declined much faster than the coir mulched maize crop (Fig 4.3). Although coir mulched maize crop was observed to have significant ($p \leq 0.05$) increases in periodic evapotranspiration and 100 cm crop available soil moisture in both seasons, this increase in water loss did not result in any significant increases in above ground biomass.

Table 4.3: Effect of coir mulch treatments on above ground biomass and grain yield of Pwani hybrid 4 maize in seasons I and II in Kilifi

	Periodic biomass in tons ha^{-1}											
	Season I (2007)						Season II (2008)					
Growth stages (DAS)	31	49	66	83	100	Grain yield **(tons ha^{-1})**	31	49	66	83	100	**Grain yield (tons ha^{-1})**
M0	0.92	2.65	6.84	10.91	14.9	4.8	0.83	4	5.6	7.0	8.5	4.3
M1	1	2.77	6.84	10.64	14.2	5.3	0.68	5.7	7.5	9.0	10.5	4.5
Mean	0.96	2.71	6.84	10.775	14.55	5.1	0.755	4.85	6.5	8.0	9.5	4.4
LSD (5 %)	0.598	0.892	2.327	4.933	9.05	0.76	0.607	2.33	3.32	4.523	5.75	0.32
Sed	0.139	0.207	0.541	1.146	2.1	0.37	0.141	0.54	0.77	1.051	1.34	

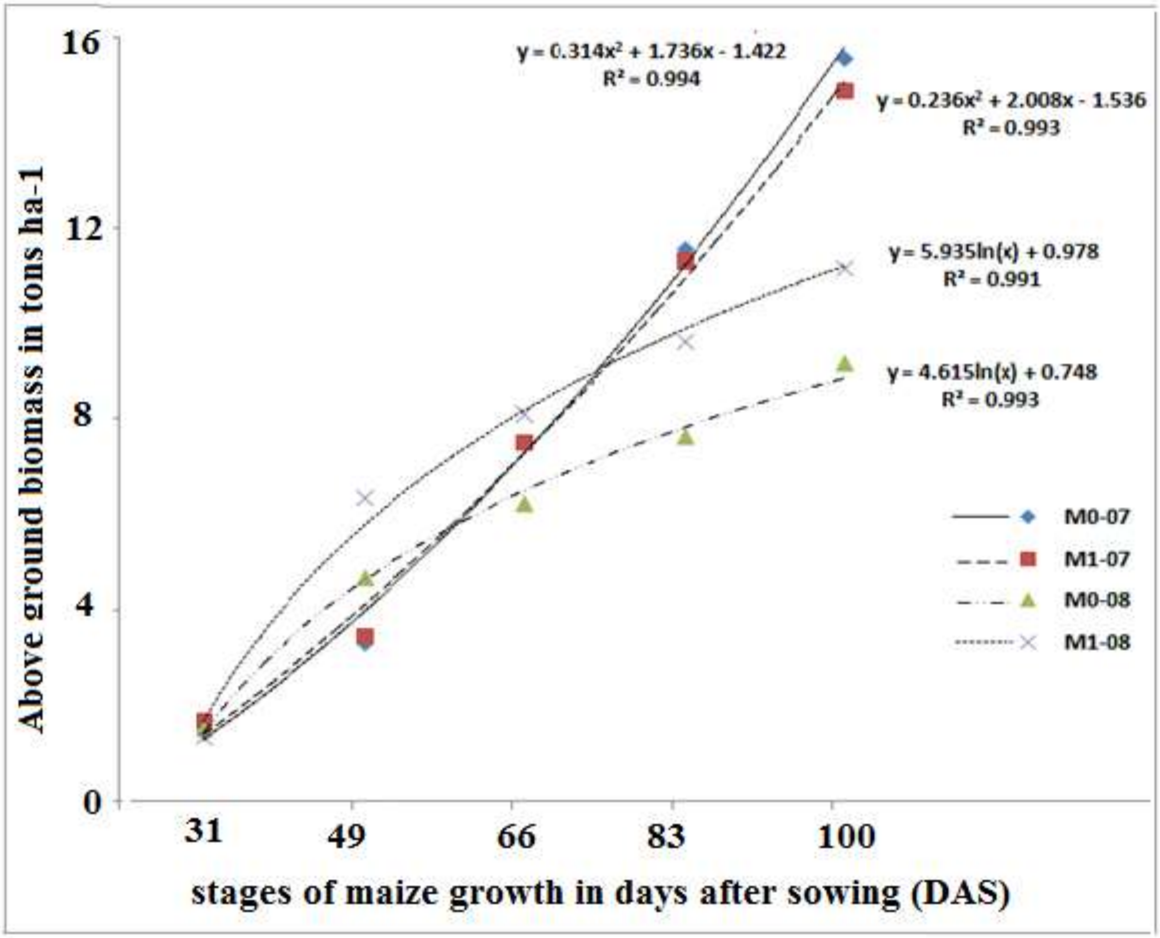


Figure 4.2: Pattern of above ground biomass accumulation in coir mulched and non-mulched maize crop during the wetter and drier seasons in Kilifi

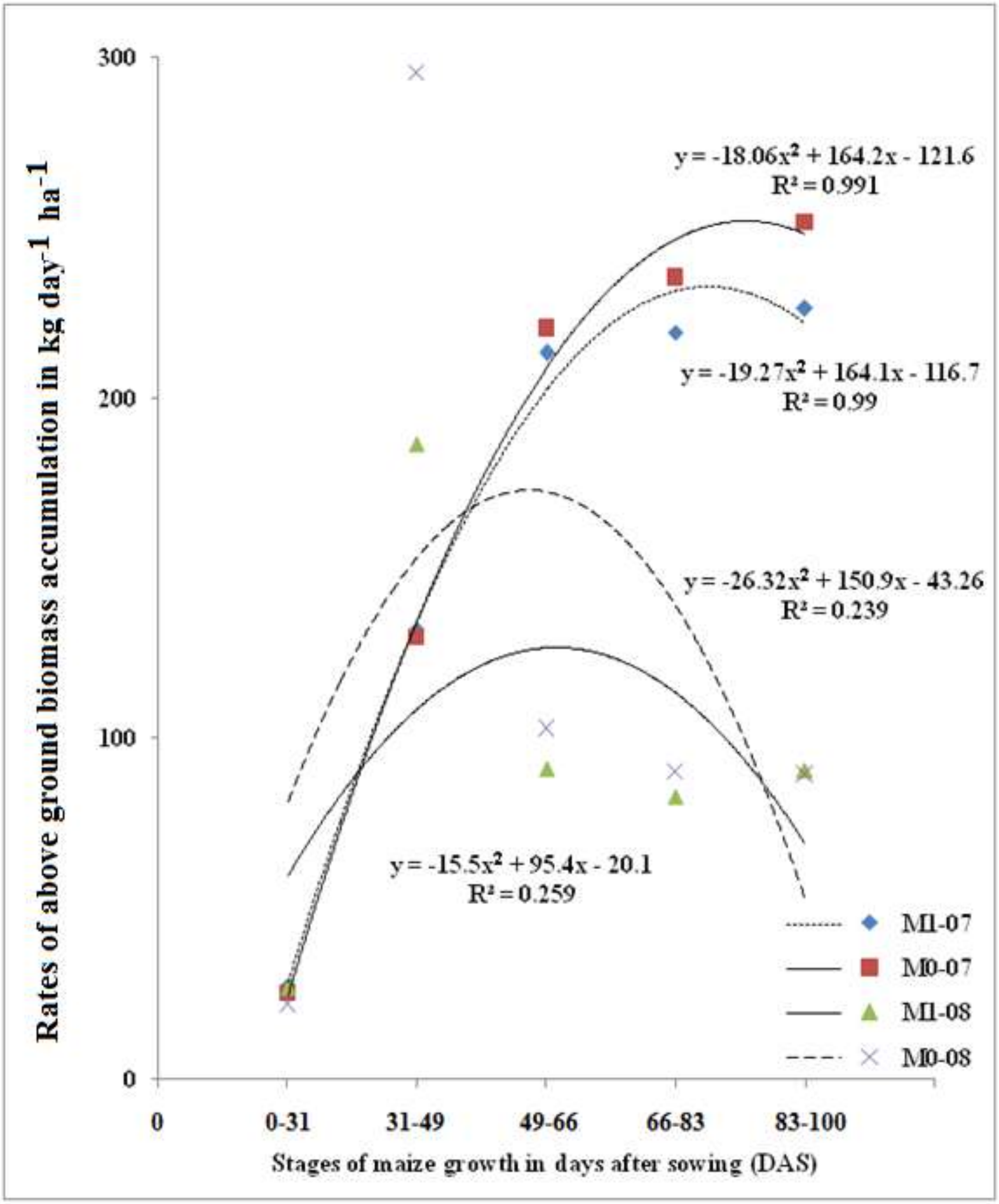


Figure 4.3: Pattern of dairy rates of above ground biomass of Pwani hybrid 4 maize due to coir mulching and non-mulched treatments during seasons I and II in Kilifi

4.4 Effect of coir mulching on grain yield of Pwani hybrid 4 maize

The grain yield obtained from coir mulched maize crop were not significantly different from those obtained in non-mulched maize crop in both seasons (Table 4.3). However the coir mulched maize crop yielded 10.7 % and 4.7 % higher grain yield over the non-mulched maize crop (control treatment)during the relatively wetter and drier seasons I and II, respectively.

4.5 Effect of foliar applied kaolin on evapotranspiration of Pwani hybrid 4 maize

Seasonal evapotranspiration of Pwani hybrid 4 maize increased linearly in season I and II for all treatments, as described by the linear functions shown in Fig 4.4.Seasonal evapotranspiration was higher ($p \leq 0.05$) during the wetter season I than during the season II (Table 4.4). Seasonal evapotranspiration at specific stages of maize growth were similar except at 0-31 DAS in season I, where application of kaolin at vegetative stages of maize growth (K1 treatment) resulted in significantly higher ($p \leq 0.05$) evapotranspiration than other kaolin treatments (Table 4.4). However, application of kaolin at floral stages of maize growth (K2 treatment) resulted in lowest significant ($p \leq 0.05$) evapotranspiration compared to when applied at vegetative (K1 treatment), or at grain-filling stages (K3 treatment). Application of kaolin at grain-filling stages (K3 treatment) resulted in higher final seasonal evaporation of 1357.5 mm ha^{-1} at100 DAS (Table 4.4). The basal evaporation values (Y-intercept) during the relatively wetter season I, was on 541.9 mm ha^{-1}, and was 67 % higher ($p \leq 0.05$) than during season II.

Kaolin application significantly increased periodic evapotranspiration throughout the relatively wetter season I. However, during season II, significant differences were at 31 DAS (Table 4.4). Thus, application of kaolin at vegetative stages (K1 treatment) during wetter season I resulted in highest significant ($p \leq 0.05$) periodic evapotranspiration at 31 and 66 DAS. Its application at floral stages (K2 treatment), resulted in highest significant ($p \leq 0.05$) periodic evapotranspiration at 31-49 DAS, while its application at grain-filling stages (K3 treatment) resulted in highest significant periodic evapotranspiration at 66-83 and 83-100 DAS, respectively (Table 4.4).K1 and K3 treatments during the relatively wetter season I occasioned comparable but opposite effects to those observed during the relatively drier season II (Fig 4.5). Application of kaolin at floral stages (K2 treatment) of maize growth gave consistent responses on % increases in periodic evapotranspiration, during the relatively wetter and drier seasons I and II at 31-49 DAS and 66-83 DAS (Fig 4.5).

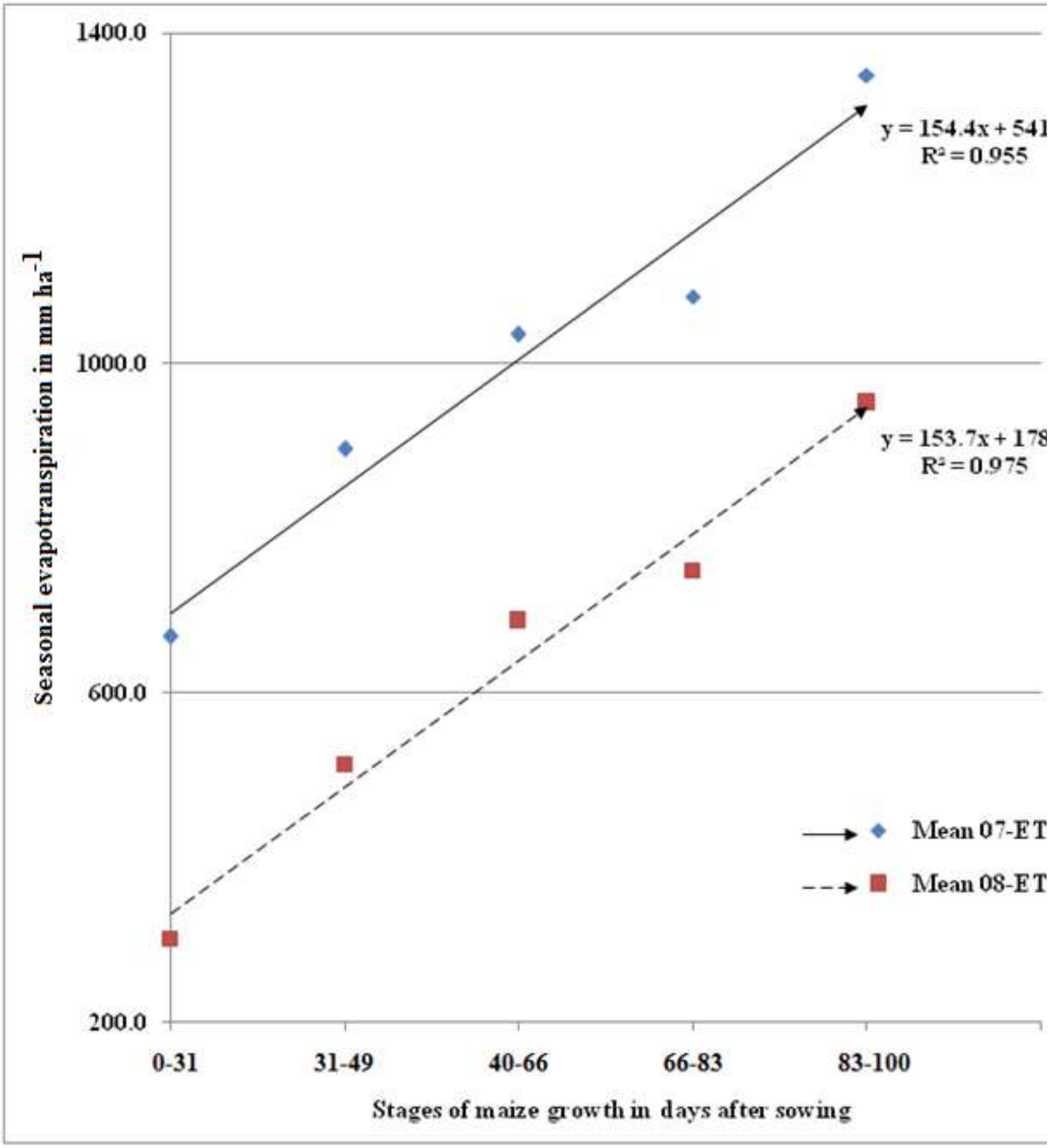


Figure 4.4: Comparison of basal seasonal evapotranspiration due to kaolin treatment on Pwani hybrid 4 maize crop during the wetter and drier seasons I and II, in Kilifi

Table 4.4: Effect of kaolin on evapotranspiration and 100 cm crop available due to Pwani hybrid 4 maize during seasons I and II, in Kilifi

Seasons	Season I						Season II					
Stages (DAS)	0	31	49	66	83	100	0	31	49	66	83	100
Treatments	Periodic evapotranspiration in mm ha^{-1}											
K0		664.8b	227.1b	138.5a	46.7ab	270.4ab		306.9	195.9c	176.5	67.6	203.8
K1		676.4a	214.9b	147.1a	46.7ab	265.1ab		298.0	223.5a	172.4	54.8	204.1
K2		662.7c	241.5a	132.1b	42.8b	258.8c		298.0	209.8b	178	60.4	203.6
K3		670b	224.3b	136.7a	50.5a	276a		301.5	214.9a	175.2	57.9	204.7
Mean		668.5	227.0	138.6	46.7	267.6		301.1	211.0	175.5	60.2	204.1
LSD (5%)		5.5	13.3	10.7	5.9	11		9.6	13	5.9	15.5	1.1
SED		2.7	6.5	5.2	2.9	5.3		3.6	4.9	2.2	4.8	0.4
								NS		NS	NS	NS
	Seasonal evapotranspiration in mm ha^{-1}											
K0		664.8b	891.9	1030.4	1077.1	1347.5		306.9	502.8	679.3	746.9	950.7
K1		676.4a	891.3	1038.4	1085.1	1350.2		298.0	521.5	693.9	748.7	952.8
K2		662.7c	904.2	1036.3	1079.1	1337.9		298.0	507.8	685.8	746.2	949.8
K3		670.0b	894.3	1031	1081.5	1357.5		301.5	516.4	691.6	749.5	954.2
Mean		668.5	895.4	1034.0	1080.7	1348.3		301.1	512.1	687.7	747.8	951.9
LSD (5%)		5.5	18.8	29.5	35.4	46.4			9.6	22.6	28.5	44
Sed		2.7	9.2	14.4	17.3	22.6			3.6	8.5	10.7	15.5
			NS	NS	NS	NS		NS	NS	NS	NS	NS
	100 cm crop available soil moisture content in mm ha^{-1}											
K0	326a	257.2a	264.7a	169.5a	241.4a	31.4a		217.6a	145.2a	140.3a	126.9a	26.6a
K1	328a	247.6b	267.2a	163.5a	235.4b	30.6a		228.6b	128.6b	127.8a	127.2a	26.6a
K2	324.9a	258.2a	251.2b	162.4a	230.5b	32.1a		225.5b	139.2a	132.9a	126.7a	26.6a
K3	329.5a	255.5a	265.7a	172.3ac	248.1bc	32.4a		226.6b	135.1a	131.6a	127.8a	26.6a
Mean	327.1	254.6	262.2	166.9	238.9	31.6		224.6	137.0	133.2	127.2	26.6
LSD (5%)	2.1	5.18	10.6	7.43	5.52	0.98		7.43	11.97	13.07	1.08	0.04
Sed	1.02	2.51	5.13	3.6	11.39	0.48		2.77	4.25	3.88	0.42	0.01

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

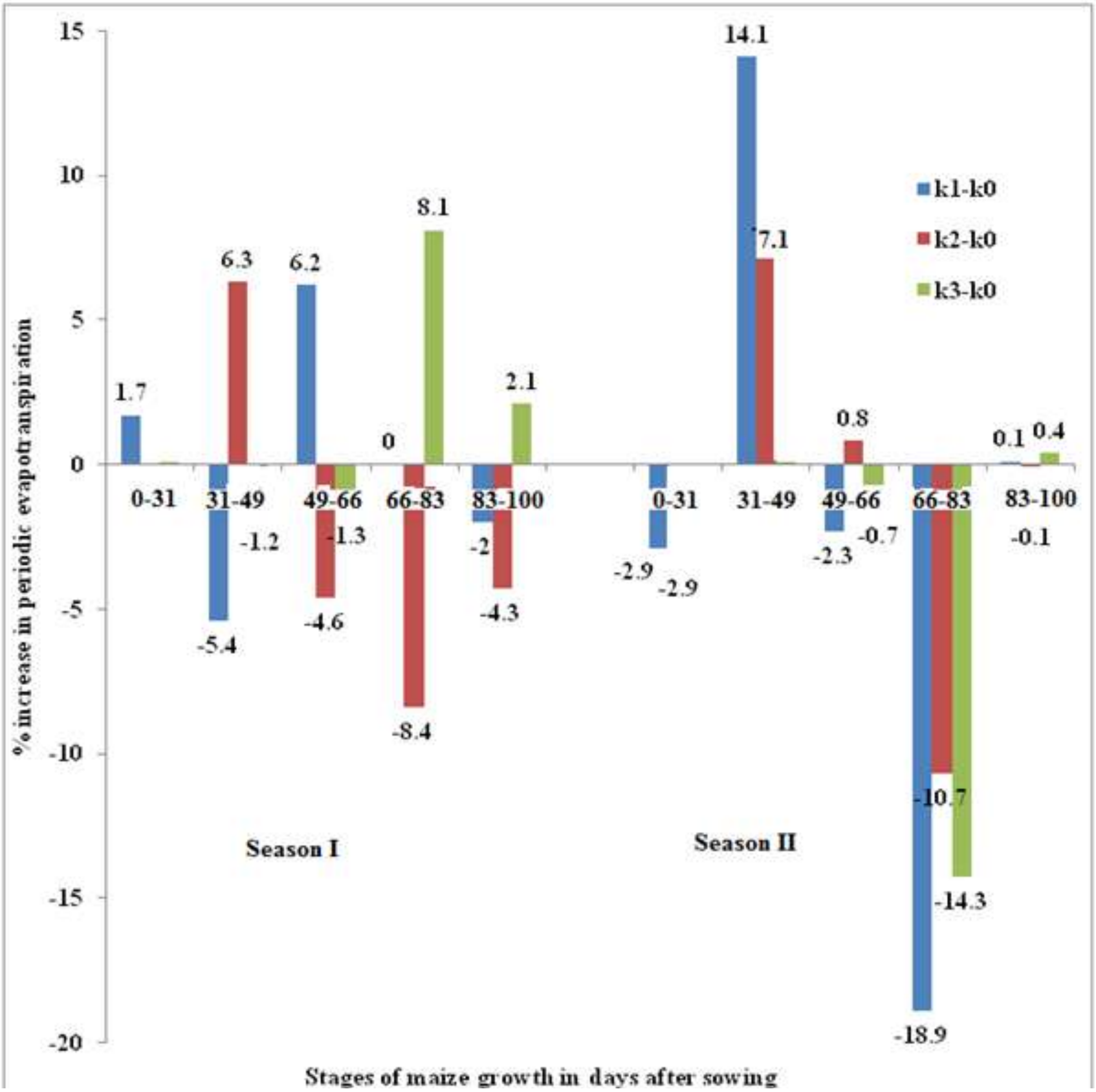


Figure 4.5: "Short and long term" effects of foliar applied kaolin on evapotranspiration of PH 4 maize crop at different stages of growth during the relatively wetter and drier seasons I and II, in Kilifi

4.6 Effect of foliar applied kaolin on biomass of Pwani hybrid 4 maize

Biomass of Pwani hybrid 4 maize increased in both seasons as the maize crop advanced in maturity (Fig 4.6). The biomass accumulation increased at an average rate of 3.5 and 2.0 tons ha^{-1} per phasic stage of maize growth during the relatively wetter and drier seasons I and II. Best fit regression functions revealed that biomass during the wetter season I increased in a hyperbolic manner (Fig 4.6),resulting in final biomass that ranged from 13.7 to 15.6 tons ha^{-1}. During the drier season II, the biomass increased in parabolic manner resulting in final biomass that ranged from 9.1 to 9.6 tons ha^{-1} (Fig 4.6). However, kaolin resulted in comparable biomass throughout the growing period.

Foliar application of kaolin resulted in attainment of peak maximum rates of growth at different stages of maize growth. Thus, application of kaolin during floral stages of maize growth (K2 treatment) resulted in prolonged period of biomass accumulation and highest growth rate at 83-100 DAS resulting in relatively highest final biomass (Fig 4.7). Its application at vegetative stages of growth (K1 treatment) resulted in second highest peak rates of growth at about 55-75 DAS, while its application at grain-filling stages resulted in attainment of peak growth rates at about 50-66 DAS. The control treatment (K0) had a peak growth rate of at 50-66 DAS (Fig 4.7). During the drier season II, the rates and period of peak maximum growth rates were comparable for all kaolin treatments, at about 45-50 DAS (Fig 4.7).

Kaolin had short and long term effect on biomass accumulation when percentage increase in biomass over the control treatment is considered, as shown in Figs. 4.8a and 4.8b. The effect of increase in % biomass was observed during the period when the maize crop was at 49-66 DAS, during the wetter season I, and during the period 0-31 DAS (Figs. 4.8a and 4.8b).

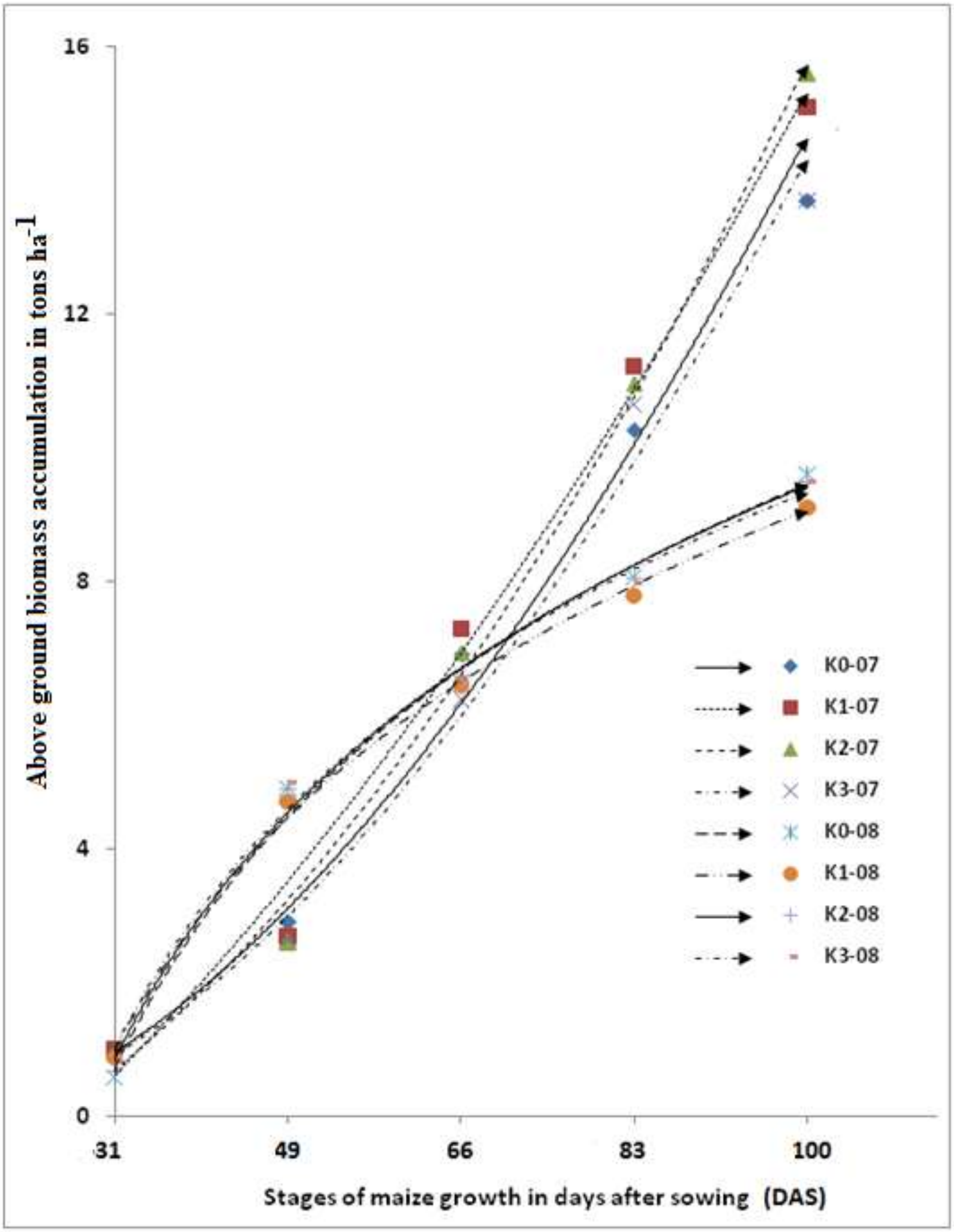


Figure 4.6: Pattern of above ground biomass of accumulation Pwani Hybrid 4 due to kaolin during seasons I and II in Kilifi

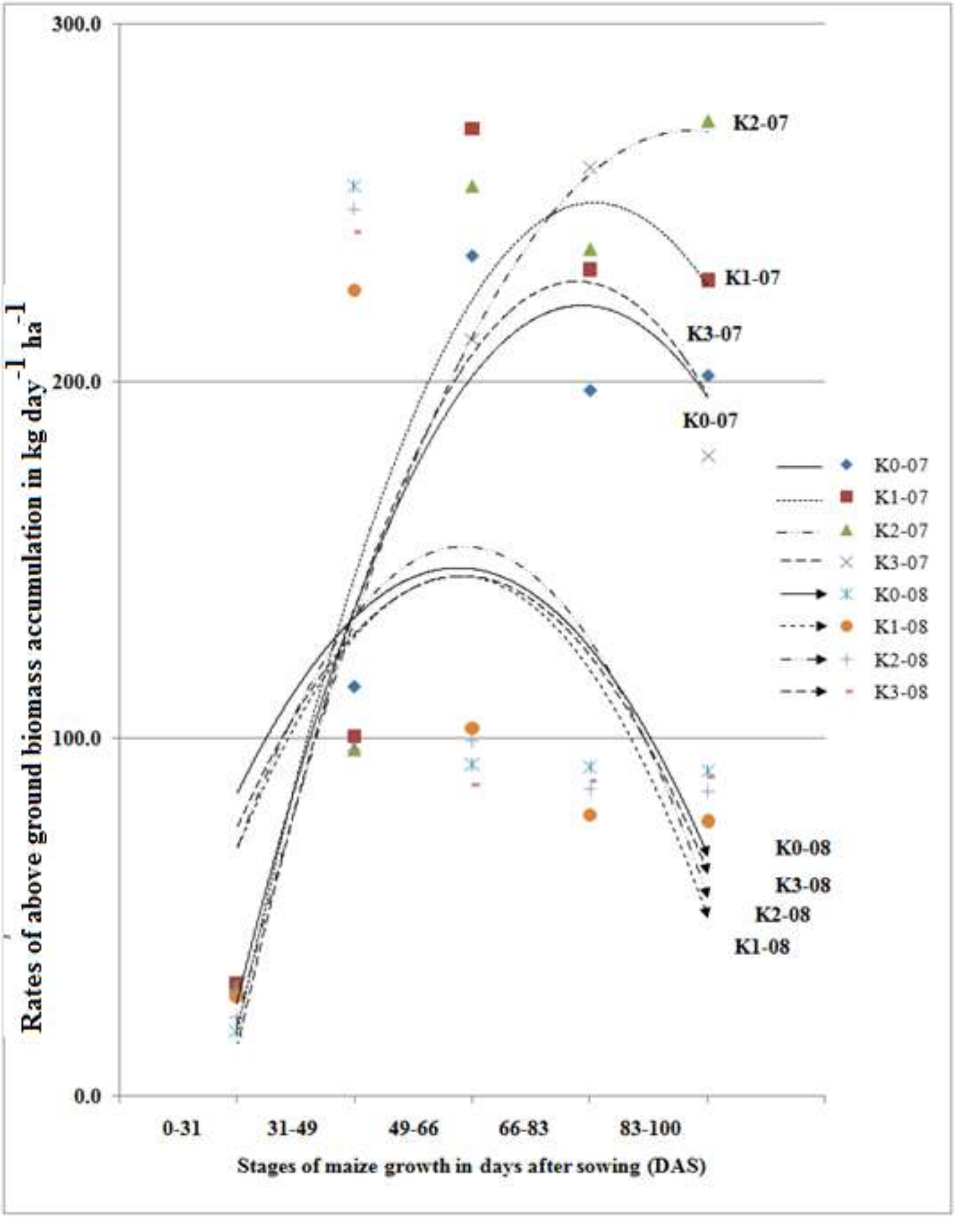


Figure 4.7: Patterns of daily rates of biomass accumulation of Pwani hybrid 4 due to kaolin treatments during seasons I and II in Kilifi

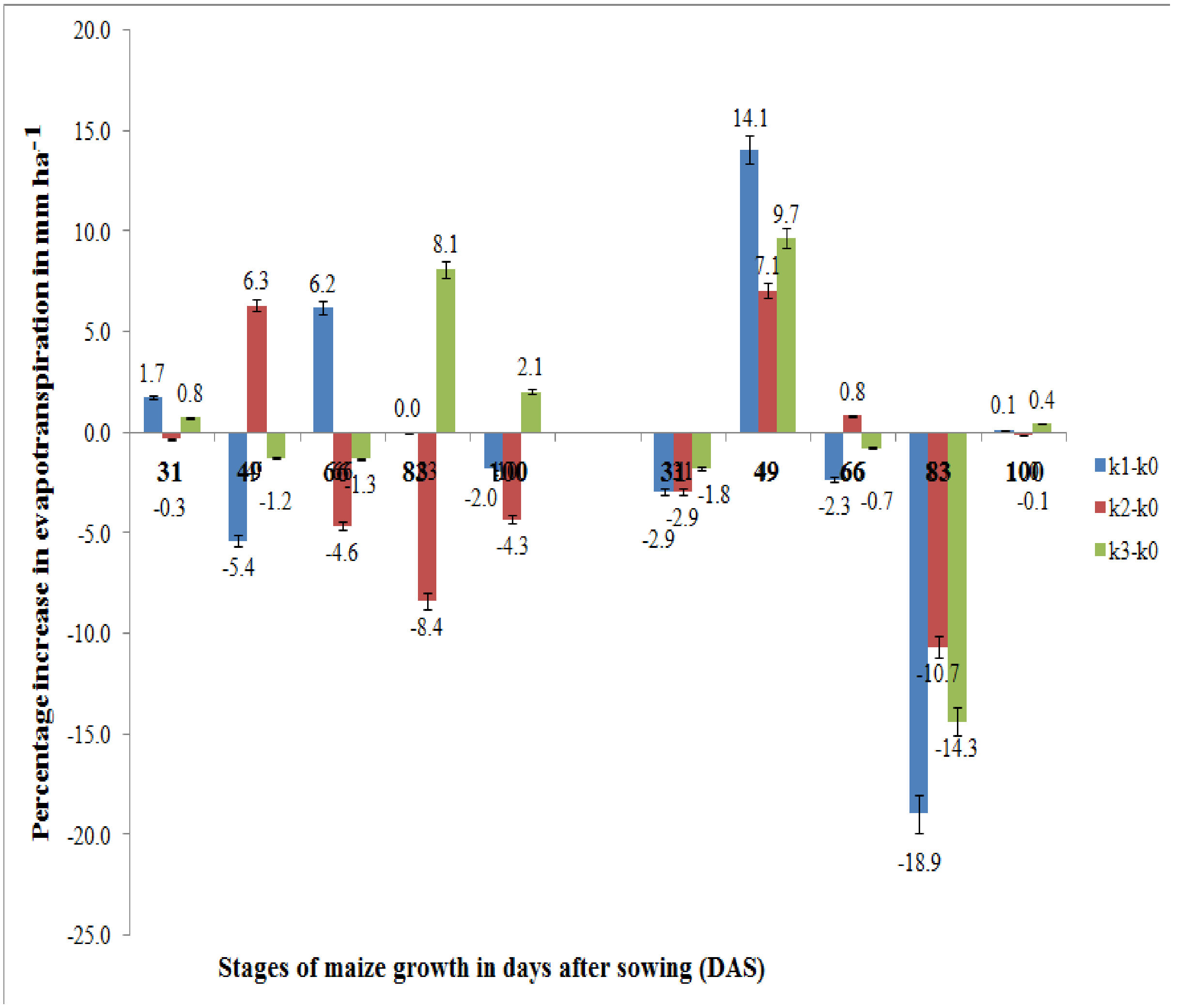


Figure 4.8a: "Short" and "long" term effect of kaolin on evapotranspiration of Pwani hybrid 4 maize crop at different stages of growth during the relatively wetter and drier seasons I and II Kilifi

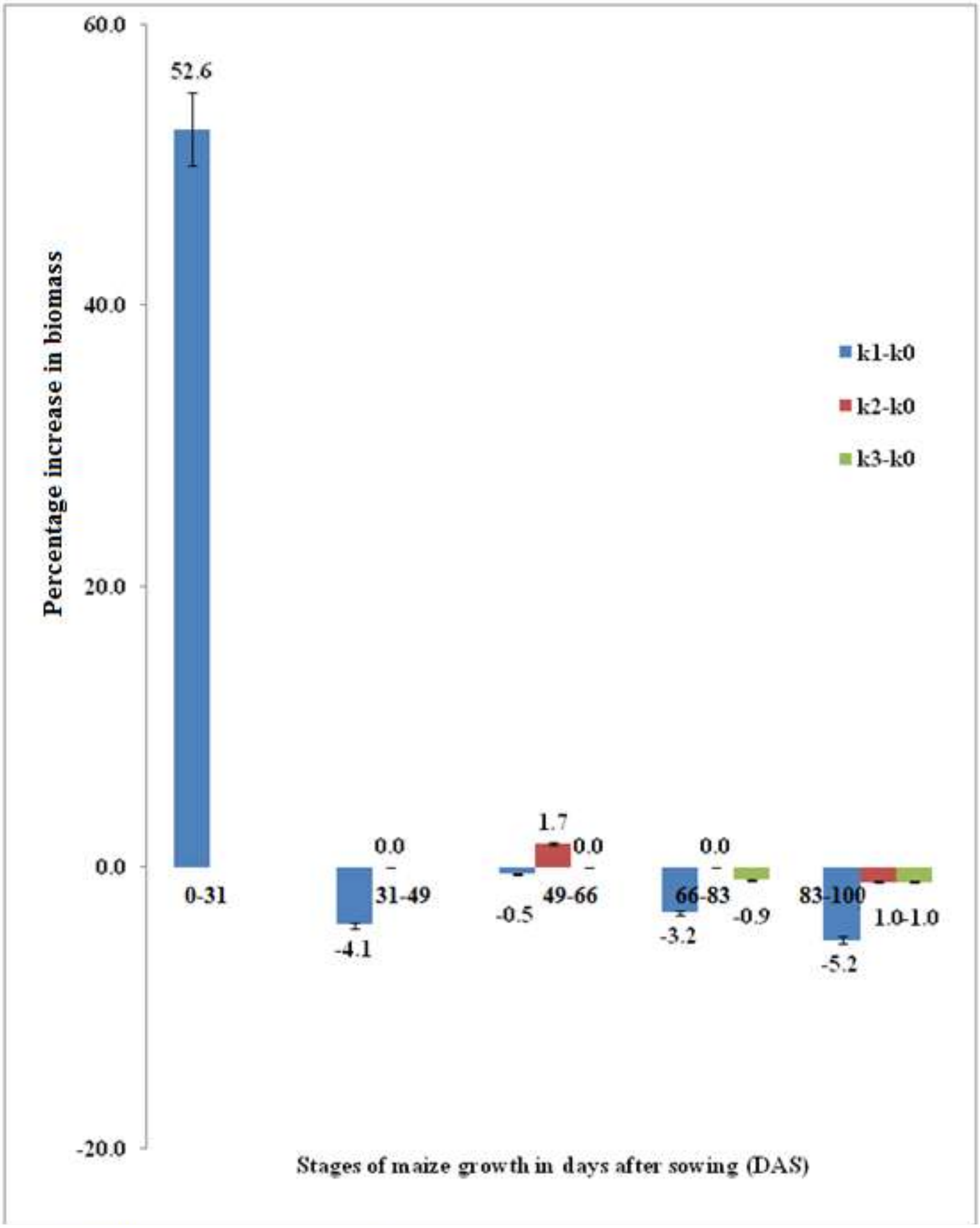


Figure 4.8b: "Short and long term" effect of kaolin on biomass accumulation of Pwani Hybrid 4 maize expressed as a percent increases in above ground biomass during the relatively drier season II, in Kilifi

4.7 Effectof foliar applied kaolin on grain yield of Pwani hybrid 4 maize

Kaolin treatments did not cause significant differences in grain although it resulted in reduced grain yield in both seasons. K0; K1; K2 and K3 treatments yielded 5.4; 5.3; 4.5 and 4.9 tons ha^{-1} of grain. However its interactions with other coir mulch and irrigation treatments moderated the levels of grain yield.

4.8 Interactions of coir mulch and irrigation on evapotranspiration of Pwani hybrid 4maize

Seasonal evapotranspiration of Pwani hybrid 4 maize increased for all coir mulched and irrigation interactions in both seasons as the maize crop advanced in age (Table 4.5 and Fig 4.9)).Season I had higher evapotranspiration ($p \leq 0.05$) than season II. Significant differences ($p \leq 0.05$) in evapotranspiration were notable only during the period 0-31 DAS and 31-49 DAS phasic stages of Pwani hybrid 4 maize growths in season I, and in most of season II except at 49-66 DAS (Table 4.5). Thus, coir mulched irrigated (M1W1 treatments) and coir mulched rainfed maize crops (M1W0 treatments) during season I had 2.7 % higher ($p \leq 0.05$) evapotranspiration than the control (M0W0 treatment), and irrigated maize crop (M0W1 treatments), respectively at 0-31 DAS (Table 4.5). At 31-49 DAS, the maize crop in control (M0W0) treatment had higher significant ($p \leq 0.05$) evapotranspiration than other coir mulch and irrigation interactions maize crop. Beyond 83 DAS, the coir mulched irrigated maize crop (M1W1 treatment) had increasing rates of evapotranspiration when maize crop in other coir mulched and irrigation treatment interactions were on their decline. The final seasonal evapotranspiration evaporation during season I was similar.

Table 4.5: Interactions of coir mulch and irrigation on evapotranspiration and 100 cmcrop available dueto Pwani hybrid 4 maize in seasons I and II

Growth stages (DAS)	0	31	49	66	83	100	0	31	49	66	83	100
	Season I (26th April-3rd Aug 2007)							Season II (26th April-3rd Aug 2008)				
Treatments					**Periodic evapotranspiration in mm ha^{-1}**							
M0 W0		662.5a	264a	109.4a	47a	242.7a		313.3a	215.5a	170.1b	28b	173.1c
M0 W1		660.5a	228.3b	152.4b	30.1b	270.3b		308.4a	196.5b	178.4a	85.3a	233.4b
M1 W0		672.5b	218.8b	136.4b	63.2c	262.9b		298.9ab	208.8ab	175.7ab	42.5b	174c
M1 W1		678.4b	196.6c	156.1bc	46.5a	294.3c		283.9c	223.3a	178a	84.9a	235.8a
Mean		668.5	226.9	138.6	-46.7	267.6		301.1	211.0	175.6	60.2	204.1
LSD		8.9	20	19.1	10.2	18.7		9.6	13	5.9	15.5	1.1
				Seasonal evapotranspiration in mm ha^{-1}								
M0 W0		662.5b	926.5a	1035.9	1082.9	1325.6		313.3a	528.8a	698.9	726.8a	899.9b
M0 W1		660.5b	888.8b	1041.2	1071.3	1341.6		308.4ab	507.7a	683.3	768.6a	1002.0a
M1 W0		672.5a	891.3b	1027.7	1090.9	1353.8		298.9b	507.2a	683.3	725.8b	899.8b
M1 W1		678.4a	875b	1031.1	1077.6	1371.9		283.9c	504.9b	685.1	770.1a	1005.8a
Mean		668.5	895.4	1034.0	1080.7	1348.2		301.1	512.1	687.7	747.8	951.9
LSD		8.9	28.9	48.0	58.1	76.8		9.6	22.5	28.5	44.0	45.1
Sed		3.4	11.3	17.8	21.7	28.8		3.6	8.5	10.7	15.5	15.9
				NS	NS	NS				NS		
					100 cm-crop available in mm ha^{-1}							
M0 W0	326.45a	259.94a	230.5a	155.6a	213.5a	27.34a	119.98a	211.7a	119.71a	118.13a	116.66a	26.6a
M0 W1	325.9a	261.42a	267.6b	167.3a	236.9b	30.72b	119.45a	216.05b	143.02b	139.42b	136.03b	26.6a
M1 W0	326.31a	249.81b	265.5b	163.6a	237.8b	31.39b	119.85a	226bc	140.68b	133.54b	117.56a	26.6a
M1 W1	329.75b	247.38b	285.2c	181.2b	267.2c	37c	123.29b	244.41d	144.61b	141.45b	138.41c	26.6a
Mean	329.8	247.4	285.2	181.2	267.2	37.0	123.3	244.4	144.6	141.5	138.4	26.6
LSD	3.023	8.99	15.66	12.7	7.65	2.015	0.781	2.621	11.966	13.065	1.075	0.037
Sed	1.221	3.404	6.39	4.89	2.35	0.726	0.319	2.772	4.245	3.875	0.416	0.014

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

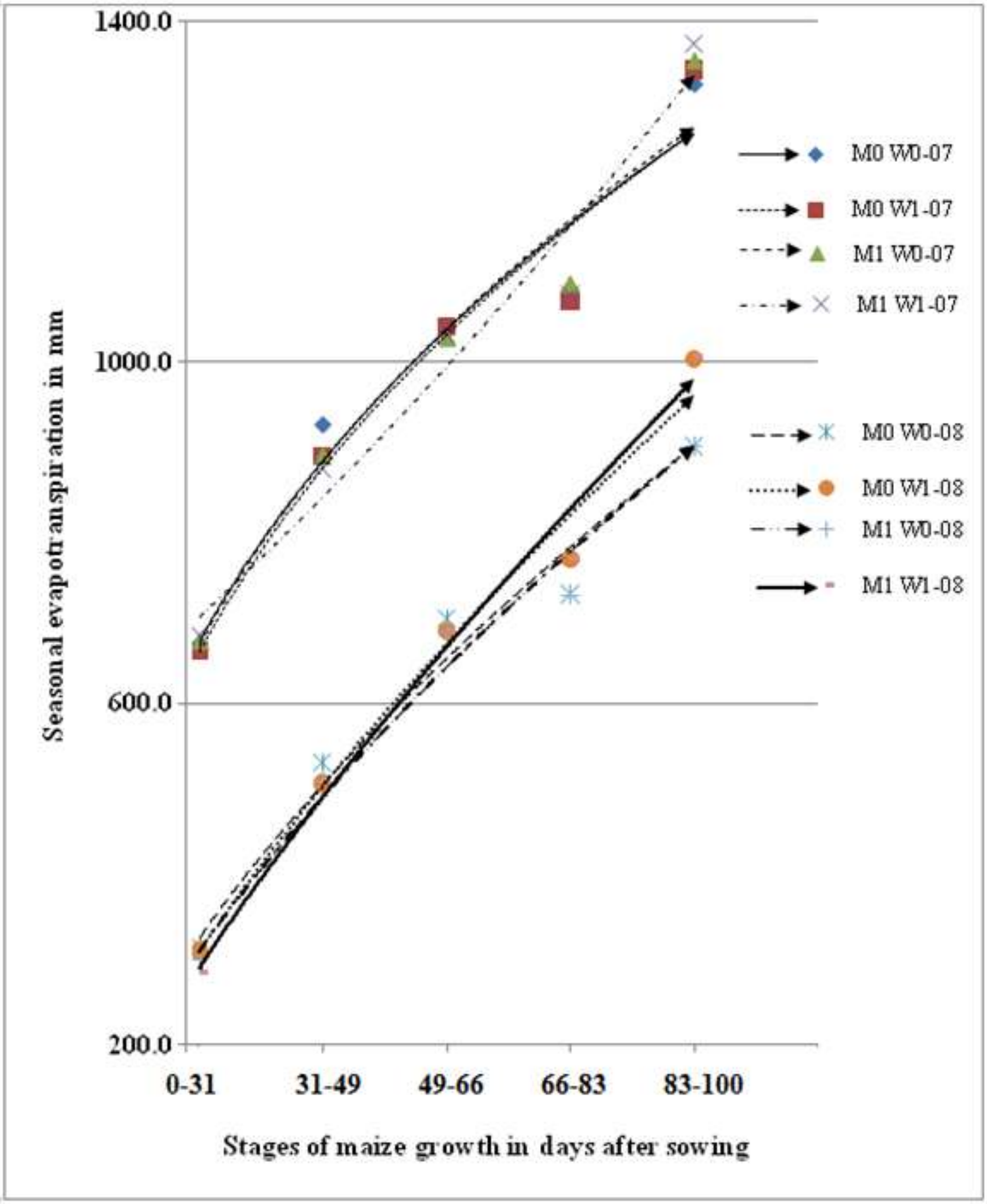


Figure 4.9: Interaction effect of coir mulch and irrigation treatments on seasonal evapotranspiration of Pwani hybrid 4 maize during seasons I and II

Peak evapotranspiration at successive maize growth stages were in the order: M0W0 at 31-49 DAS; <M0W1 at 49-66 DAS; <M1W0 at 66-83 DAS; <M1W1 at 83-100 DAS (Table 4.5).Although maize crops in coir mulched (M1W0 treatments) and coir mulched-irrigated (M1W1) interactions had lower evapotranspiration at 31-49 DASand at 49-66 DAS respectively, the maize crops resulted in 3.5 % and 2.1 % relatively higher final evapotranspiration than control treatment maize crop (M0W0) (Table 4.5). During the drier season II evapotranspiration was significantly different ($p \leq 0.05$) at all stages of maize growth except at 49-66 DAS (Table 4.5). The control treatment (M0W0) maize crop had 9.4 % and 4.5 % higher ($p \leq 0.05$) evapotranspiration at 0-31 DAS and 31-49 DAS, respectively compared to coir mulched-irrigated maize crop (M1W1 treatment) (Table 4.5).

By 83-100 DAS in season II, coir mulched-irrigated maize crop (M1W1treatment) and irrigated maize crop (M0W1 treatments) had similar and higher significant ($p \leq 0.05$) final evaporation than control and coir mulched maize crop (M1W0 treatments), with the latter having similar evapotranspiration (Table 4.5). The coir mulched maize crop (M1W0 treatments) had the lowest significant evapotranspiration at 66-83 and 83-100 DAS (Table 4.5). The highest differences in evapotranspiration between coir mulch and irrigation treatments at the end of wetter season I was less than 3.5 %, while during the drier season II was 11.8 % (Table 4.5 and Figs 4.10 and 4.11).

Periodic evapotranspiration fluxes decreased hyperbolically as the crop advanced in age to lowest at 66-83 DAS, followed by increase (Fig 4.12). Although significant differences in periodic evapotranspiration fluxes occurred throughout the growing period in both seasons, the magnitude of these differences was increased as the maize crop approached maturity (Fig 4.12). The wetter season I had significantly ($p \leq 0.05$) higher levels of periodic evapotranspiration values than the drier season II except at the period 49-83 DAS (Table 4.5). Between the period 31-49 DAS coir mulched and irrigated interactions resulted in significant depression in periodic evapotranspiration in the order: M1W1 > M1W0 > and M0W1 (Fig 4.11). However, at 49-66 DAS M1W1 and M0W1 treatments had two-fold increase in periodic evaporation than coir mulched (M1W0) treatment (Fig 4.11). Beyond 49 DAS and 66 DAS during the wetter and drier seasons I and II respectively, coir mulched and irrigated interactions had significantly higher periodic evapotranspiration than control treatment (M0W0) (Fig 4.11).

At 66-83 DAS when periodic evapotranspiration was lowest for all coir mulch and irrigation interactions in both seasons, only irrigation alone (M0W1) and coir mulched irrigated (M1W1) treatments had positive increase in % periodic evapotranspiration fluxes, with coir mulched (M1W0) treatments having 16.2 % decline in periodic evapotranspiration fluxes (Fig 4.11). By 83-100 DAS irrigated treatments M0W1 and M1W1 had the highest significant ($p \leq 0.05$) increases in soil moisture. Interactions of coir mulching and irrigation resulted in higher levels of % crop available moisture beyond 49 DAS in both seasons that were over 15 % (Fig 4.13).

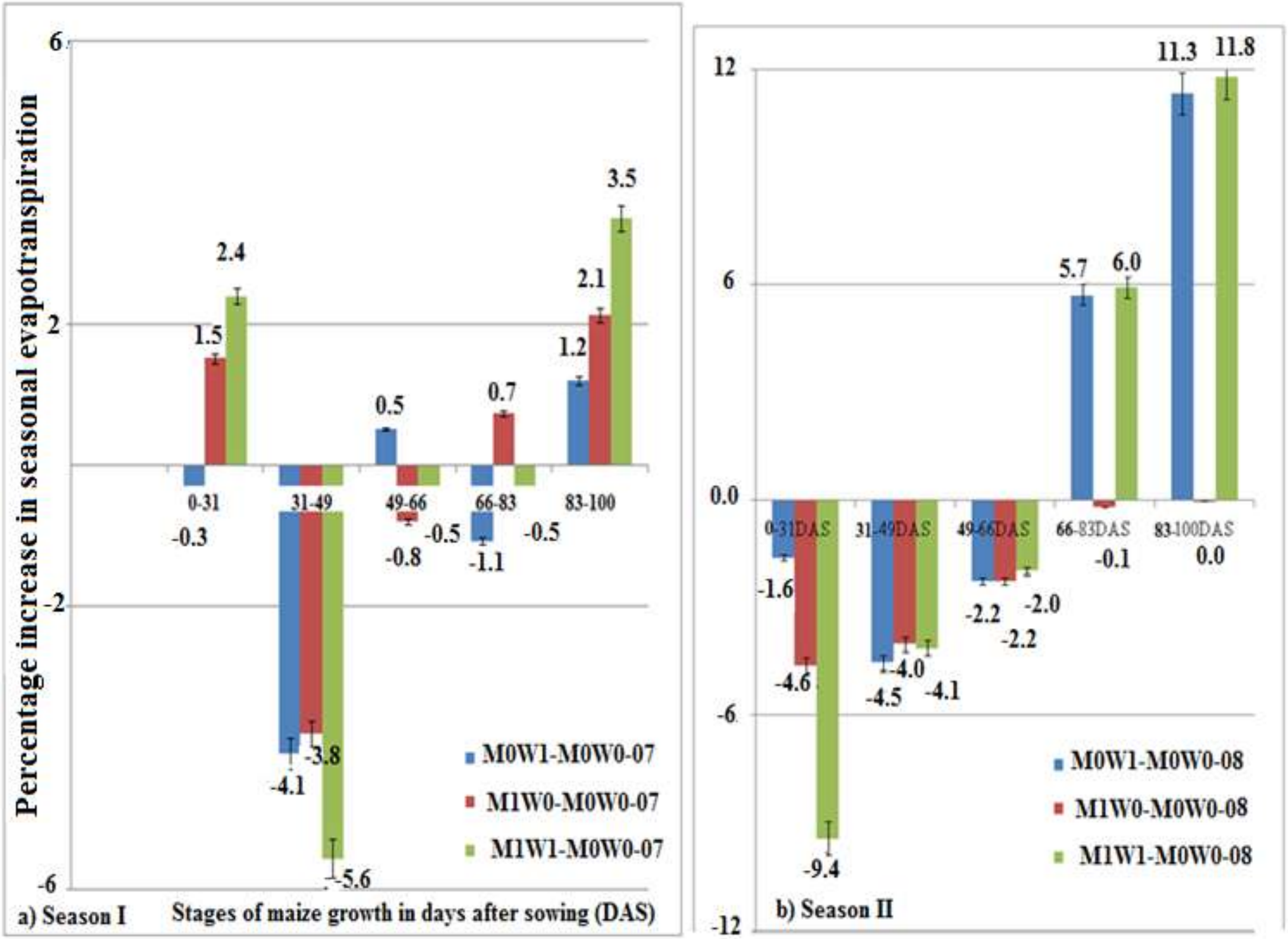


Figure 4.10: Percentage increase in evapotranspiration of Pwani hybrid 4 maize due to coir mulch and irrigation interactions during seasons I and II in Kilifi

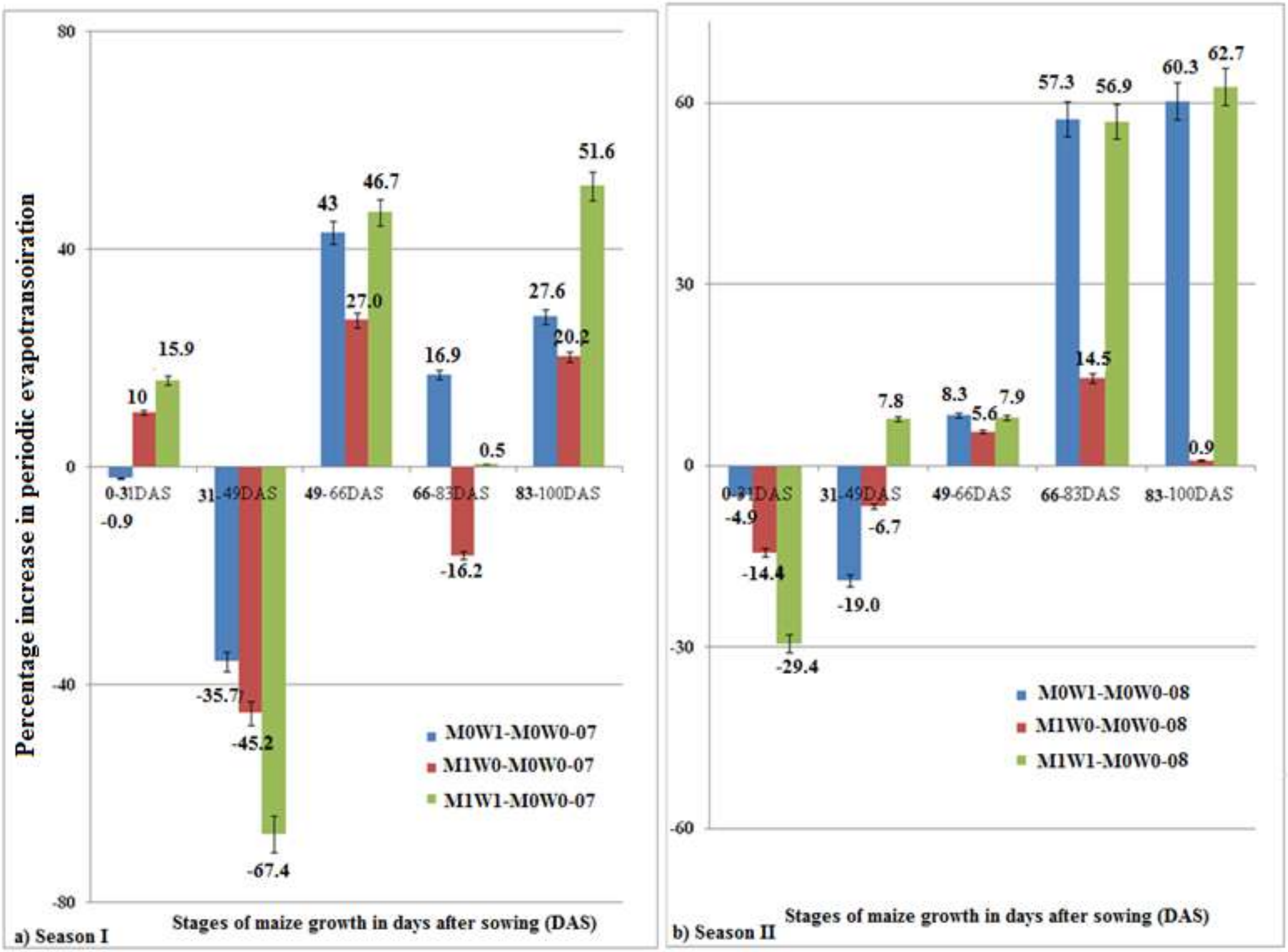


Figure 4.11: Percentage increase in periodic evapotranspiration fluxes on Pwani hybrid 4 maize (over control) due to interaction effect of coir mulch and irrigation in seasons a) I and II in Kilifi

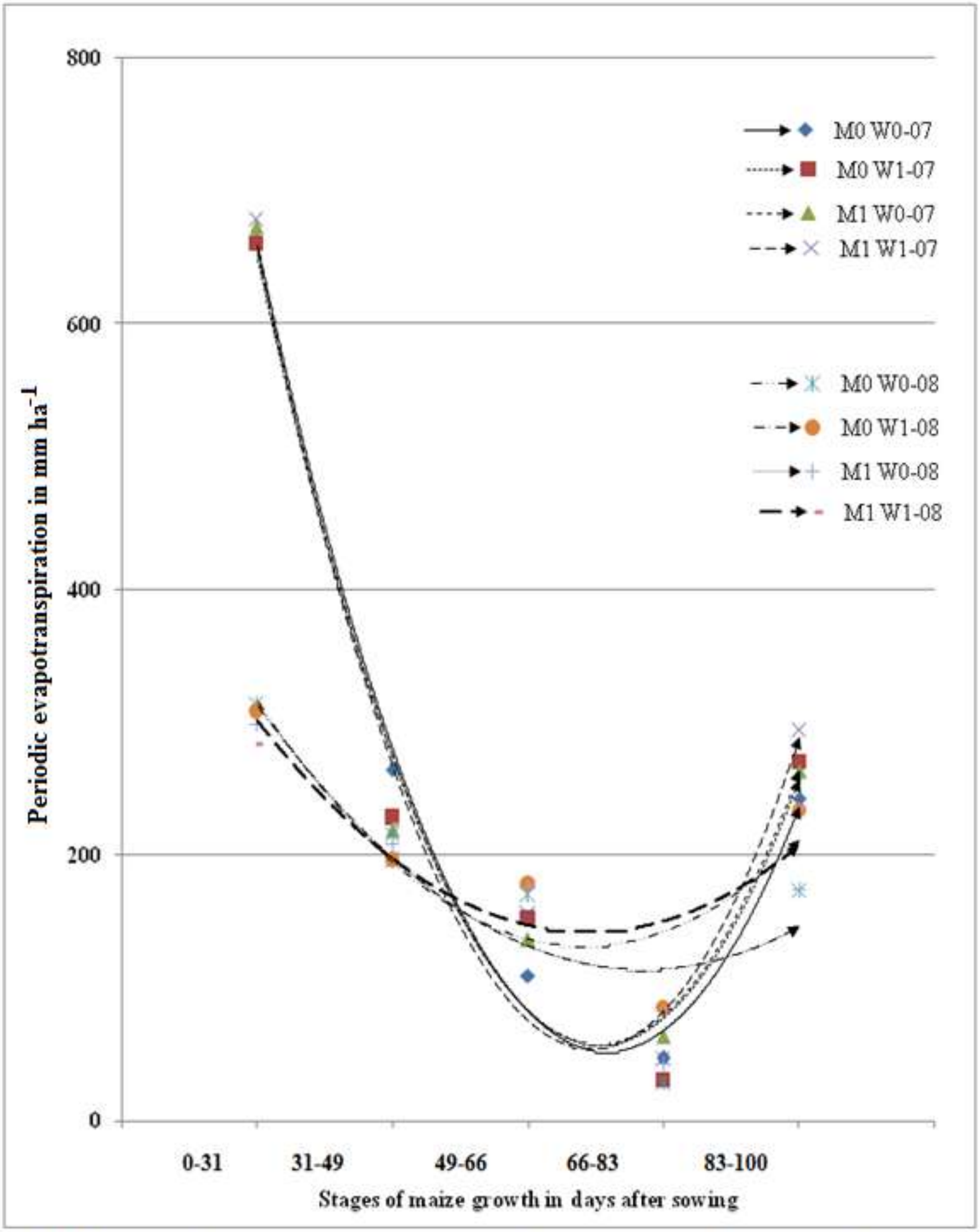


Figure 4.12: Interaction effect of coir much and irrigation treatments on periodic evapotranspiration of Pwani hybrid 4 maize during seasons I and II in Kilifi

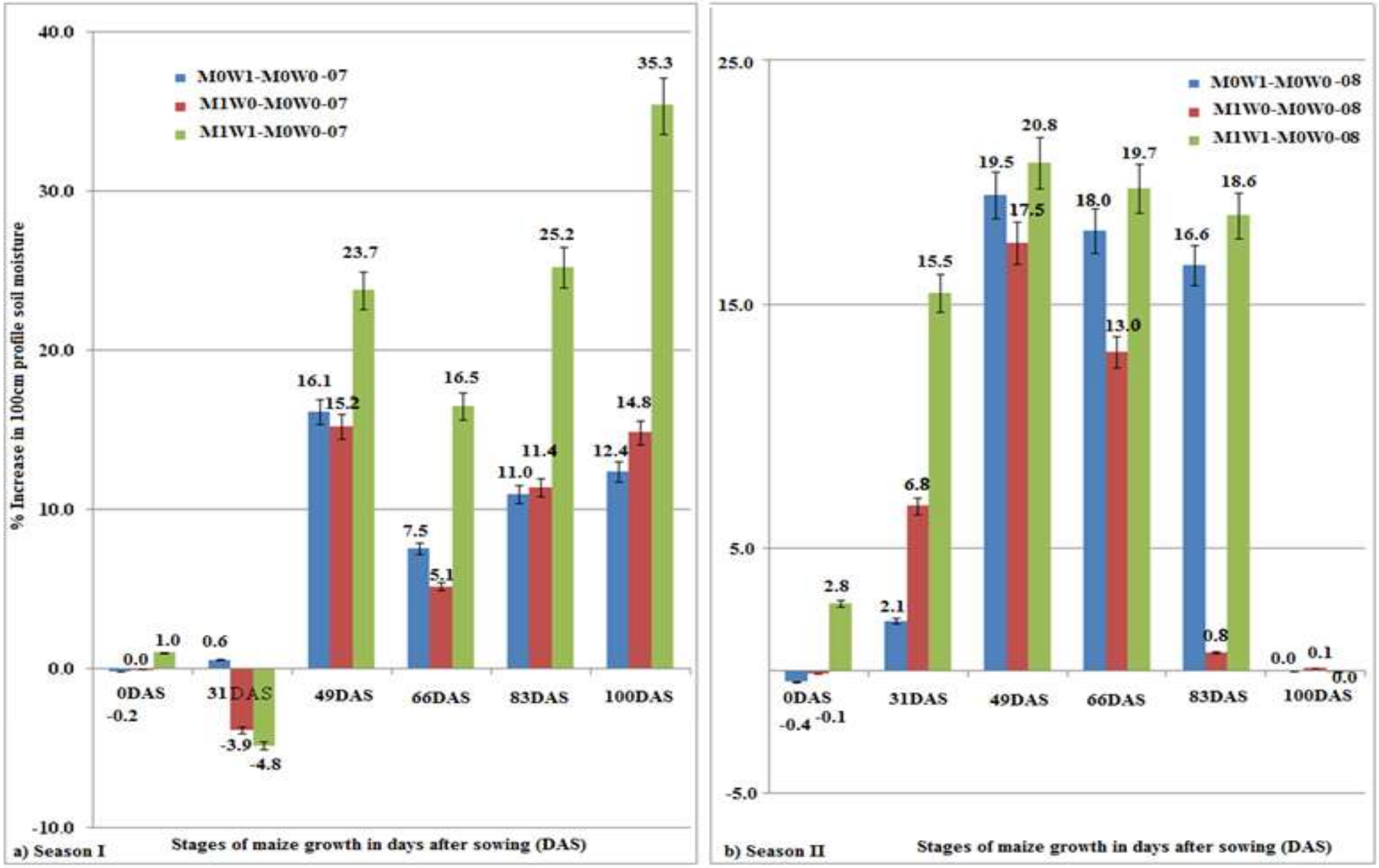


Figure 4:13: Percentage increase in 100 cm-profile soil moisture due to coir mulch and irrigation treatments interactions on Pwani hybrid 4 maize during season a) I and b) II in Kilifi

4.9 Interactions of coir mulch and irrigation on biomass of Pwani hybrid 4 maize

The above ground biomass of Pwani hybrid 4 maize increased in both seasons as the maize crop advanced in age (Figs 4.14 and 4.15). During the wetter season I daily rates of biomass accumulation in irrigation alone maize crop (M0W1 treatment) had prolonged period of biomass accumulation, attaining its peak growth rate around 90 DAS, whereas coir mulch alone (M1W0) and coir mulched-irrigated maize crops (M1W1 treatments) had their peak rate of growth at 49-66 DAS (Fig 4.15). During the drier season II, the maize crop attained peak rates of growth earlier between 45-66 DAS (Fig 4.15). However, there were time differences in period at which they attained their peak growth rates. Thus, although maize crop in coir mulch (M1W0) and coir–mulched-irrigated (M1W1) treatments in season II had peak growth rates occurring at about 47-50 DAS, the maize crop in coir mulched irrigated treatments had slightly longer period of growth than the maize in coir mulch (M1W0) treatment (Fig 4.15). Although coir mulch and irrigation interactions had similar biomass during season I, the magnitude of the differences in biomass increased as the maize crop approached physiological maturity (Figs 4.14). There were no significant differences in biomass accumulation in season I.

In season II significant differences ($p \leq 0.05$) in biomass was observed at 31-49 DAS, where coir mulched–irrigated maize crop (M1W1 treatment) yielded significantly ($p \leq 0.05$) 41.7 % higher biomass, attaining a final biomass of 10.9 tons ha^{-1} (Table 4.6 and Fig 4.14). Between the period 31-49 DAS, season II maize crop had significantly ($p \leq 0.05$) higher rates of biomass accumulation than during season I. However, beyond 66 DAS the rate of biomass accumulation in season I was similar (Fig 4.15).Coir mulch (M1W0) treatments during season I had high (though insignificant) biomass at early stages of growth, which beyond 49 DAS declined to lowest final biomass, while that due to irrigated treatments increased towards later stages of growth to 17.5 % (Fig. 4.16a). The coir mulched maize crop towards maturity senesced much early than non-mulched maize crop that remained green long after physiological maturity. The bulk of rooting system in coir mulched and non-mulched maize crops was concentrated in the upper 0-20 cm at interface with coir mulch material (Plates 3; 4 and 5). However during the drier season II, coir mulching and coir mulched irrigated maize crops had higher ($p \leq 0.05$) % increases in biomass from 49 DAS and progressively declined with maturity (Fig 4.16b).

Table 4.6. Interactions of coir mulch and irrigation treatments on biomass and grain yield of Pwani hybrid 4 maize in seasons I and II

Seasons	Season I (26th April-3rd Aug 2007)							Season II (26th April-3rd Aug 2008)						
Stages of growth (DAS	0	31	49	66	83	100		0	31	49	66	83	100	
Treatments	**Above ground biomass in tons ha^{-1}**						Grain yield (**tons ha^{-1}**)	Above ground biomass in **tons ha^{-1}**						Grain yield (**tons ha^{-1}**)
M0 W0		1.0	2.6	6.7	10.3	13.7	4.1b		0.7	3.5b	5.1	6.7	8.3	4.2
M0 W1		0.8	2.7	7.0	11.5	16.1	5.5a		0.9	4.5a	6.0	7.2	8.4	4.4
M1 W0		1.0	2.8	6.7	10.5	13.9	5.0ab		0.6	5.5a	7.5	8.8	10.1	4.4
M1 W1		1.0	2.7	7.0	10.8	14.6	5.5a		0.8	6.0a	7.4	9.2	10.9	4.6
Mean		1.0	2.7	6.8	10.8	14.6	5.0		0.8	4.9	6.5	8.0	9.4	4.4
LSD (5%)		0.47	0.73	1.84	4.12	7.58	1.08		0.57	1.88	2.70	3.68	4.63	0.46
Sed		0.168	0.284	0.659	1.263	2.31			0.23	0.72	0.88	1.19	1.54	
		NS	NS	NS	NS	NS			NS		NS	NS	NS	NS

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

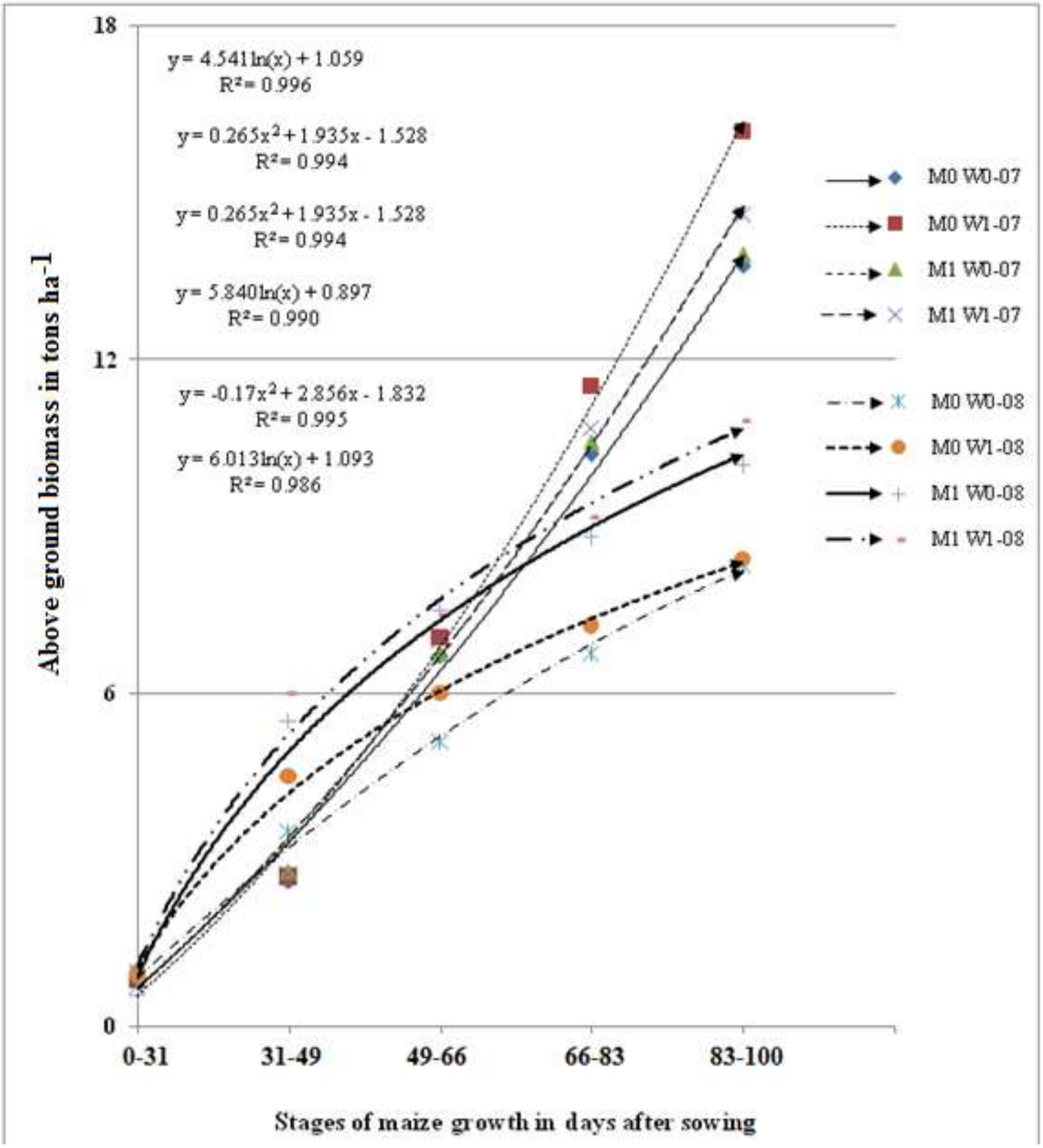


Figure 4.14: Pattern of above ground biomass accumulation of PH4 maize due to interaction effect of coir mulch and irrigation treatments in seasons I and II in Kilifi

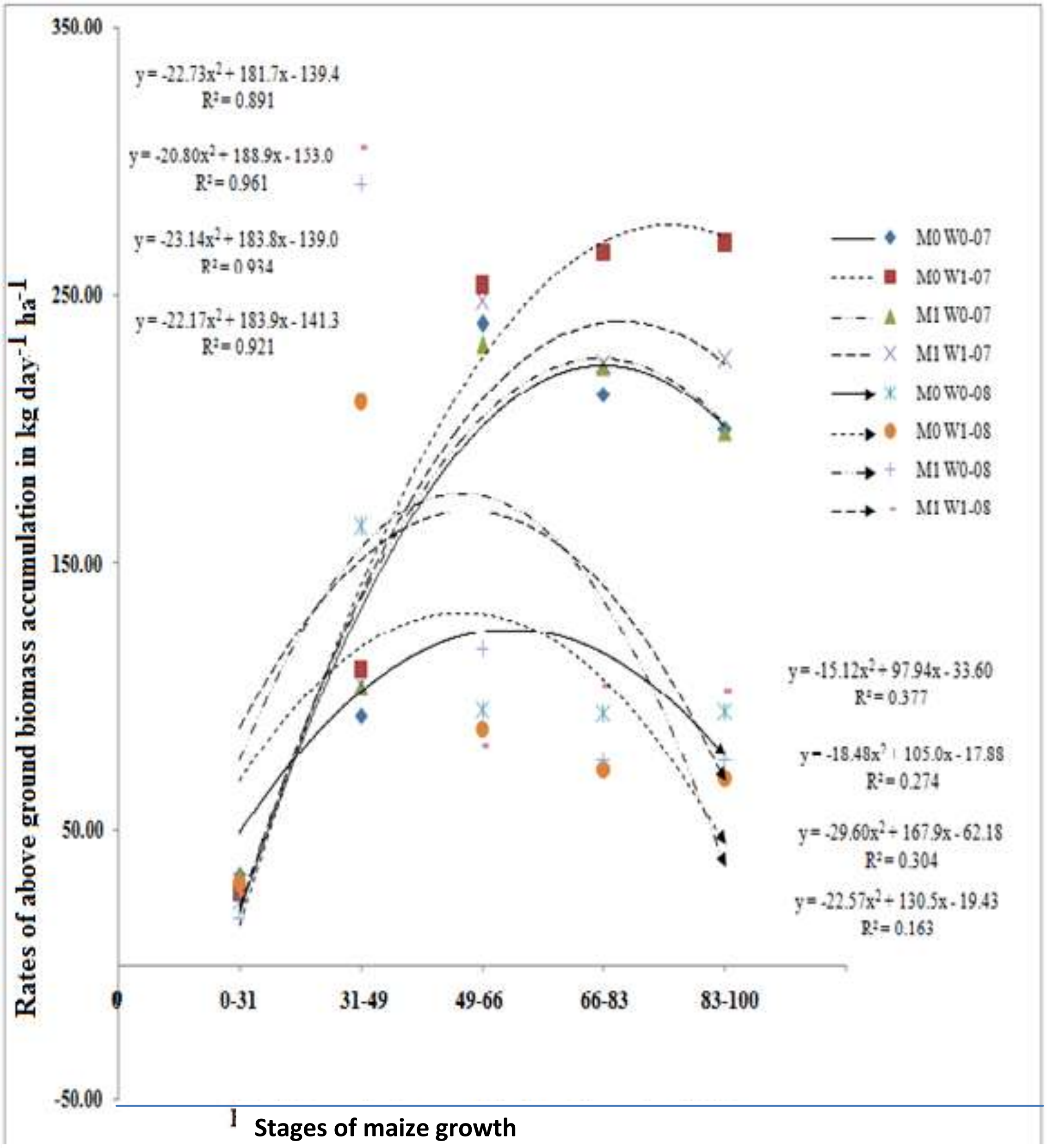


Figure 4.15: Pattern of daily rates of above ground accumulation of Pwani hybrid 4 maize due to interaction effect of coir mulch and irrigation treatments during seasons I and II in Kilifi

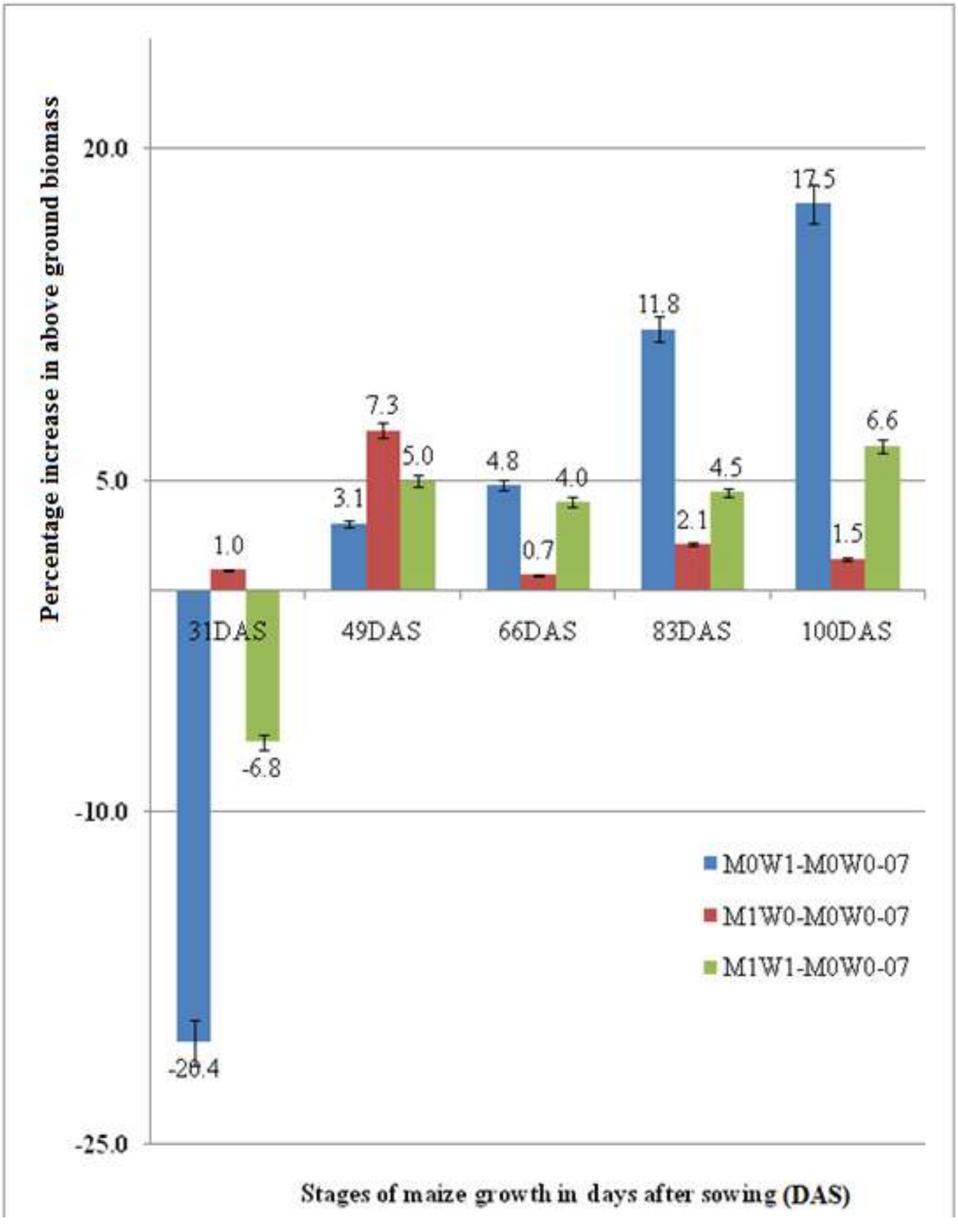


Figure 4.16a: Percentage increase in above ground biomass of PH4 maize due to interactions of coir mulch and irrigation treatments during the relatively wetter seasons I

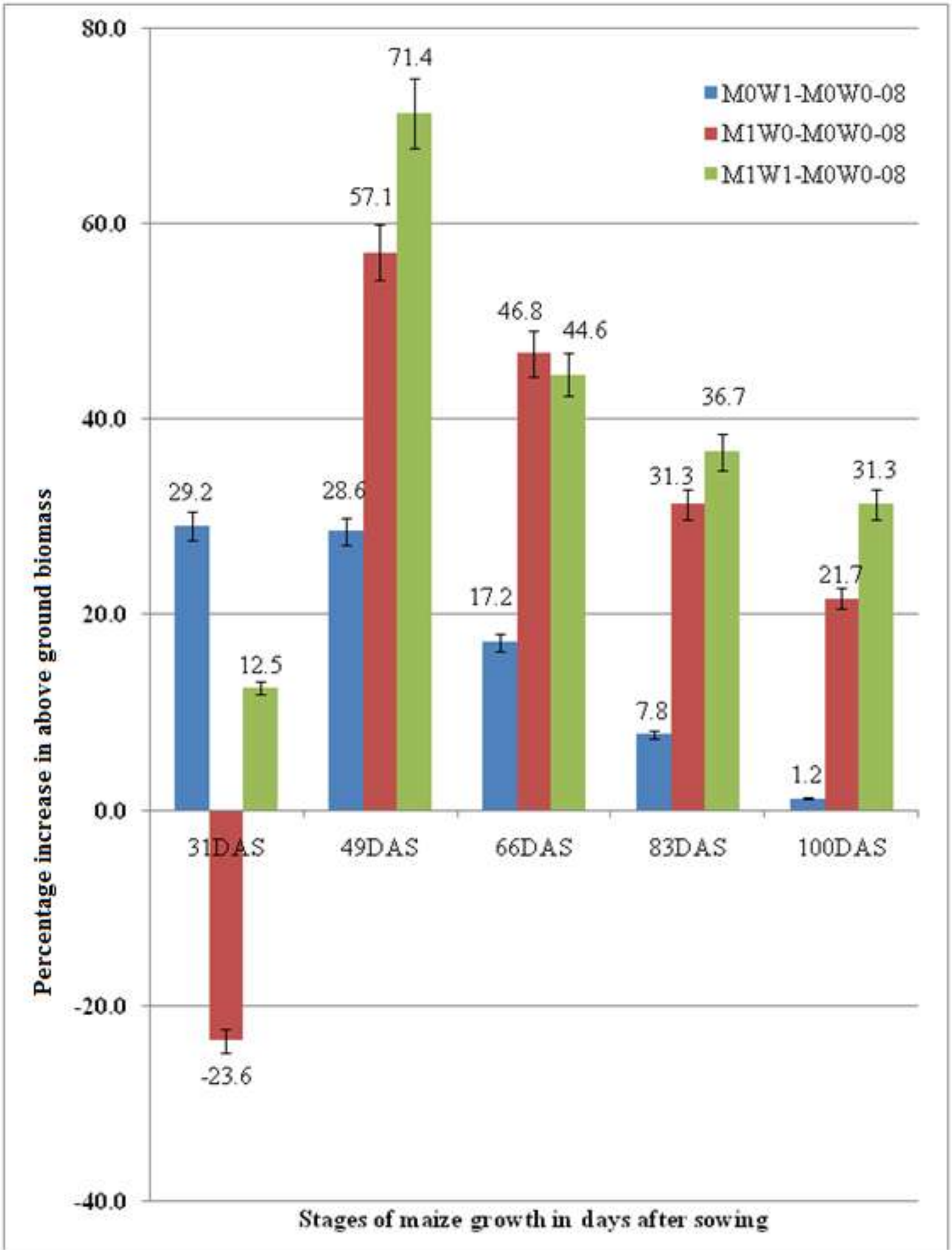


Figure 4.16b: Percentage increase in above ground biomass of PH4 maize due to interact ion effect of coir mulch and irrigation treatments during season II in Kilifi

Plate 3: Maize prop roots entangling with coir mulch and concentrating in the upper 0-15 cm to form a root mass ball

Plate 4: Maize roots at harvest from (a) coir mulched and (b) non-mulched treatments.
Note the dense root matt/mass ball in (a) where over 95 % of the roots were concentrated in coir mulch and in (b) note the few large but deep roots

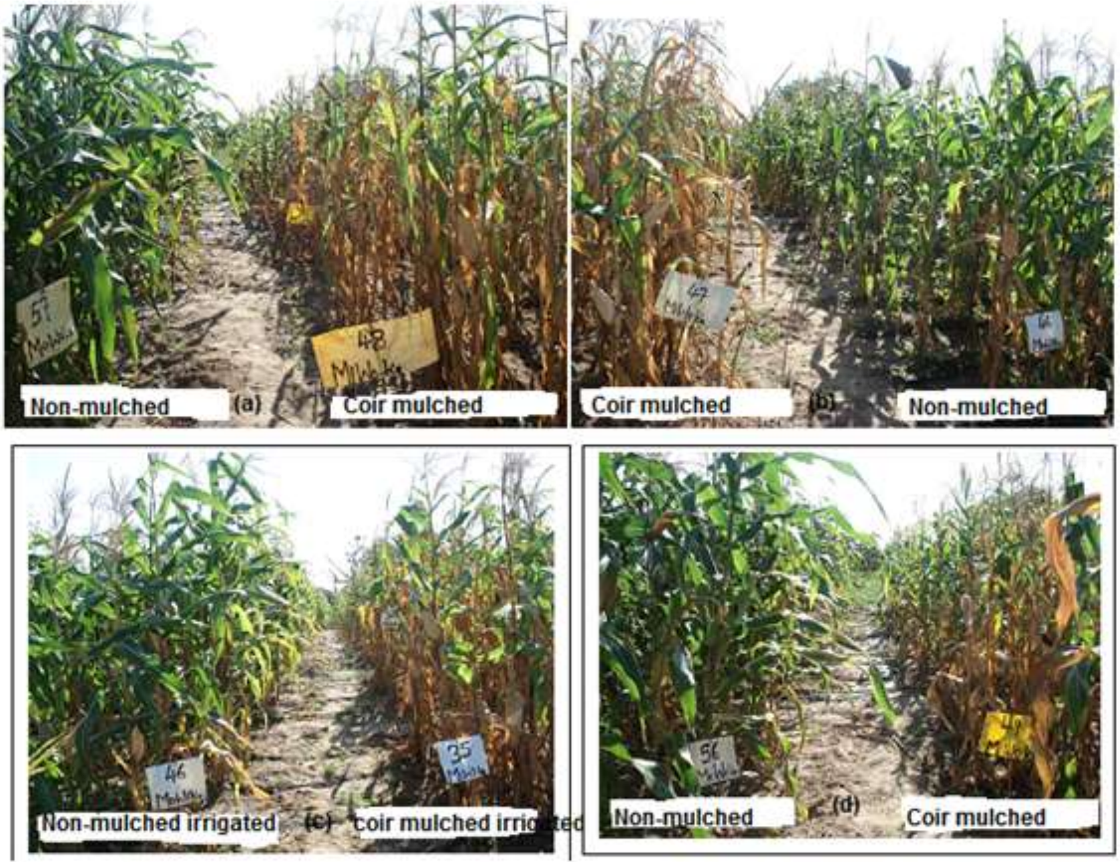


Plate 5: The Effects of coir mulching treatments on rates of PH4 maize senescing.
Note early maturity and senescing of maize in all coir mulched treatments even in coir mulched irrigated treatments (c). All non-mulched treatments retained their green color past physiological maturity stage

4.10 Interactions of coir mulch and irrigation on grain yield of Pwani hybrid 4 maize

During the relatively wetter season I significant differences in grain yield due to coir mulch and irrigation interactions were only observed in irrigated treatments, where irrigated (M0W1 treatments) and coir mulched irrigated (M1W1 treatments) maize crops yielded similar and significantly higher ($p \leq 0.05$) grain yield(of 5.5 tons ha^{-1}), than the control (M0W0) treatment (Table 4.6). During the drier season II, the maize crop yielded similar levels of grain yield, with maize crop in coir mulched (M1W0) and irrigation alone (M0W1) treatments yielding 4.8 % more grain than (M0W0) control treatment maize crop (Fig. 4.17).

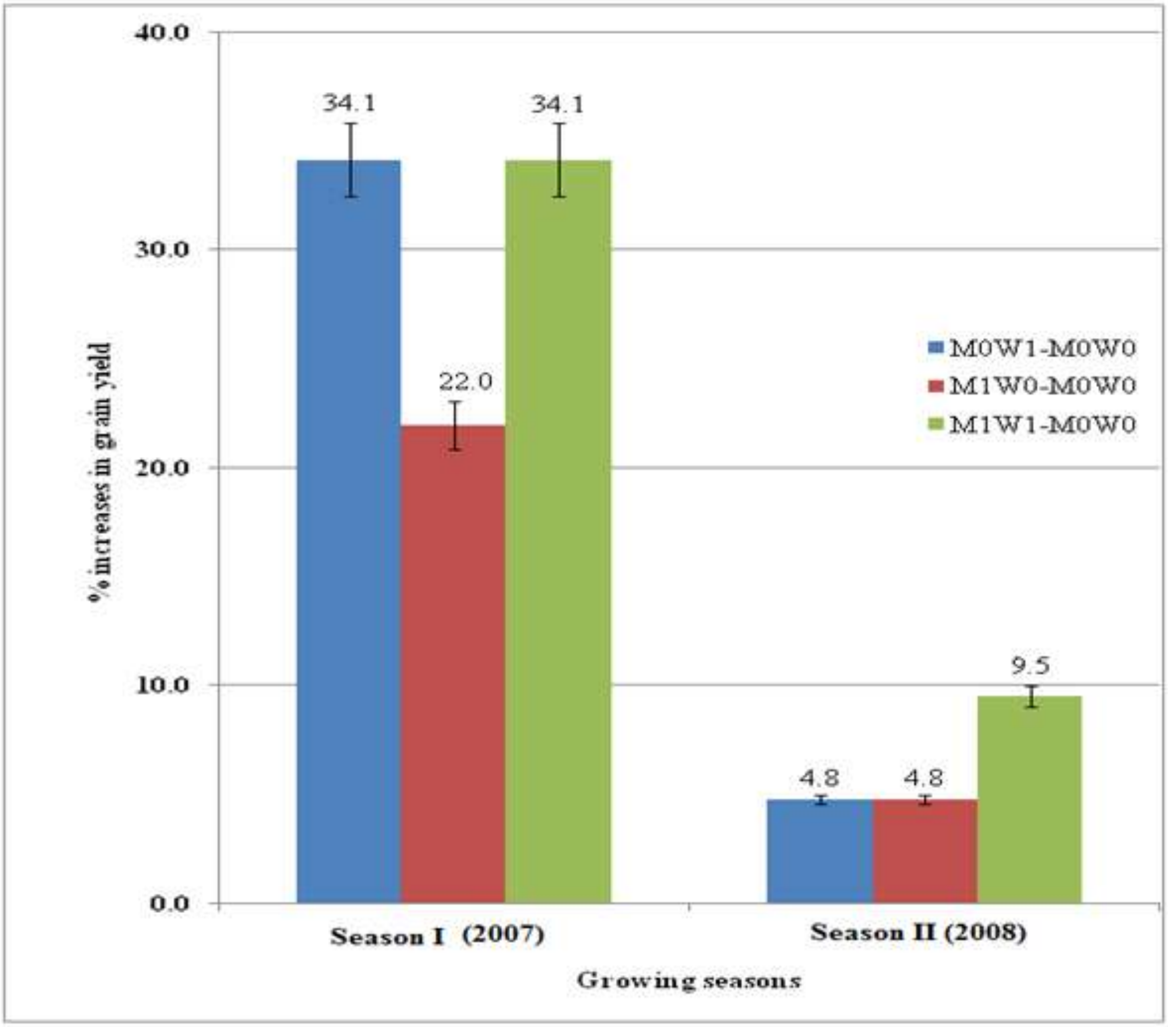


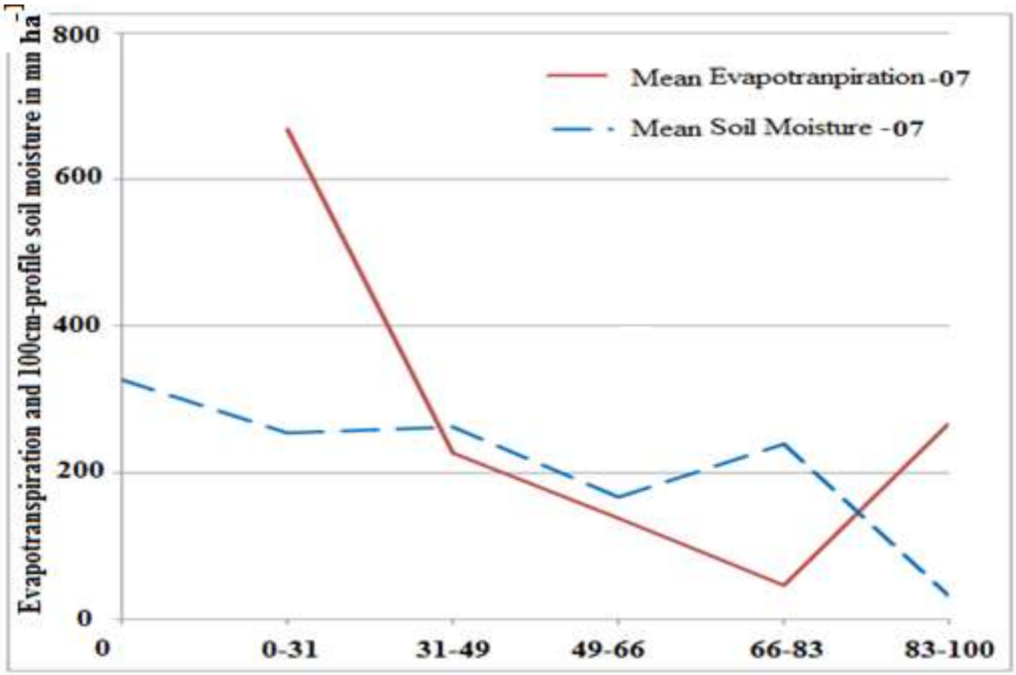
Figure 4.17: Percentage increase in grain yield of Pwani hybrid 4 maize due to interaction effect of coir mulch and irrigation over control treatment in seasons I and II in kilifi

4.11 Complementary relationship between coir mulch and irrigation treatments

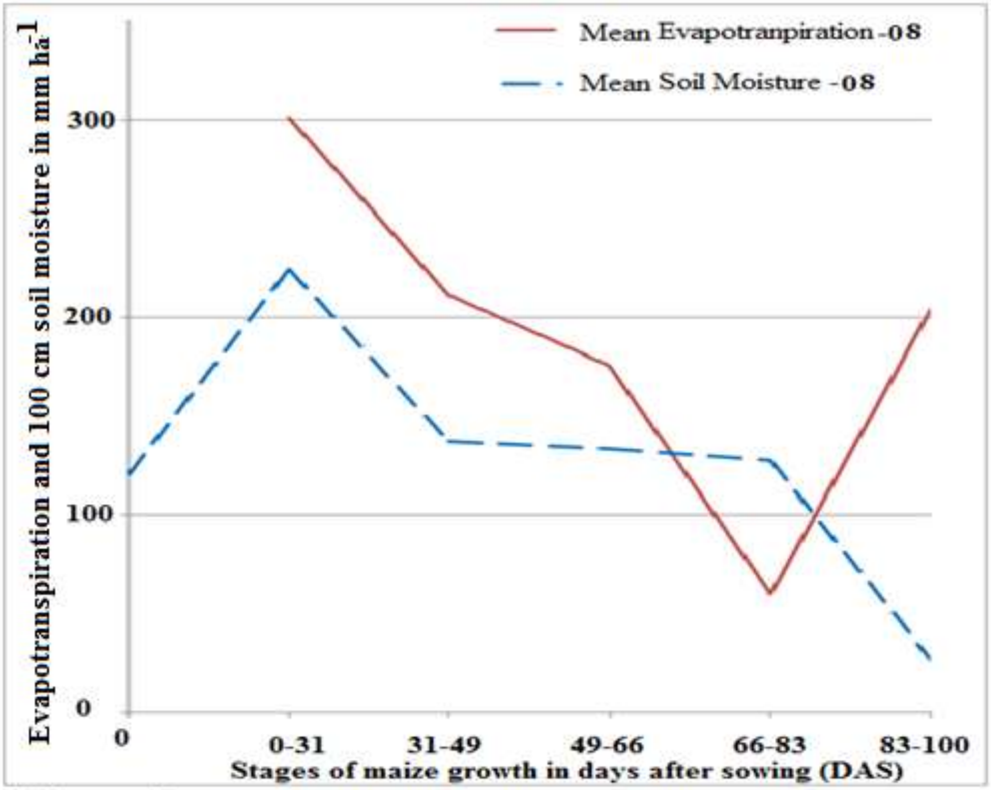
Significant changes in seasonal and periodic evapotranspiration fluxes during the growing period caused significant changes in 100 cm-crop available moisture for similar growth periods (Table 4.5 and Fig 4.18).Thus, on average, periodic evapotranspiration varied in unison with 100 cm-crop available, except early in the season at 0-31 DAS, and late in the season where periodic evapotranspiration values were higher than 100 cm-crop available (Fig 4.18).

Between the period 0-49 DAS, coir mulched interactions resulted in significantly ($p \leq 0.05$) higher levels, (almost two-fold), in conserved soil moisture than irrigated treatments (Fig 4.19a). However, beyond 49-66 DAS, the conserved soil moisture declined to lower levels of less than 9.1%. Beyond 66 DAS, as the conserved soil moisture declined, irrigation treatment interactions increased amounts of soil moisture up to 16.2 % by 83 DAS, before declining. During the relatively wetter season I, coir mulching resulted in comparable levels of conserved soil moisture to that of irrigated treatment interactions (Fig 4.19a-c).

Although coir mulched (M1W0) and non-mulched irrigated (M0W1) treatments occasioned comparable levels of % increase in soil moisture during the relatively wetter season, the interactions of coir mulch and irrigation (M1W1 treatment) resulted in 28.6 % higher levels of soil moisture for most part of the growing period (Figs. 4.19 c-e).



a) Season I



b) Season II

Figure 4.18: Relationship between periodic evapotranspiration of Pwani hybrid 4 maize and 100 cm profile soil moisture due to coir mulch and irrigation treatment interactions during seasons a) I and b) II in Kilifi

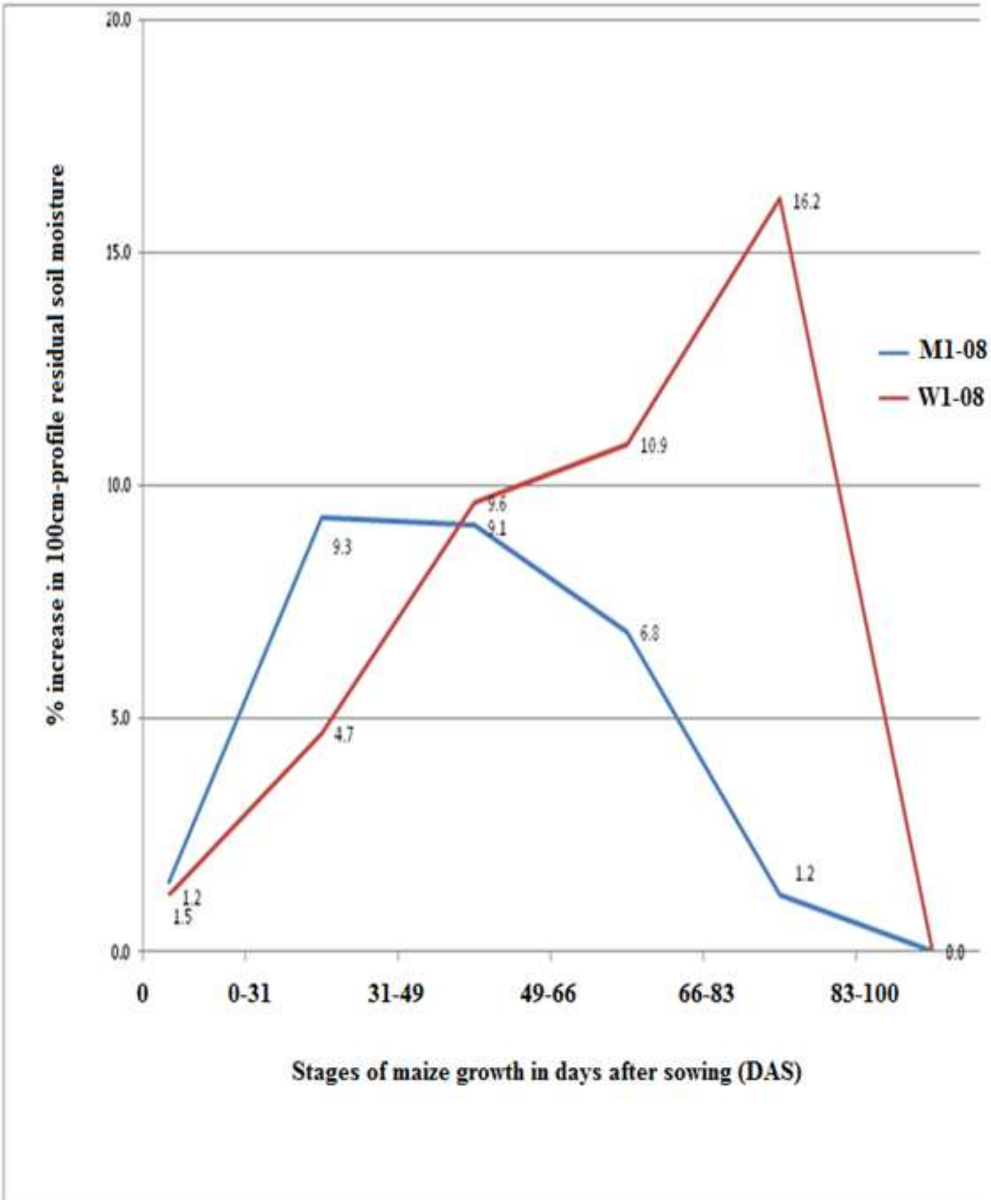


Figure 4.19a: Percentage changes in 100 cm profile soil moisture due to conservation by coir mulching and addition by irrigation treatments under Pwani hybrid 4 maize in season II

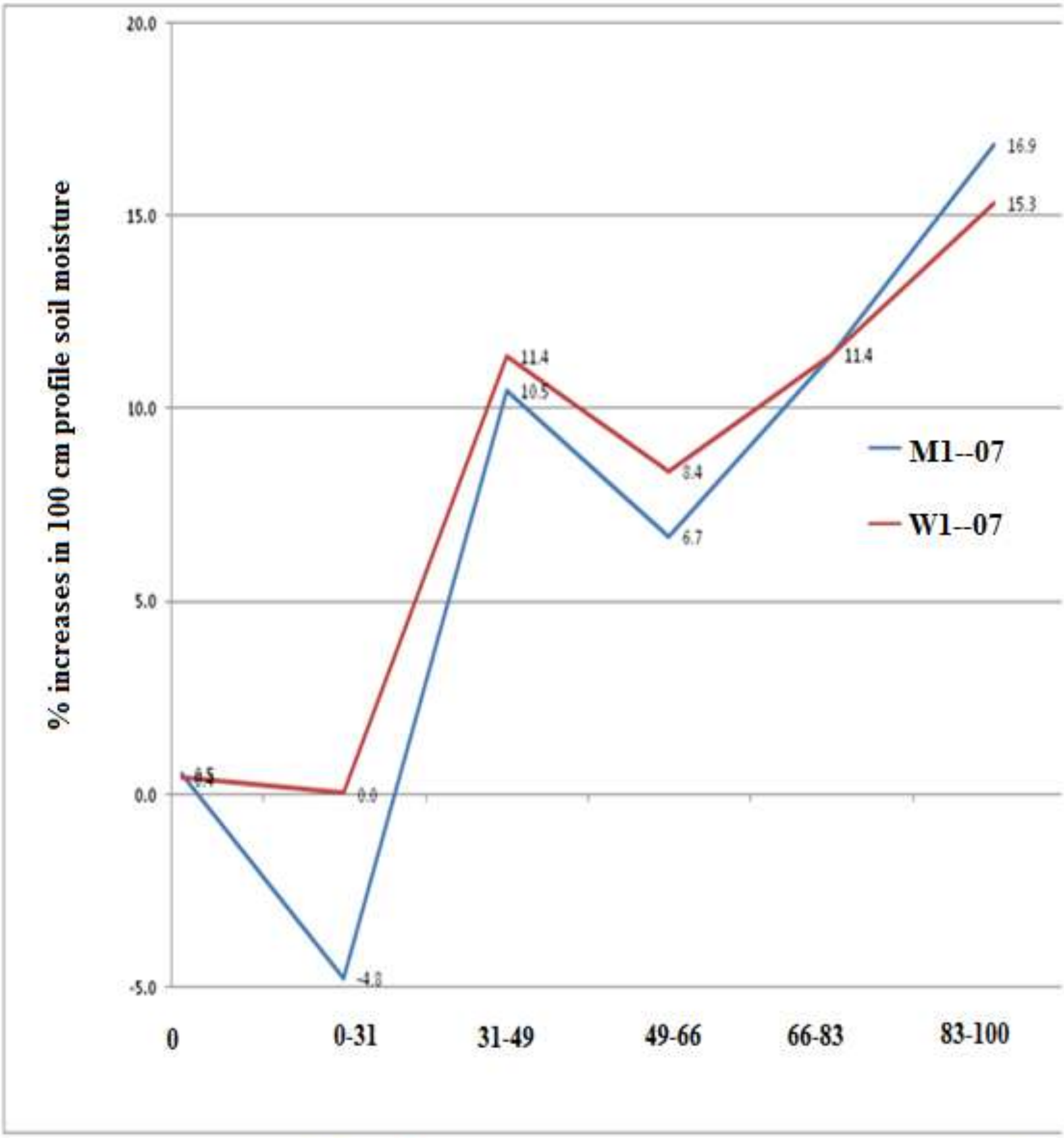


Figure 4.19b: Comparison of contribution of percentage increases in 100 cm profile soil moisture due to conservation by coir mulching and additions by irrigation treatments under Pwani hybrid 4 maize during the wetter season I

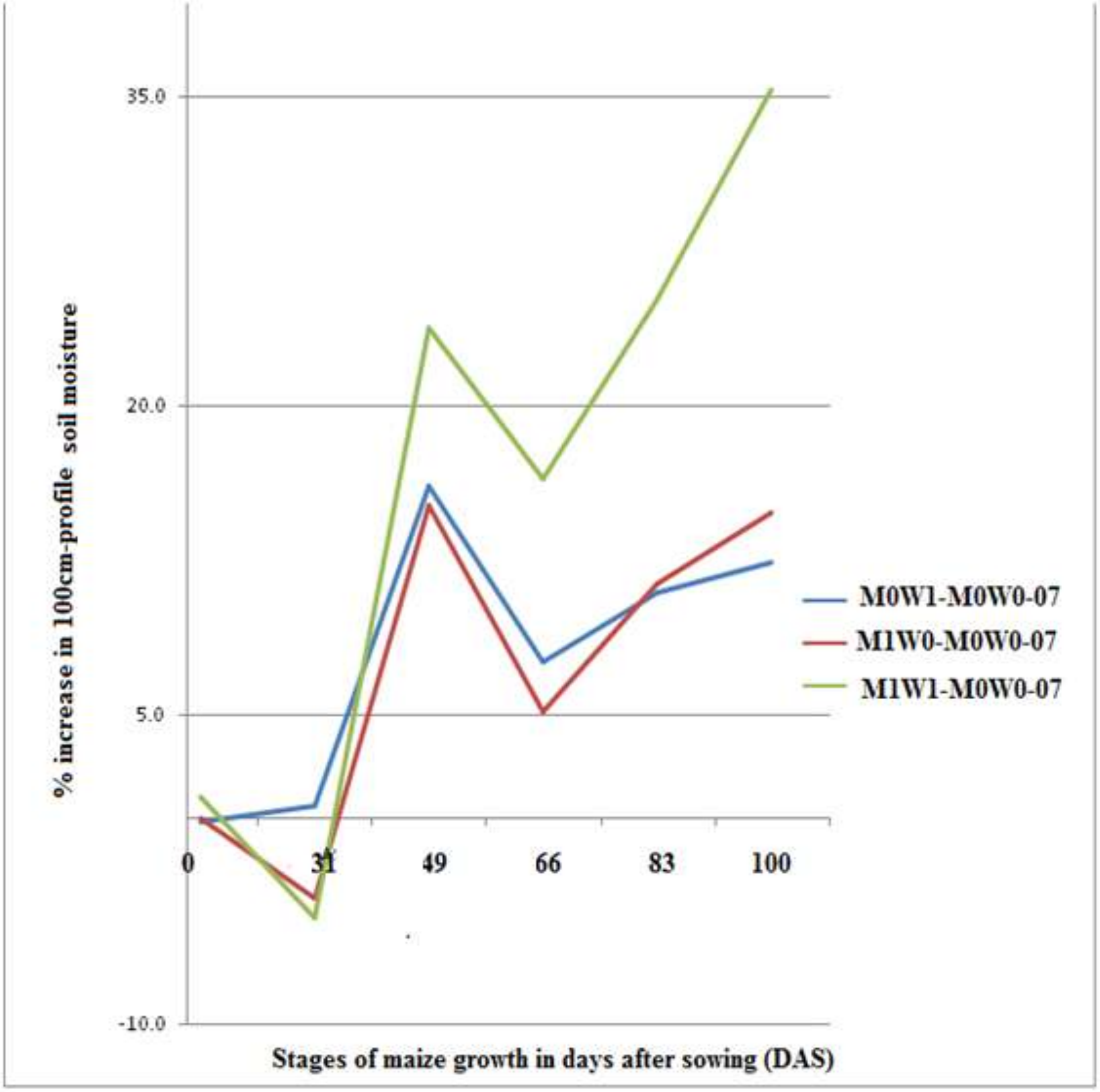


Figure 4.19c: Contributions to 100 cm-profile soil moisture by treatment combinations of coir mulch and irrigation over control treatment (M0W0) under PH4 maize during the relatively wetter season I.

Note the depression occasioned by occurrence of June winds at 49-66 DAS

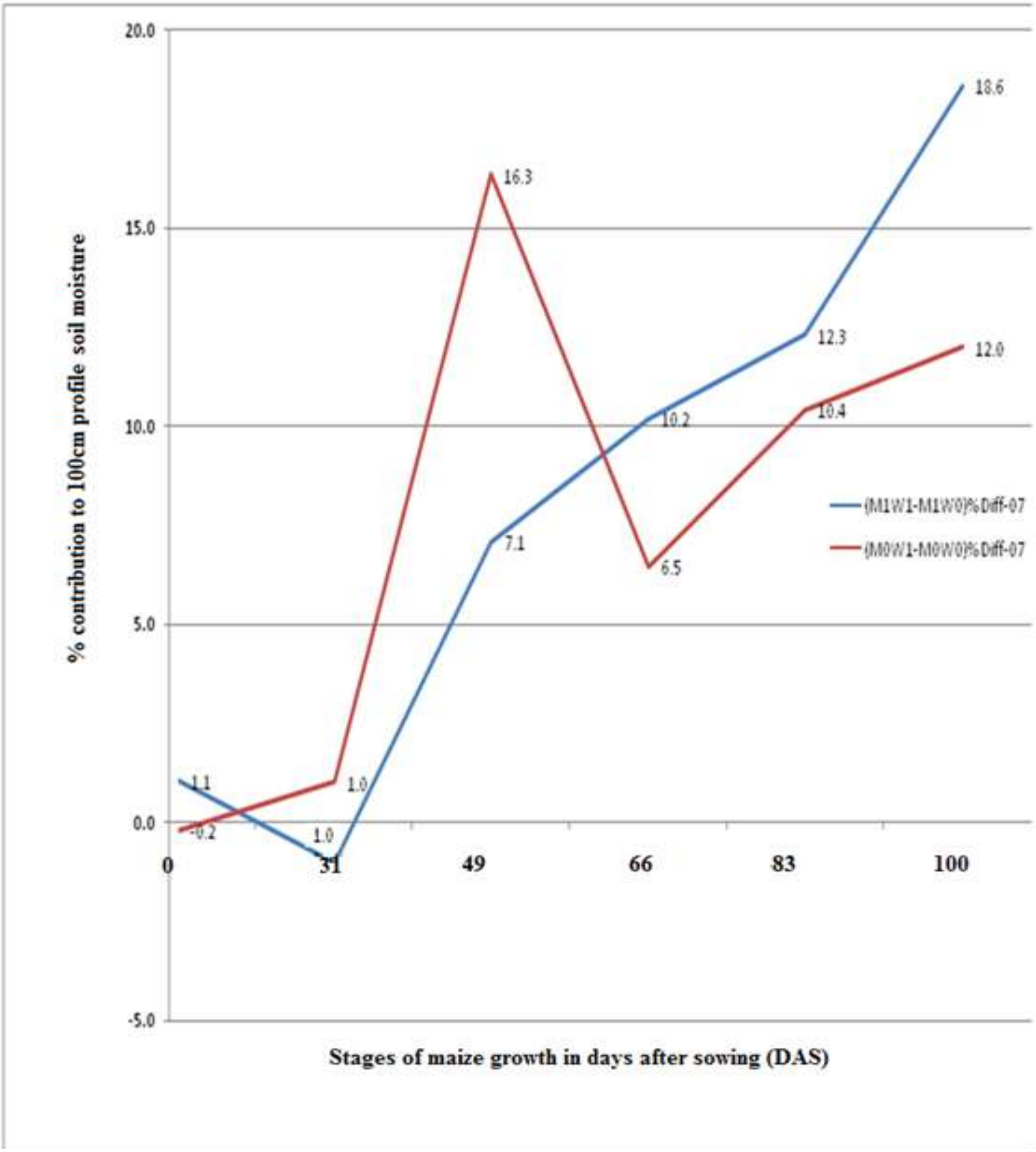


Figure 4.19d: Stabilizing and buttering effects of treatment interactions of coir mulch and irrigation on June winds depressing effects on 100 cm-profile soil moisture during the relatively wetter season I

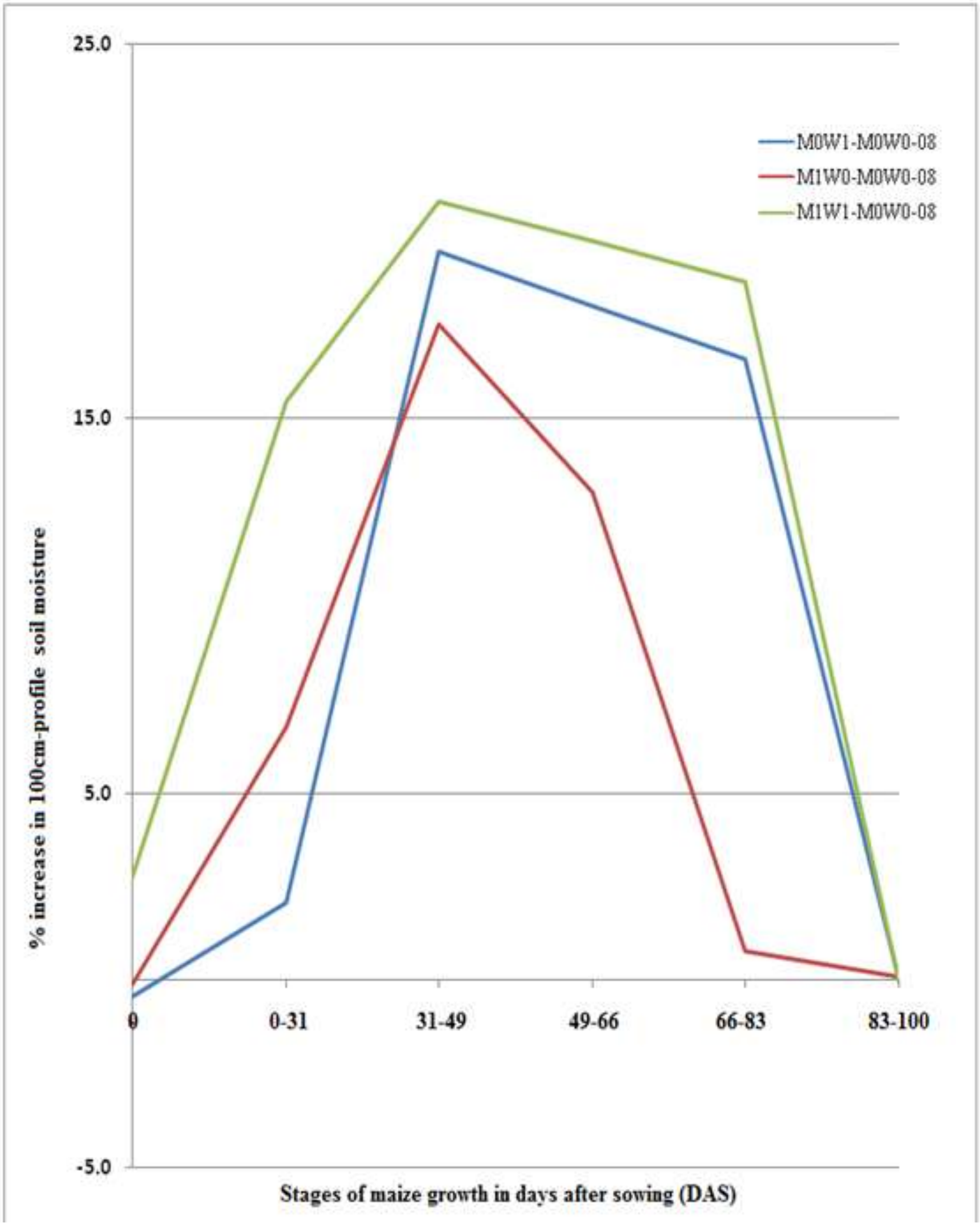
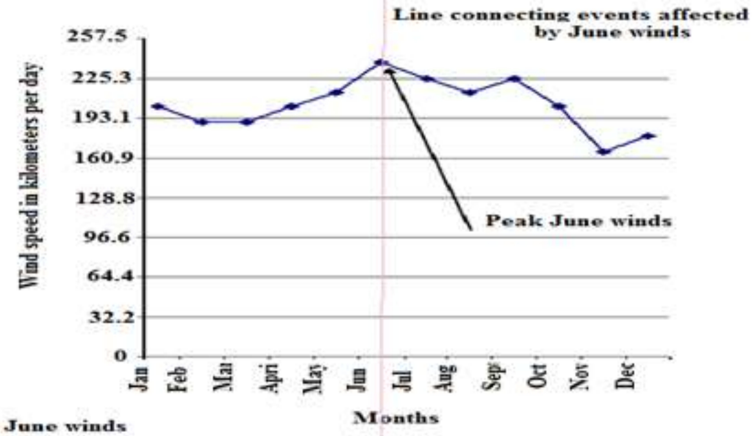


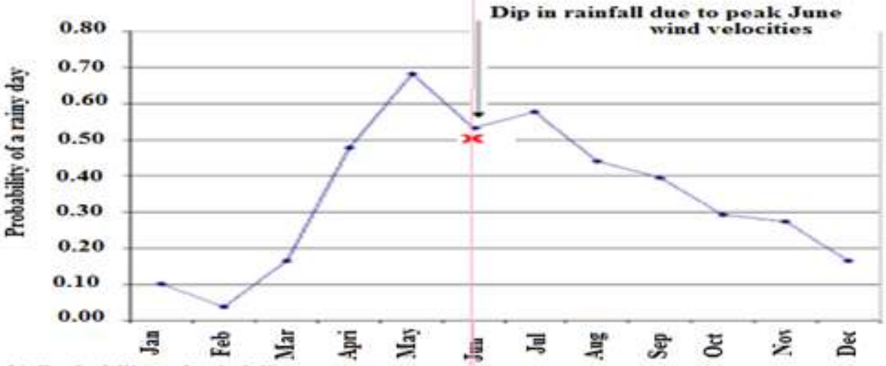
Figure 4.19e: Contributions to 100 cm-profile soil moisture by treatment interactions of coir mulched and irrigation over control treatment (M0W0) under PH4 maize during the relatively drier season II

4.12 Effect of June winds on rainfall and soil moisture

In both seasons I and II, between the period 49-66 DAS, the rates of evapotranspiration and 100 cm-crop available soil moisture declined to lowest levels in coir mulched, non-mulched, rainfed and irrigated maize crops (Table 4.2 and Fig 4.1). This period coincided with period of peak June wind velocities, low rainfall probability and period of tasseling and silking (critical) stages of maize crop (Fig. 4.20). Thus, after peak long rains in early May, the probability of a rainy day and amounts of rainfall declined to a lower level, marked X, in Fig 4.20a, mid-way between the months of May and June. The period within which peak June wind velocities coincided with period of reduced rainfall probability lasted about 5 to 10 days (Fig. 4.20a, d).During this period, ambient atmospheric conditions were fairly hot at 32-34^{0}C and cloud free (as indicated by maximum temperature of study site). Beyond this period, June winds speed declined and the probability of rainfall reverted back towards its earlier higher levels in June-July period before finally declining to a minimum (Fig 4.20b, d).



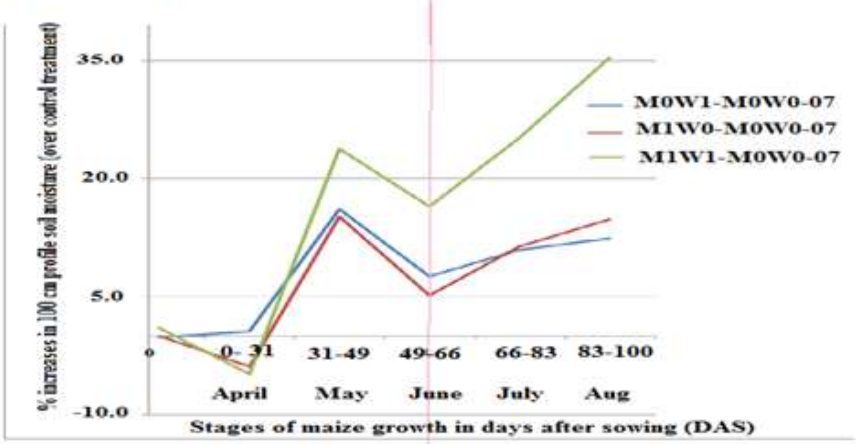
a) Peak June winds



b) Probability of rainfall

Growth stages					Planting				Flo/Init				Tas/Silk				Fert-G/Set			G/Fil		P/M		
Month	March				April				May				June				July				Aug			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

c) Stages of maize growth



d) Depression in soil moisture due to June winds occurence

Composite chart showing June winds effects on various parameters

Figure 4.20: Composite chair showing June winds effect on i) rainfall ii) floral stages, iii) and 100 cm profile soil moisture during season I in Kilifi

Key:

Pl=planting; Fi=Floral initiation; Ta= Tasseling; Si=Silking; Fe= Fertilization; G/fil=Grain set/ grain filing; PM=Physiological Maturity.

The top-bottom arrow connects timing of June winds occurrence with other variables.

4.13 Interactions of coir mulch, irrigation and kaolin on seasonal evapotranspiration of Pwani hybrid 4 maize

Seasonal evapotranspiration of Pwani hybrid 4 maize increased as the maize crop advanced in age (Table 4.7). The wetter season I had significantly higher evapotranspiration than the drier season II. Significant differences in seasonal evapotranspiration between coir mulch, irrigation and kaolin treatments during season I were only notable at 0-31 DAS and 31-49 DAS, whereas in season II, significant differences were observed at all stages of maize growth (Table 4.7). Thus, during the relatively wetter season I at 0-31 DAS, maize crop in M1W1K1 treatment had highest significant ($p \leq 0.05$) evapotranspiration that was 5.5 % higher than maize crop under control (M0W0K0) and M0W1K2 treatment. In general, maize crop in coir mulched (M1W-K-) treatment had higher ($p \leq 0.05$) evapotranspiration than maize crop in non-mulched (M0W-K-) treatment. Under non-mulched rain-fed (M0W0K-) conditions at 0-31 DAS, maize crop in M0W0K1 treatment had significantly ($p \leq 0.05$) 2.8 % higher evapotranspiration than maize crop in control (M0W0K0) treatment, while under non-mulched-irrigated (M0WIK-) conditions, maize crop in M0W1K3 treatment resulted in 3.2 % higher evapotranspiration than control treatment maize crop.

Maize crops in coir mulched irrigated (M1W1K-) interactions generally had higher evapotranspiration than maize crop in coir mulched–rain-fed (M1W0K-) treatments. Thus, in coir mulched rain-fed (M1W0K-) conditions, maize crop in M1W0K1 resulted in the highest significant ($p \leq 0.05$) evapotranspiration, while maize crop in M1W0K2 treatments resulted in lowest significant ($p \leq 0.05$) evapotranspiration at 0-31 DAS (Table 4.7).

Table 4.7 Evapotranspiration of Pwani hybrid 4 maize as influenced by coir mulch, irrigation and kaolin treatments during seasons i and ii, in Kilifi

Season	Season I (2007)					Season II (2008)				
Stages of growth (DAS)	31	49	66	83	100	31	49	66	83	100
Treatments	**Seasonal evapotranspiration in mm ha^{-1}**									
M0W0K0	652.1gh	927ab	1038.6	1094.6	1342.4	309.3bc	529.9ab	699.2abc	726.5cdef	900.1b
M0W0K1	670.7cde	934.9a	1040.8	1086.7	1325.2	297.5de	531.3ab	701.8ab	729.6bcdef	900.7b
M0W0K2	663.3defg	934.4a	1033.3	1084.4	1327.1	318.5ab	517.2abc	690.5abcd	721.8ef	895.1b
M0W0K3	664.1def	909.6abc	1030.8	1065.7	1307.4	327.8a	536.8a	704a	729.5bcdef	903.9b
M0W1K0	656.9fgh	899.9abc	1040.8	1062.8	1326.7	306.9cd	501.2cdef	680.1abcd	765.7abcde	1001.7a
M0W1K1	660.5efgh	872.6cd	1045.5	1073.8	1340	305cd	511.2bcd	686.9abcd	769.8abc	1003.4a
M0W1K2	650.8h	890.2bcd	1023.9	1058.1	1343.7	323a	485.8f	672.7cd	766abcd	998.1a
M0W1K3	673.7bcd	892.5bcd	1054.8	1090.8	1356.1	298.7de	521.6abc	693.7abc	773.1ab	1004.9a
Mean	661.5	907.6	1038.6	1077.1	1333.6	310.8	516.9	691.1	747.8	951.0
M1W0K0	670.3cde	881.7cd	1017.5	1075	1342.3	324.1a	488.5ef	662.5d	729.7bcdef	899.7b
M1W0K1	684.3ab	904.3abc	1038.2	1100.2	1352	303cd	511.9bcdd	689.4abcd	724.8def	899b
M1W0K2	6-63.9def	891.6bcd	1030.7	1087.9	1341	276.3g	511bcde	687.1abcd	721.4f	897.2b
M1W0K3	671.5cde	887.7bcd	1024.4	1100.4	1379.8	292ef	519.3abc	694.3abc	727.4cdef	903.3b
M1W1K0	679.8abc	858.6d	1024.2	1075.5	1377.8	287.4f	491.9def	675.6abcd	765.9abcd	1001.5a
M1W1K1	690.1a	853.3d	1028.8	1079.4	1382.7	286.3f	531.4ab	697.4abc	770.5abc	1008a
M1W1K2	673bcd	900.7abc	1057.4	1086.2	1339.7	274.3g	517.4abc	693abc	775.6a	1008.9a
M1W1K3	670.7cde	887.5bcd	1014.2	1069.4	1386.8	287.6f	488.1f	674.7bcd	768.5abcd	1005.2a
Mean	675.5	883.2	1029.4	1084.3	1362.8	291.4	507.4	684.3	748.0	952.9
Overall mean	668.5	895.4	1034.0	1080.7	1348.2	301.1	512.2	687.7	747.9	951.9
LSD (5%)	11.9	40.1	63.3	76.4	100.6	9.6	22.6	28.5	44	45.1
			NS	NS	NS					

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

At 31-49 DAS, during the relatively wetter season I, maize crop in non-mulched (M0W-K-) treatments generally had higher evapotranspiration than maize crop in coir mulched (M1W-K-) treatments, whereas under non-mulched conditions, maize crop in rain-fed (M0W0K-) treatment had significantly ($p \leq 0.05$) higher evapotranspiration than all other coir mulch, irrigation and kaolin treatments. Thus, the maize crop in M0W0K1 treatments had higher significant ($p \leq 0.05$) evapotranspiration than M1W1K0 and M1W1KI treatments at 31-49 DAS (Table 4.7). The maize crops in M0W1K- and M1W0K- treatments had comparable evapotranspiration at 31-49 DAS. However, in non-mulched irrigated (M0W1K-) conditions, maize crop in M0W1K0 treatment had the highest significant ($p \leq 0.05$) evapotranspiration at 31-49 DAS. Thus application of kaolin under non-mulched irrigated (M0W1K-) conditions at 31-49 DAS resulted in depressed evaporation with application of kaolin at vegetative stages of maize growth (M0W1K1 treatment) resulting in 3.1 % reduction in evapotranspiration.

The maize crop in coir mulched rain-fed conditions (M1W0K0 treatment) had relatively lower evapotranspiration at 31-49 DAS. Thus application of kaolin at 31-49 DAS in coir mulched rain-fed conditions resulted in increased evapotranspiration, with maize crop in M1W0K1 treatment resulting in relatively higher evapotranspiration (Table 4.7).In coir mulched-irrigated (M1W1K-) conditions, the maize crop in M1W1K1 treatment resulted in lowest significant ($p \leq 0.05$) evapotranspiration, while the maize crop in M1W1K2 treatments had highest evapotranspiration ($p \leq 0.05$) at 31-49 DAS. The maize crop in M1W1K3 and M1W0K3 treatment at 31-49 DAS had similar evapotranspiration, while maize crop in M1W1K2 and M1W0K2 had comparable evapotranspiration (Table 4.7). Beyond 31-49 DAS during the relatively wetter season I, there were no significant differences in evapotranspiration within specific stages of maize growth. Although at 83-100 DAS all coir mulch, irrigation and kaolin treatments has similar evapotranspiration, maize crop in coir mulched irrigated (M1W1K-) treatments, namely M1W1K3 treatment attained insignificantly 3.2 % higher evapotranspiration of 1386.8 mm ha^{-1} than the control (M0W0K0) treatment. The maize crop in M0W0K3 treatment had relatively lowest final evapotranspiration (Table 4.7).

During the drier season II, significant differences in coir mulch, irrigation and kaolin treatments were observed throughout the growing period (Table 4.7). Thus, between the period 0-31 and 31-

49 DAS, maize crop in non-mulched rainfed (M0W0K-) treatments had higher ($p \leq 0.05$) evapotranspiration than maize crop in non-mulched irrigated (M0W1K-) treatments (Table 4.7). However, beyond 49 DAS, non-mulched irrigated maize crop (M0W1K- treatments) had higher ($p \leq 0.05$) evapotranspiration than non-mulched rainfed maize crop (M0W0K- treatments), attaining 27.3 % higher evapotranspiration at 83-100 DAS (Table 4.7). Under coir mulched rainfed (M1W0K-) treatments the maize crop in M1W0K0 treatment had significantly highest ($p \leq 0.05$) evaporation and also highest significant ($p \leq 0.05$) biomass at 0-31 DAS.

The maize crop in coir mulched irrigated (M1W1K-) treatments generally had relatively higher evapotranspiration than coir mulched rainfed maize crop at growth stages beyond 31 DAS. Also at 31-49 DAS in season II, non-mulched rain-fed (M0W0K-) treatments generally resulted in relatively higher evapotranspiration (Table 4.7). Under non-mulched irrigated (M0W1K-) treatments, M0W1K2 treatment had the lowest ($p \leq 0.05$) evapotranspiration at 31-49 DAS. Under coir mulched (M1W-K-) conditions, M1W0K0 and M1W1K3 treatments caused the highest reduction in evapotranspiration at 31-49 DAS. However, treatment combinations of coir mulch and kaolin in rainfed conditions (M1W0K1 treatment) caused significant ($p \leq 0.05$) increases in evapotranspiration (Table 4.7). Although the M1W1K- treatments generally had higher evapotranspiration, the M1W1K3 treatments caused the lowest ($p \leq 0.05$) evapotranspiration at 31-49 DAS.

During the drier season II the pattern of evapotranspiration of Pwani hybrid 4 maize at 49-66 DAS was similar to that at 31-49 DAS, except that evapotranspiration at 49-66 DAS was higher ($p \leq 0.05$) by between 31-38 % (Table 4.7). Similarly, the pattern of evapotranspiration of Pwani hybrid 4 maize at 66-83 DAS during season II was similar to that at 83-100 DAS, only that the evapotranspiration at 83-100 DAS was higher ($p \leq 0.05$) by between 24-31 % (Table 4.7). Towards the end of the season II at 66-83 and 83-100 DAS irrigated maize crop had relatively higher evapotranspiration than rain-fed maize crop. Thus, at 83-100 DAS all irrigated treatments had significantly higher ($p \leq 0.05$) final evapotranspiration than rainfed treatments. All rainfed treatments had similar or comparable final evapotranspiration, whereas all irrigated treatments had similar final evapotranspiration levels (Table 4.7). Irrigated maize crop at 83-100 DASin season II had final evapotranspiration of more than 998.0 mm ha^{-1}, while rain-fed maize crop had final evapotranspiration of less than 904.0 mm ha^{-1}. Thus, maize crop under M1W1K2 treatment had highest significant ($p \leq 0.05$) final evapotranspiration of 1008.9 mm ha^{-1} whereas maize crop in M0W0K2 treatment had the lowest significant ($p \leq 0.05$) final evapotranspiration of 895.1 mm ha^{-1} (Table 4.7).

4.14 Interaction of coir mulch, irrigation and kaolin on above ground biomass of Pwani hybrid 4maize

Above ground biomass of Pwani hybrid 4 maize increased as the maize crop advanced in age in seasons I and II (Table 4.8).Significant differences ($p \leq 0.05$) in biomass accumulation due to coir mulch, irrigation and kaolin treatments in season I occurred at 0-31, 31-49 and 66-83 DAS, at all growth stages during the drier season II, except at 83-100 DAS. The maize crop in season I had 28 %; 5.2 %; 35.1 % and 54.0 % higher biomass ($p \leq 0.05$) than in season II at 31st; 66th; 83rd and 100th DAS, except at 31-49 DAS where season II had 44.7 % higher ($p \leq 0.05$) biomass (Table 4.8). The magnitude of differences in biomass due to treatments effects increased beyond 49 DAS as the maize crop advanced in maturity. During the drier season II, maize crop in coir mulched treatments had relatively higher biomass compared to non-mulched maize crop, between the period 31-83 DAS. The maize crops in coir mulched irrigated (M1W1K-) treatments had on average, 7.8 % higher biomass than maize crop in coir mulched rainfed (M1W0K-) treatments (Table 4.8).

During season I the maize crops in control (M0W0K0) and M1W0K1 treatments had similar but highest significant ($p \leq 0.05$) biomass at 0-31 DAS. The maize crop in M1W0K1 treatment, had significantly higher ($p \leq 0.05$) biomass than maize crop in M0W1K1 treatment, that had lowest biomass ($p \leq 0.05$) at 0-31 and 31-49 DAS. At 66-83 DAS, maize crop under coir mulch alone (M1W0K0) treatment during the relatively wetter season I had 7.9 % lower biomass than control (M0W0K0) treatment and 43.8 % lower biomass than maize crop in M0W1K2 treatment (Table 4.8). The pattern of biomass accumulation due to coir mulch, irrigation and kaolin treatments at 66-83 DAS during the wetter season I was similar to that at 83-100 DAS, except that the biomass at 83-100 DAS was higher ($p \leq 0.05$) by 14-31.8 % (Table 4.8). At 83-100 DAS during season I, application of kaolin or irrigation or combination of both resulted in similar levels of biomass to control (M0W0K0) treatment.

M0W1K2 treatment had relatively highest final biomass of 18.7 tons ha^{-1} (Table 4.8). In season I maize crop in coir mulch alone (M1W0K0) treatment resulted in relatively lowest final biomass similar to control (M0W0K0) treatment). However, combination of the coir mulch treatment with either kaolin or irrigation or both resulted in 22.2 % more biomass. Thus, maize crop under M1W1K1 treatment yielded 16.2 tons ha^{-1} biomass. During the drier season II, maize crops in M0W1K3 and M1W1K1 treatments had higher biomass ($p \leq 0.05$) compared to control (M0W0K0) treatment at 0-31 DAS. The maize crop in coir mulched rain-fed (M1W0K-) treatments generally had relatively lower biomass than control (M0W0K0 treatment) at 0-31 DAS. Application of kaolin on maize crop in season II under non-mulched irrigated conditions (M0W1K-) resulted in higher ($p \leq 0.05$) biomass, whereas its application under coir mulched rain-fed (M1W0K-) conditions resulted in lower but insignificant biomass compared to control at 0-31 DAS (Table 4.8).

Between 49-83 DAS, coir mulch, irrigation and kaolin treatments had similar pattern of biomass accumulation, with the biomass increasing at successive stages of maize growth by between 9.8 % and 41.7 % (or an average of 25.3 %) between 31-49 and 49-66 DAS, and by between 11.6 % and 28.3 % (or an average of 18.8 %) between 49-66 DAS and 66-83 DAS during the relatively drier season II. Thus maize crops in M1W0K0, M1W1K1 and M1W1K3 treatments maintained highest significant ($p \leq 0.05$) biomass than maize crop in M0W0K3 treatment (Table 4.8). The maize crop in M0W0K3 treatment had lowest significant ($p \leq 0.05$) biomass during the relatively drier season II. Between the period 31-100 DAS in season II, the maize crop in coir mulched treatments (M1W0K- and M1W1K-) including M0W1K2 and M0W1K3 treatments, yielded relatively higher ($p \leq 0.05$) biomass than maize crop in non-mulched rain-fed (M0W0K-) treatments (Table 4.8). Although final biomass due to coir mulch, irrigation and kaolin during drier season II were not significantly different the maize crop under M1W1K3 treatment had relatively highest final biomass of 11.9 tons ha^{-1}, while maize crop in M0W0K3 treatment that had maintained the lowest significant biomass from 31-100 DAS, yielding relatively lowest ($p \geq 0.05$) final biomass of 7.5 tons ha^{-1}.

Table 4.8. Above ground biomass of Pwani hybrid 4 maize as influenced by interactions of coir mulch, irrigation and kaolin treatments during seasons I and II, in Kilifi

Season	Season I (2007)					Season II (2008)				
Stages of maize growth (DAS)	31	49	66	83	100	31	49	66	83	100
Treatments	Biomass in **tons ha^{-1}**									
M0W0K0	1.2a	2.98ab	6.93	9.93ab	12.9	0.34c	3.7bc	4.9cd	6.83ab	8.8
M0W0K1	1ab	2.46ab	6.73	10.43ab	14	0.64abc	3.8bc	5.7abcd	7.07ab	8.5
M0W0K2	0.89ab	2.37ab	6.5	10.1ab	14.7	0.97abc	4.0abc	5.2cd	6.83ab	8.5
M0W0K3	1.02ab	2.63ab	6.57	10.8ab	13.3	0.95abc	2.7c	4.63d	6.05b	7.5
M0W1K0	0.76ab	3.12ab	7.37	11.33ab	15.3	0.72abc	3.5c	5.43bcd	6.91ab	8.4
M0W1K1	0.67b	1.99b	6.47	11.07ab	15.8	1.08abc	3.8bc	5.27cd	6.57ab	7.8
M0W1K2	1ab	2.91ab	7.77	13.23a	18.7	0.61abc	5.4abc	6.78abcd	7.92ab	9
M0W1K3	0.84ab	2.73ab	6.4	10.37ab	14.4	1.33a	5.4abc	6.47abcd	7.48ab	8.5
Mean	0.9	2.6	6.8	10.9	14.9	0.8	4.0	5.5	7.0	8.4
M1W0K0	0.89ab	2.74ab	6.27	9.2b	12.6	0.77abc	6.4ab	8.47a	9.6a	10.7
M1W0K1	1.22a	3.33a	7.73	11.17ab	14.6	0.46c	4.8abc	6.63abcd	8.23ab	9.8
M1W0K2	1ab	2.49ab	7	10.33ab	15.1	0.44c	5.5abc	7.53abc	8.63ab	9.8
M1W0K3	1.03ab	2.63ab	5.9	11.37ab	13.2	0.51bc	5.4abc	7.37abcd	8.73ab	10.1
M1W1K0	0.99ab	2.82ab	7.07	10.6ab	14.1	0.46c	6abc	7.1abcd	8.85ab	10.6
M1W1K1	1.03ab	2.99ab	8.23	12.27ab	16.2	1.31ab	6.4ab	8.2ab	9.28ab	10.4
M1W1K2	0.89ab	2.63ab	6.47	10.17ab	13.9	0.7abc	4.9abc	6.83abcd	8.83ab	10.9
M1W1K3	0.94ab	2.52ab	6.03	10.0ab	14	0.76abc	6.7a	7.43abcd	9.67a	11.9
Mean	1.0	2.8	6.8	10.6	14.2	0.7	5.8	7.4	9.0	10.5
Overall Mean	0.96	2.71	6.84	10.77	14.55	0.75	4.9	6.5	7.97	9.45
LSD (5%)	0.494	1.147	2.423	3.946	6.86	0.797	2.76	2.84	3.518	4.43
Sed	0.225	0.56	1.169	1.772	2.82	0.388	1.34	1.319	1.533	1.9
			NS		NS					NS

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

The maize crop under coir mulched irrigated (M1W1K-) treatments yielded final biomass of more than 10.0 tons ha^{-1}, whereas the maize crop in non-mulched rain-fed (M0W0K-) treatments yielded final biomass of less than 8.8 tons ha^{-1}. The maize crop in coir mulched rain-fed treatments (M1W0K-) yielded final biomass of more than 9.8 tons ha^{-1}. Thus, treatments that increased final biomass were in the order: M1W1K->M1W0K->M0W1K->M0W0K-.

4.15 Interactions of coir mulch, irrigation and kaolin on grain yield of Pwani hybrid 4 maize

The coir mulch, irrigation and kaolin treatments caused significant differences in grain yield. The differences in grain yield between the wetter and drier seasons I and II was greater than 16.7 %, for other treatments combinations of coir mulch, irrigation and kaolin except for M0W0K3, M0W1K1, M1W0K3 and M1W1K0 treatments where the differences in grain yield was less than 9.6 % (Table 4.9 and Fig 4.21).However, the maize crops in M0W0K0, M1W0K2 and M1W0K3 treatments during the relatively drier season II yielded 19.4 %; 16.7 % and 2.6 % higher grain yield ($p \leq 0.05$) than maize crop in season 1 (Table 4.9 and Fig 4.21). During season I, the maize crops in M0W1K0, M1W0K0, and M1W1K1 treatments interactions yielded significantly higher grain yield that were 31.1 %; 26.9 % and 26.7 % higher than those of season II. Also, the maize crop in coir mulching alone (M1W0K0) treatment yielded higher ($p \leq 0.05$) grain yield than maize crops in M0W0K2; M0W0K0; M0W0K3; M0W1K1; M1W0K2 and M1W0K3 treatments.

The maize crop in non-mulched irrigated (M0W1K-) treatments generally yielded grain yield of more than 5.6 tons ha^{-1} (or 35.7 % higher than control treatment), except maize crop under M0W1K1 treatments that resulted in grain yield of 4.0 tons ha^{-1} (or 10.0 % higher than control maize crop (Fig 4.21). Maize crops in coir mulched irrigated treatments (M1W1K-) resulted in second highest grain yield of more than 5.2 tons ha^{-1} (or 30.8 % higher grain yield than control), while maize crops in non-mulched rain-fed (M0W0K-) treatments resulted in lowest grain yield of less than 4.0 tons ha^{-1}, except maize crop in M0W0K1 treatment that yielded 5.4 tons ha^{-1}(Table 4.9). Thus, with the few exceptions, the order of main treatments yielding relatively highest ($p \leq 0.05$) amount of grain in season I was: M1W0K- > M0W1K-; >M1W1K-;

>M0W0K-.The individual treatments of coir mulch, irrigation and kaolin yielding highest ($p \leq 0.05$) grain during the wetter season I were: - M1W0K0; > M0W0K2; >M0W0K0; > M1W1K1.

Table 4.9: Grain yield of Pwani hybrid 4 maize due to interactions of coir mulch, irrigation and kaolin treatments in seasons I and II

	Season I (2007)	Season II (2008)
Treatment	Grain yield in **tons ha^{-1}**	
M0W0K0	3.6ef	4.3ab
M0W0K1	5.4abcde	4.0ab
M0W0K2	2.9f	3.9b
M0W0K3	4.4bcdef	4.7ab
M0W1K0	6.1abc	4.2ab
M0W1K1	4.0cdef	4.0ab
M0W1K2	6.2ab	4.9a
M0W1K3	5.6abcde	4.6ab
Mean	4.8 bcdef	4.34.2ab
M1W0K0	6.7a	4.9a
M1W0K1	5.7abcde	4.6ab
M1W0K2	3.6ef	4.2ab
M1W0K3	3.9def	4.0ab
M1W1K0	5.2abcde	4.7ab
M1W1K1	6.0abcd	4.4ab
M1W1K2	5.2abcde	4.3ab
M1W1K3	5.8abcd	4.8ab
Mean	5.3 abcde	4.54.2ab
Overall mean	5.1	4.4
LSD (5 %)	2.15	0.92
sed	1.05	0.32

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

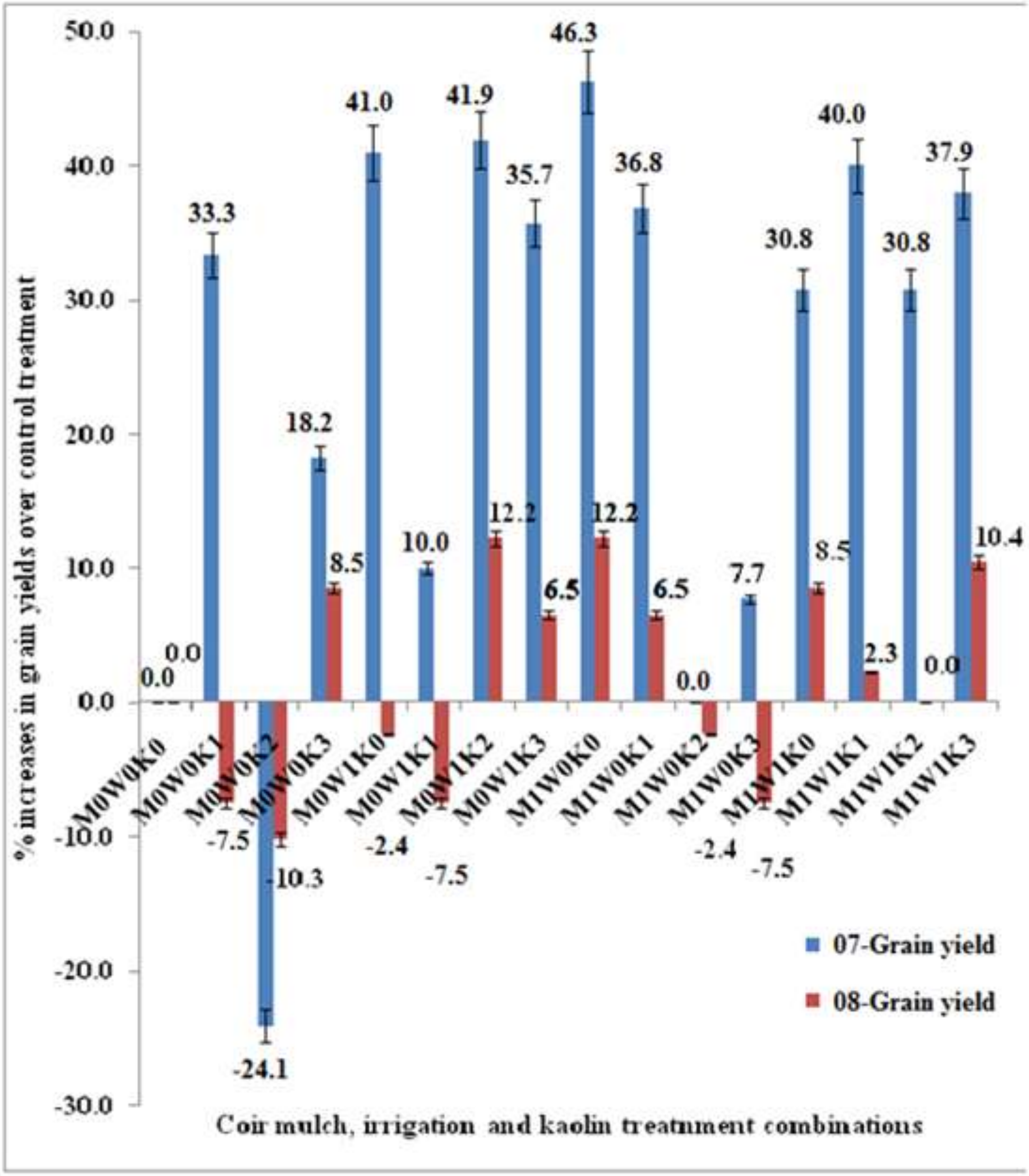


Figure 4.21: Percentage increases in grain yield of PH4 maize due to interaction effect of coir mulch, irrigation and kaolin over control treatment in season I and II

Application of kaolin at vegetative stages under non-mulched rain-fed (M0W0K-) conditions (M0W0K1 treatment) and at grain-set/grain filling stages (M0W0K3 treatment) during the wetter season I increased grain yield by 33.3 % and 18.2 %, respectively. Its application at floral stages (M0W0K2 treatment) resulted in19.4 % lower grain yield and lowest ($p \leq 0.05$) grain yield of 2.9 tons ha^{-1} (Table 4.9 and Fig 4.21).In non-mulched irrigated conditions (M0W1K- set of treatments), maize crop in M0W1K2 treatment yielded among the highest 6.2 tons ha^{-1} of grain, while maize crop in M0W1K1 treatment yielded the lowest grain yield of 4.0 tons ha^{-1}. Under coir mulched rain-fed conditions (M1W0K- set of treatments), maize crop in M1W0K0 treatment yielded significantly ($p \leq 0.05$) the highest grain yield of 6.7 tons ha^{-1}, whereas maize crop in M1W0K2 yielded lowest significant ($p \leq 0.05$) grain yield of 3.6 tons ha^{-1}. In coir mulched irrigated conditions (M1W1K- set of treatments) maize crop in M1W1K1 treatment yielded grain yield of 6.0 tons ha^{-1} while maize crops in M1W1K0 and M1W1K2 treatments yielded similar but lowest levels of grain yield of 5.2 tons ha^{-1} (Fig 4.21).

4.16 Production functions relating seasonal evapotranspiration to biomass of Pwani hybrid 4 maize

The production functions relating evapotranspiration to biomass accumulation indicated that above ground biomass increased linearly with increase in evapotranspiration in both seasons. The rates of biomass accumulation was described ($R^2 \geq 0.92$) by the equations illustrated in Fig 4.22. The average rate of biomass accumulation was 21.0 and 13.0 kg mm^{-1} ha^{-1} in seasons I and II respectively. In both seasons the correlation coefficients of determination, R^2 was high; with that of the drier season II being relatively higher (Fig. 4.22). The regression curve crossed the X-axis (intercept) at 680 mm ha^{-1} mark during the wetter season I and at 200 mm ha^{-1} mark during the drier season II (Fig. 4.22).

Water use efficiency (WUE) during the drier season II was 19.6 % higher than during the wetter season I (Table 4.10). M1W1K- and M0W1K- treatments had similar evapotranspiration efficiency of 4.1 during the wetter season I, whereas during the drier season II, M1W0K- had relatively higher WUE of 4.9 (Table 4.10).

Table 4.10 Relationship between final seasonal evapotranspiration, above ground biomass, grain yield, HI and WUE of Pwani hybrid 4 maize as influenced by coir mulch, irrigation and kaolin treatments in seasons I and II

	Season I					Season II				
	ETc	DM	Grain	HI	WUE	ETc	DM	Grain	HI	WUE
Treatments	mm ha^{-1}	**tons ha^{-1}**	**tons ha^{-1}**	Grain kg^{-1}dm	Grain mm^{-1} ha^{-1}	mm ha^{-1}	**tons ha^{-1}**	**tons ha^{-1}**	Grain kg^{-1}dm	Grain mm^{-1} ha^{-1}
M0W0K0	1342.4	12.9	3.6ef	0.28	2.7	900.1b	8.8	4.3ab	0.49	4.8
M0W0K1	1325.2	14	5.4abcde	0.39	4.1	900.7b	8.5	4.0ab	0.47	4.4
M0W0K2	1327.1	14.7	2.9f	0.20	2.2	895.1b	8.5	3.9b	0.46	4.4
M0W0K3	1307.4	13.3	4.4bcdef	0.33	3.4	903.9b	7.5	4.7ab	0.63	5.2
Mean	1325.5	13.7	4.5	0.33	3.4	900.0	8.3	4.2	0.51	4.7
M0W1K0	1326.7	15.3	6.1abc	0.40	4.6	1001.7a	8.4	4.2ab	0.50	4.2
M0W1K1	1340	15.8	4.0cdef	0.25	3.0	1003.4a	7.8	4.0ab	0.51	4.0
M0W1K2	1343.7	18.7	6.2ab	0.33	4.6	998.1a	9	4.9a	0.54	4.9
M0W1K3	1356.1	14.4	5.6abcde	0.39	4.1	1004.9a	8.5	4.6ab	0.54	4.6
Mean	1341.6	16.1	5.5	0.34	4.1	1002.0	8.4	4.4	0.52	4.4
M1W0K0	1342.3	12.6	6.7a	0.53	5.0	899.7b	10.7	4.9a	0.46	5.4
M1W0K1	1352	14.6	5.7abcde	0.39	4.2	899b	9.8	4.6ab	0.47	5.1
M1W0K2	1341	15.1	3.6ef	0.24	2.7	897.2b	9.8	4.2ab	0.43	4.7
M1W0K3	1379.8	13.2	3.9def	0.30	2.8	903.3b	10.1	4.0ab	0.40	4.4
Mean	1353.8	13.9	5.0	0.36	3.7	899.8	10.1	4.4	0.44	4.9
M1W1K0	1377.8	14.1	5.2abcde	0.37	3.8	1001.5a	10.6	4.7ab	0.44	4.7
M1W1K1	1382.7	16.2	6.0abcd	0.37	4.3	1008a	10.4	4.4ab	0.42	4.4
M1W1K2	1339.7	13.9	5.2abcde	0.37	3.9	1008.9a	10.9	4.3ab	0.39	4.3
M1W1K3	1386.8	14	5.8abcd	0.41	4.2	1005.2a	11.9	4.8ab	0.40	4.8
Mean	1371.8	14.6	5.6	0.38	4.1	1005.9	11.0	4.6	0.42	
LSD (5%)	100.6	14.55	5.1			45.1	9.45	4.4		
Sed	48.5	6.86	2.15			15.9	4.43	0.92		
		2.82	1.05				1.9	0.32		
	NS	NS					NS			

Treatment means followed by same letters are not significantly different at $p \leq 0.05$ LSD

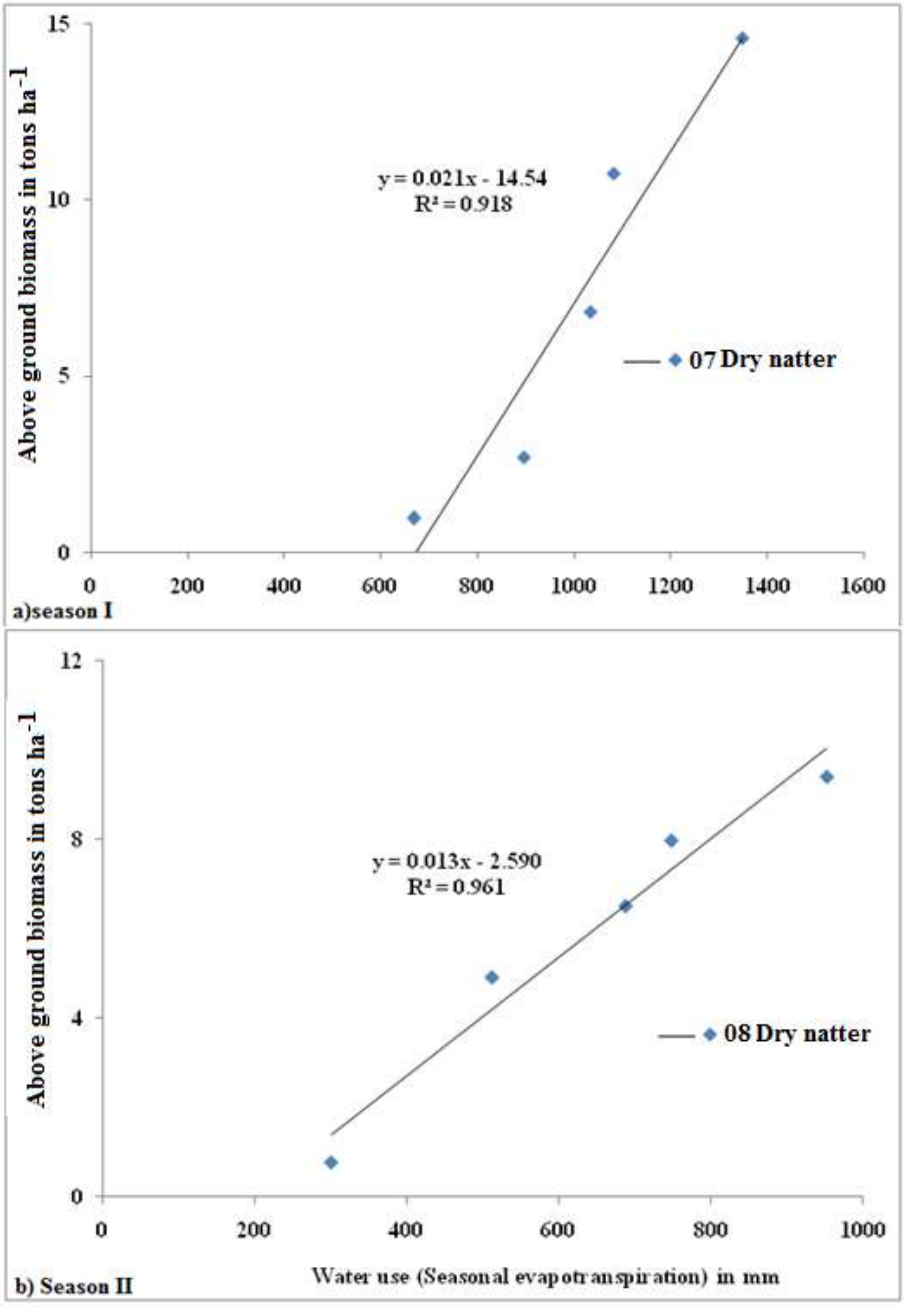


Figure 4.22: Production function relating evapotranspiration of Pwani hybrid 4 to above ground biomass during seasons a) I and b) in Kilifi

4.17 ET-yield production functions based on Singh and Kumar model equations

Fig 4.23 shows that during the wetter season I, the yield response factor was 1.998, while during the drier season II, the yield response factor was 1.333. Thus, during the wetter season I, when soil moisture deficit increased by one unit, the biomass decreased by 1.998 units. During the drier season II, an increase in soil moisture deficit of one unit caused biomass to decrease by 1.333 units (Fig. 4.23). The seasonal yield depression factor increased from 0.4 as the soil moisture deficit increased beyond 0.2, whereas during the drier season II, the yield depression factor increased from 0.4 when the soil water deficit increased beyond 0.35 (Fig. 4.23).

Table 4.11 Computation of seasonal yield depression factors and season water deficit (relative evapotranspiration deficit) in seasonsI and II based on Singh (1987); Kumar (1997) and Allen (1998) methods

A. Season I

	DM Yield **(tons ha^{-1})**	Max DM yield	Rel. yield	Yield depression			Seasonal ET	Max ET	Relative ET	Water deficit (Rel. ETc deficit)			Ratio: Sensitivity of DM to moisture deficit
Stages of growth (DAS)	Y	14.6	Y/Y_m	$1-(Y/Y_m)$	$(1-Y/Y_m)^2$	$[1-(1-Y/Y_m)^2]$	ET	ET_m	ET/ET_m	$1-(ET/ET_m)$	$(1-ET/ET_m)^2$	$[1-(1-ET/ET_m)^2]$	$\{[1-(1-Y/Y_m)^2]\}/\{[1-(1-ET/ET_m)^2]\}$
31	0.96	14.6	0.07	0.93	0.86	0.14	668.5	1348.2	0.50	0.50	0.25	0.75	0.19
49	2.71	14.6	0.19	0.81	0.66	0.34	895.4	1348.2	0.66	0.34	0.11	0.89	0.38
66	6.84	14.6	0.47	0.53	0.28	0.72	1034	1348.2	0.77	0.23	0.05	0.95	0.76
83	10.8	14.6	0.74	0.26	0.07	0.93	1080.7	1348.2	0.80	0.20	0.04	0.96	0.97
100	14.6	14.6	1.00	0.00	0.00	1.00	1348.2	1348.2	1.00	0.00	0.00	1.00	1.00
B. Season II													
31	0.75	9.5	0.08	0.92	0.85	0.15	301.1	951.9	0.32	0.68	0.47	0.53	0.29
49	4.9	9.5	0.52	0.48	0.23	0.77	512.1	951.9	0.54	0.46	0.21	0.79	0.97
66	6.5	9.5	0.68	0.32	0.10	0.90	687.6	951.9	0.72	0.28	0.08	0.92	0.98
83	7.97	9.5	0.84	0.16	0.03	0.97	747.8	951.9	0.79	0.21	0.05	0.95	1.03
100	9.45	9.5	0.99	0.01	0.00	1.00	951.9	951.9	1.00	0.00	0.00	1.00	1.00

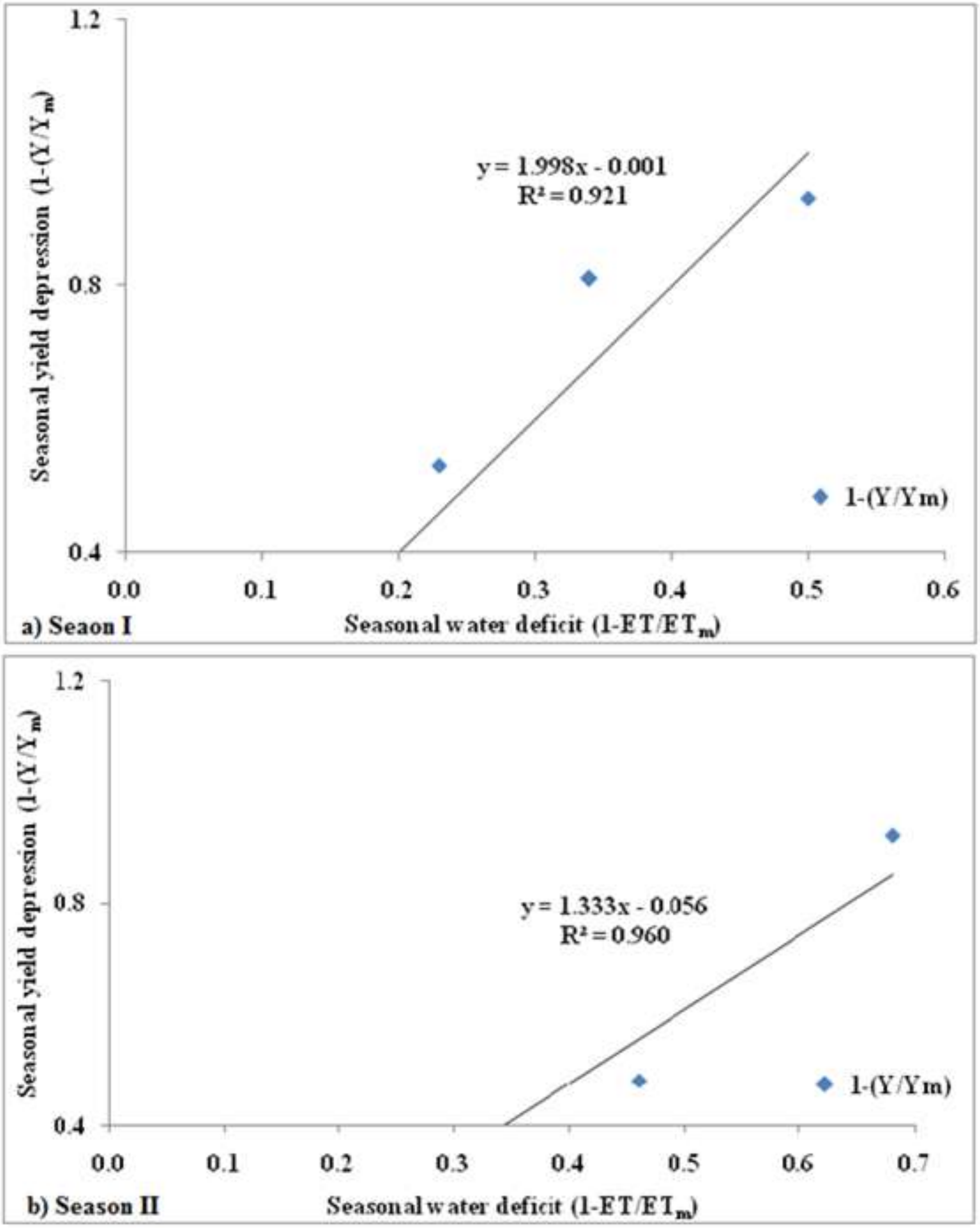


Figure 4.23: Production functions relating season yield depression of PH4 maize, to seasonal water deficit (relative evapotranspiration deficit during seasons a) I and b) II, in Kilifi

4.18 Determination of empirical constants a and b in Sigh (1987); Kumar (1997) and Allen (1998) model equations

The correlation coefficients relating biomass to evapotranspiration function $[1-(1-ET/ET_m)^2]$ of equation (4) were estimated from production functions shown in Figs. 4.6.5. Thus, the values of empirical constants a and b in Singh (1987) model equation in season I were: a = -3.429 and b = 3.537, whereas for season II were a = -0.227 and b = 2.04 (Fig 4.24).

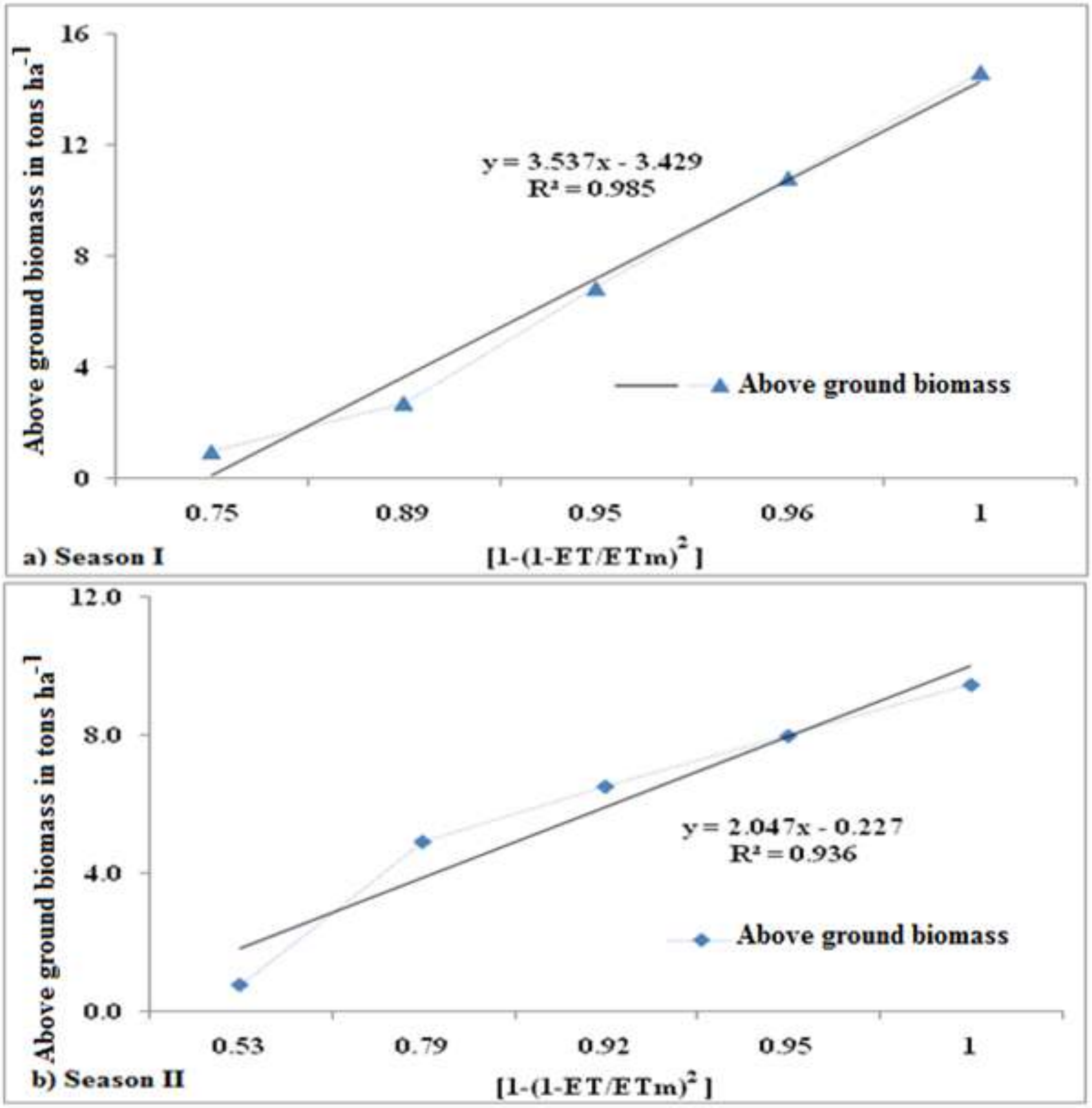


Figure 4.24: Estimation of empirical constants "a" and "b" in Singh (1987) model equation in seasons a) I and b) II

Fig 4.25 indicates that the sensitivity or rate of response of biomass accumulation of Pwani hybrid 4 maize increased with increased soil moisture deficit.

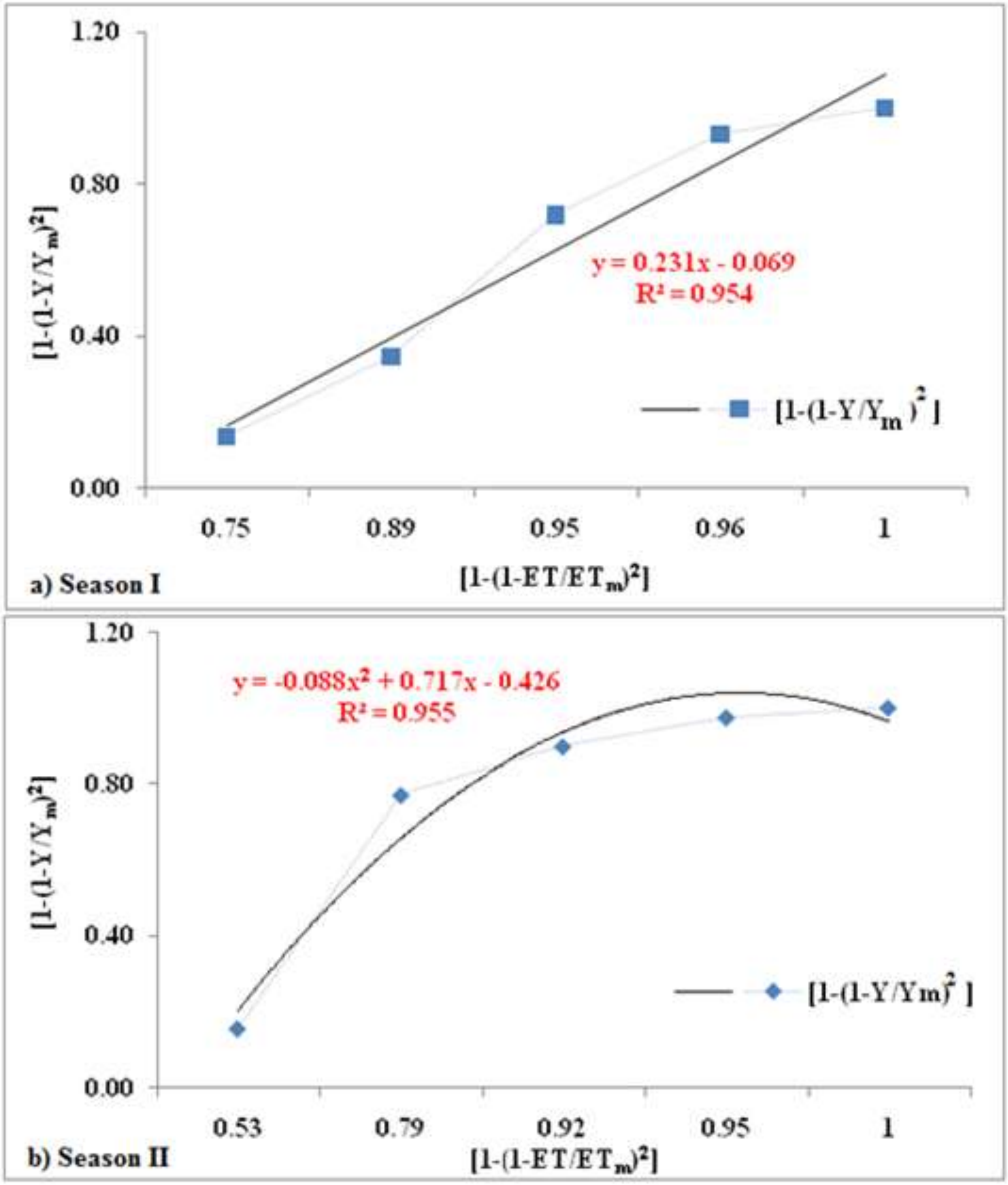


Figure 4.25: Production functions relating sensitivity of biomass accumulation of Pwani hybrid 4 maize to soil moisture deficit during seasons a) I and II, in Kilifi

4.19 Pwani hybrid 4 maize grain yield production function

The multiple regression analysis of interactions of coir mulch, irrigation and kaolin treatments generated the following model equations for predicting grain yield of Pwani hybrid 4 maize.

Season I: $Y=3.602+3.05M1+2.50W1$---(7)

Season II: $Y=4.319+ 0.528M1-0.147W1-0.277K_1-0.380K_2+ 0.355K_3$ $(p>0.337)$ -----------------(8)

Thus, during the wetter season I, coir mulching and irrigation treatments had greater influence in increasing ($p \leq 0.05$) grain yield. However, during the drier season II, coir mulched increased grain yield but irrigation and kaolin did not significantly contribute to increased grain yield.

4.20 Comparative analysis of coir mulch, irrigation and kaolin treatments that resulted in higher grain yield

A simple analysis of grain yield advantage of using the coir mulch, irrigation and kaolin treatments under conditions of wetter and limited rainfall is indicated in Table 4.12. The table shows that, using an assumed price of maize grain of ksh. 40 per kg, M1W0K0, M1W0K1, M0W0K1, and M0W0K3 treatments would give relatively higher gross returns where supplementary irrigation would not be possible during a wetter season. M1W0K0 treatment yielded the highest grains in both drier and wetter season, and also relatively highest gross returns.

Table 4.12 Basket of adoptable low cost options for increased maize grains yield and income in Coastal Kenya

A. Higher rainfall seasons, (Season I)

Treatment and benefits of low evapotranspiration options						Treatment and benefits of high evapotranspiration options					
	Grain Yield (tons ha^{-1})			Income/ha (k sh)			Grain Yield (tons ha^{-1})			Income (k sh)	
Treatments	**tons ha^{-1}**	90 kg Bags	% Gain	Gross income	Net income	Treatments	**tons ha^{-1}**	90kg Bags	% Gain	Gross income	Net income
M1W0K0	6.7	74	46.3	268,000	124,000	M0W1K0	6.1	68	2.5	244,000	100,000
M1W0K1	5.7	63	36.8	228,000	84,000	M1W1K1	6.0	67	2.4	240,000	96,000
M0W0K1	5.4	60	33.3	216,000	72,000	M0W1K2	6.2	69	2.6	248,000	104,000
M0W0K3	4.4	49	18.2	176,000	32,000	M1W1K3	5.8	64	2.2	232,000	88,000
						M0W1K3	5.6	62	2.0	224,000	80,000
						M1W1K2	5.2	58	1.6	208,000	64,000
						M1W1K0	5.2	58	1.6	208,000	64,000
						M0W1K1	4.0	44	0.4	160,000	16,000
M0W0K0	3.6	40.0		144,000		M0W0K0	3.6	40		144,000	

B. Lower rainfall seasons, (Season II)

Treatment and benefits of low evapotranspiration options						Treatment and benefits of high evapotranspiration options					
	Grain Yield (tons ha^{-1})			Income/ha (k sh)			Grain Yield (tons ha^{-1})			Income (k sh)	
Treatments	**tons ha^{-1}**	90 kg Bags	% Gain	Gross income	Net income	Treatments	**tons ha^{-1}**	90 kg Bags	% Gain	Gross income	Net income
M1W0K0	4.9	54	0.6	196000	24,000	M1W1K3	4.8	53	0.5	192000	20,000
M0W0K3	4.7	52	0.4	188000	16,000	M1W1K0	4.7	52	0.4	188000	16,000
M1W0K1	4.6	51	0.3	184000	12,000	M1W1K1	4.4	49	0.1	176000	4,000
M0W0K0	4.3	48		172000		M0W0K0	4.3	48		172000	

CHAPTER FIVE

DISCUSSIONS

5.1 Rainfall characteristics during long rains, in seasons I and II in Kilifi

The study area had bimodal rainfall, with most of the rainfall being received during long rains. In both seasons much of the rainfall, over 50 % was received during the month of May, causing water logging conditions, with the other months of the growing season receiving much lower rainfall that could not sustain optimal crop production. This is evidenced by the fact that only two months in the whole year had positive moisture regimes, since in all other months' potential evapotranspiration exceeded received rainfall. Therefore, the rainfall distribution in the region posed major challenge in crop production, since low rainfall resulted in soil moisture stress that led to reduced yield. Occurrence of June winds further aggravated this situation by inducing cloud free conditions (McGregor and Nieuwolt, 1998; Muti and Ng'etich, 2009).

5.2 Effect of coir dust mulch on evapotranspiration of Pwani hybrid 4 maize

The study indicated that Kilifi and much of the Coastal region experienced high levels of atmospheric demand due to high ambient temperatures where large amounts of water had to be evaporated (expended) as basal evaporation to meet the high evaporative demand before any tangible maize yield could be obtained. This basal evaporation represented 48.2 % and 17.0 % of seasons' I and II total rainfall, suggests that despite the high amounts of seasonal rainfall received in the region during season I, almost 50 % of this rainfall was not used for grain production, but was mainly lost as non-productive component of seasonal evapotranspiration, namely soil evaporation.

Liu *et al*. (2002) reported that surface evaporation accounted for 25-50 % of total evapotranspiration and that mulching resulted in reduced evaporation and therefore soil moisture conservation. The rainfall distribution during season I indicated that much of this basal evaporation was met from initial rainfall received during the months of March and April and the remainder was met from the peak rainfall received in the month of May. This left only less than

48 % of received rainfall to sustain the maize crop to maturity. This explains why soil moisture conservation through coir mulching of the maize crop would be very crucial since it would resulted significant amount of conserved soil moisture for crop growth. It can therefore be said that this high basal evaporative demand limits the region's productivity potential and ability to attaining maximum evapotranspiration efficiencies. Similar high levels of basal evaporation have been reported by Daniel and Yair (1973), and Irmak (2015), whose values ranged from 216.0 mm ha^{-1} to 418.0 mm ha^{-1}. Daniel and Yair (1973) had reported that there was a threshold seasonal evapotranspiration of 250–300 mm ha^{-1} below which production was negligible and above which production increased linearly with the amount of applied water. Irmak (2015) had observed that this threshold seasonal evapotranspiration was dependent on the amount of initial irrigation or rainfall available, with highest levels of irrigation or rainfall resulting in highest basal seasonal evaporation. These high basal seasonal evaporation values are a common characteristic in most wet and dry climates, and also in arid and semis arid regions. This partly explains the low levels of food production prevalent in Coastal region of Kenya despite the observed high annual rainfall that ranges between 1000-1200 mm ha^{-1} (Jaezold and Schimdt, 1983).

The results also showed that during the phasic growth stages when coir mulched maize crop had declining evapotranspiration, the 100 cm- crop available soil moisture was noted to be on the increase. This suggests that although coir mulching of maize crop resulted in low levels of evapotranspiration between the period 49-66 DAS, it resulted in significantly higher amounts of conserved soil moisture, which was used by the maize plants during later stages of growth. Michael (2013) reported that mulching lowered soil temperatures, reduced evaporation, and improved soil fauna activity and soil structure resulting in better infiltration, reduced run-off and improved evapotranspiration efficiency. Aggassi *et al.* (2004) and Aggarwal *et al*. (2004) had also observed that use of composted manure as surface mulch improved soil moisture relations, and moderated soil structure resulting in improved water holding capacity, aeration and consequent in increase biomass and almost doubled grain yield. Steiner, (1989); Baumhardt and Jones, (2002); Kar and Singh, (2004) reported that use of wheat straw resulted in significant increases in water retention, prevented soil evaporation and also ensured a more even moisture distribution throughout the soil profile, which further improved evapotranspiration. Shumavo,

(2010) similarly observed that soil mulching resulted in substantial decreases in evapotranspiration early in the growing period, enhancing soil moisture conservation which later in the season supported increased transpiration and crop growth resulting in final higher seasonal evapotranspiration and increased biomass. Thus the findings of this study are in agreement with similar studies by the above reported authors.

The interaction of coir mulching increased levels of conserved moisture which later supported higher levels of evapotranspiration during later stages of maize growth. This implies that coir mulching could be used to complement and supplement irrigation, where since during early part of the growing season coir mulch conserved as much soil moisture as that added by supplementary irrigation, the supplementary irrigation should be done beyond 49 DAS when conserved moisture got depleted.

5.3 Effectof coir dust mulch on above ground biomass of Pwani hybrid 4 maize

Although coir mulching did not cause significant increases in biomass compared to control, it caused conservation of more soil moisture that led to in significant increase in biomass especially during the drier season II. This suggests that coir mulching was more beneficial during the relatively drier season II than the wetter season I, since it resulted in a two-fold increase in biomass. Thus, what would otherwise have been an agricultural waste and an environmental pollutant can be used to conserve more soil moisture, and provide more resources for improving crop productivity and also reduce weeding costs. Teasdale and Mohler (2000); Ossom *et al*. (2001) similarly observed that a 5-10 cm layer of mulch prevented weed seedling growth by inhibiting light penetration to the soil surface, where lower weed prevalence significantly improved evapotranspiration efficiency.

5.4 Effect of coir dust mulch on grain yield of Pwani hybrid 4 maize

Coir mulching did not cause significant increases in grain yield. It however resulted in 10 % increase in grain yield during the wetter season I and 4.7 % during the drier season II. This low yield increases could perhaps be explained by the observation that, by the 49th-66th DAS, most of the conserved soil moisture due to coir mulching had exhausted and the maize crop had to do with the limited soil moisture up to the end of the season. This was compounded by the fact that the bulk of the rooting system of coir mulched maize plants was concentrated in the upper soil surface intertwined with coir mulch material, such that when the conserved soil moisture got depleted, the crop did not benefit from moisture in the deeper root zone. This may be a major limitation in use of coir mulch technology for increasing biomass and grain yield in Coastal region, since the region's long rains normally decline and cease just before or immediately after tasseling especially with the onset of June winds (Muti and Kibe 2009).

Maize crop stages when moisture is most critical for its development are floral to grain-set to grain-filling stages. Therefore, occurrence of soil moisture deficit during these stages adversely affects final grain yield (Steduto 1998; Zhang *et al*. 2004; Villalobos *et al*. 2004). Since mulch of conserved soil moisture due to coir mulching gets exhausted at 49-66 DAS, supplementary beyond 49 DAS irrigation would be advantageous for increased grain yield.

5.5 Reduction in biomass under coir mulched treatments beyond 49 DAS during the relatively wetter season I

Coir mulch (M1W0) treatments during season I had high (though insignificant) biomass at early stages of growth, which beyond 49 DAS declined to lowest final biomass. This was unlike during the relatively drier season II where coir mulching alone (M1W0) treatment occasioned 17.8 % higher biomass comparable to that of M1W1 treatment. This reduction in biomass due to coir mulching alone treatment could be explained by the fact that, in all coir mulched treatments, most of the maize roots appeared to be concentrated at the upper 0-15 cm soil profile layer where much of the conserved soil moisture was concentrated, forming a dense ball mass of fibrous and hair roots. This was unlike the maize crops in non-mulched treatments where the roots were plain and extensively longer.

It had been observed that in coir mulched treatments especially when water was limiting, the soil immediately below the surface mulch had more soil moisture and fairly "soft" soil compared to non-mulched soil surfaces, an observation also reported by Aggarwal *et al*. 2004 and Singh *et al.* (2011). This encouraged root and hair root development and possibly facilitated scavenging for the available soil moisture and plant nutrients (Munns and Cramer, 1996; Steinberg *et al.* 1990). Thus, as the rainfall subsided and soil conditions became drier, the maize plants redirected more of their biomass partitioning of assimilates towards root growth over shoot development, (perhaps to later shift this allocation towards shoot development when crop available improved) (Munns and Cramer, 1996). This observation is in line with the theory of "functional balance" which explains plant responses to biomass partitioning where shortage of essential nutrients makes the plant invest more in structures that are responsible for acquisition of the limiting nutrient resources (Hilbert, 1990; Linker and Johnson, 2005). However as the rainfall subsided and the conserved available soil moisture got exhausted with advance in maturity, the coir mulched maize plants experienced drought stress. This is because all the roots were concentrated (as a dense root matt) at the upper 0-15cm soil surface that was now much drier, and could not benefit from moisture in the deeper soil layers. Thus with increasing moisture stress and in absence of further moisture injection, these maize plants showed early senescing and faster maturity resulting in the observed highest reductions in biomass and early drooping of the maize cobs for most of coir mulched treatments during the relatively wetter season I.

The maize plants in non-mulched conditions remained green characteristics long after physiological maturity as evidenced by prolonged retention of their green chlorophyll content. Therefore, mulching as a cultural practice would appear to have promoted development of shallow root masses in the upper 0-15 cm soil layers, perhaps as a strategy of harnessing conserved soil moisture. Similar observations have been reported by Steinberg *et al.* (1990), where the shift in biomass partitioning towards root development resulted in reduced biomass and a major reduction in shoot-to-root ratio.

5.6 Effect of foliar applied kaolin on evapotranspiration of Pwani hybrid 4 maize

Kaolin treatments had significant effects mainly on periodic and 100 cm crop available moisture. It increased or decreased periodic evapotranspiration at different stages of maize growth and depending on soil moisture regime and whether it was a wetter or a drier season. Thus significant effect of kaolin treatments on periodic evapotranspiration (over the control treatment) were observed during the entire wetter season I, and early part of season II when rainfall was at its peak, suggesting that Pwani hybrid 4 maize crops' response to kaolin application was relatively higher when soil moisture levels were relatively high. However its application during floral stages during wetter season caused significant reduction in periodic evapotranspiration, implying that sensitivity of Pwani hybrid maize to kaolin was more at floral stages. Kaolin was also observed to have “short term”, or immediate and “long term” effects on evapotranspiration, and biomass depending on levels of soil moisture and stage of maize growth. These “long term” effects of kaolin were more pronounced during periods of highest growth rates, and least pronounced during periods of slow growth. Similar observations were made by Kindred and Zajicek, (1996) where application of anti-transpirants on ornamental plants exhibited immediate and later effect of reduction in transpiration and therefore evapotranspiration.

5.7 Effectof foliar applied kaolin on biomass of Pwani hybrid 4 maize

In both seasons kaolin treatments did not cause significant increases in biomass. However, its combination with coir mulch and irrigation resulted in significant increases or reduction in biomass.

5.8 Effectof foliar applied kaolin on grain yield of Pwani hybrid 4 maize

Kaolin did not cause significant increase in grain yield. However, its interactions with coir mulch and irrigation resulted in significant increases or reduction in biomass. Kaolin application at floral stages resulted in 16.7 % reduction in grain yield, suggesting that the sensitivity of Pwani hybrid 4 maize to kaolin was relatively highest at floral stages of maize growth and development. This suggests that foliar spray of kaolin during flowering might have interfered with either the processes of pollen formation, silk formation and receptivity of pollen by stigma, or fertilization, thereby resulting in most maize plants being barren or empty stalks. This therefore confirms the postulation that foliar spray of kaolin suspension during flowering might have interference with the processes of pollination and or fertilization. It was however, noted earlier that application of kaolin at floral stages had resulted in prolonged period of biomass accumulation and highest rates of growth culminating in relatively higher final biomass of 15.6 tons ha^{-1}. This suggests that either the bulk of the observed high final biomass was not involved in or translocated for grain formation. This observation on grain yield appear to disagree with that reported by Finkner, (1983) where foliar application of Folicote (a hydrocarbon film-type of anti-transpirants) prior to tasseling on moisture-stressed field corn resulted in grain yield increases of 11-17 %, suggesting a feasible method of increasing corn yield under moisture stressed conditions. This difference in observation may be speculated to be due to the fact that while Folicote was a film-type of anti-transpirant with reflective properties just like kaolin, kaolin to some extent may have had some tonic effects, and therefore influenced certain physiological processes. However further research is necessary to establish these facts.

5.9 Interactions of coir mulch and irrigation on seasonal evapotranspiration of Pwani hybrid 4 maize

The levels of evapotranspiration observed during the season I were dependent on the capacities of the coir mulch and irrigation treatments being able to result in more soil moisture for evapotranspiration as the maize crop advanced in age. Thus, whereas coir mulch alone (M1W0) and in coir mulched irrigated (M1W1) treatments had relatively lower evapotranspiration during early parts of the growing season, they made major contributions to evapotranspiration in both seasons at later stages of maize growth beyond 66 DAS when rainfall and soil moisture were declining. Therefore, supplementary irrigation was of major importance in increasing evapotranspiration through replenishing and increasing soil moisture at these later stages of growth when the conserved moisture due to coir mulching was long exhausted. This observation is in agreement with Shumavo, (2010) who had similarly observed that soil mulching resulted in substantial decreases in evapotranspiration early in the growing period, thereby enhancing soil moisture conservation, which later in the season supported increased transpiration for crop growth.

Coir mulching was able to reduce by 50 % the high of basal evaporation compared to non-mulched treatments, suggesting that early application of 0.1 m layer of coir mulch between and within maize rows a week after maize crop emergence would contribute significantly in conserving soil moisture which would be available at later stages of crop growth and yield formation. Shumavo, 2010 made similar observations where mulching improved soil moisture status resulting in higher yield.

The final evapotranspiration observed in this study ranged from 800 mm ha^{-1} to 1383 mm ha^{-1}, and are consistent with those observed by Yildirim and Kodal (1998); Gencoglan and Yazar (1999), Oktem *et al*. (2003) and Hayrettin *et al*. (2013) where irrigation treatments resulted in increased evapotranspiration. The seasonal evapotranspiration values reported by Hayrettin *et al*. (2013) ranged from 311 to 1078 mm ha^{-1} in 2007 and from 298 to 1061.0 mm ha^{-1} in 2008, with the highest seasonal evapotranspiration values being observed under highest irrigation treatment and the lowest evapotranspiration occurring under rain-fed treatments. Yildirim and Kodal (1998) reported that seasonal evapotranspiration in maize varied between 300 and 1024.0 mm ha^{-1} in Ankara, Turkey. Gencoglan and Yazar (1999) obtained seasonal evapotranspiration values in maize of 1026.0 mm ha^{-1} for full irrigation treatment and 410.0 mm ha^{-1} for rain-fed treatment under furrow irrigation. Oktem *et al*. (2003) found that seasonal evapotranspiration for maize using drip irrigation method varied between 701-1040 mm ha^{-1}.

5.10 Interactions of coir mulch and irrigation on biomass of Pwani hybrid 4 maize

Although M0W1 and M1W1 treatments had similar and highest final evapotranspiration, M1W1 treatment resulted in relatively highest biomass, while M1W0 that had lowest evapotranspiration resulted in 16 % higher biomass comparable to that of M1W1. This suggests that irrigation alone per se in the M1W1 treatment combination is not what contributed to the highest final biomass, but rather there could have been synergy and positive interactive effect due to the micro-conditions offered by both the coir mulch and irrigation treatments. This observation suggests that application of coir mulch alone (M1W0) treatment during a relatively drier season could (up to some extend) substitute irrigation alone (M0W1) treatments, since coir mulching alone treatments offered superior conditions for biomass accumulation.

The lower final biomass associated with irrigation alone (M0W1) treatment implies that much of the applied irrigation water into these sandy loam soils was either lost through luxurious consumption or through the non-productive surface evaporation to satisfy the high atmospheric demand, rather than being used in transpiration where it would have caused increases in biomass since biomass accumulation is directly related to the amount of transpired water (Njoka *et al*. 2004; Zhang *et al*. 2004). Similar observations were reported by Yildirim and Kodal (1998); Farré and Faci (2009) and Hayrettin *et al*. (2013) who observed that applications of excessive irrigation water did not necessarily lead to increased biomass or grain yield since some of the applied irrigation water was lost through deep percolation and soil evaporation, and that the relationship between increased irrigation evapotranspiration and biomass or grain yield adopted a quadratic rather than linear pattern.

5.11 Interactions of coir mulch and irrigation on grain yield of Pwani hybrid 4 maize

Irrigated treatments (M0W1 and M1W1) had the highest (34.1 %) grain yield enhancing effects in seasons I. This suggests that for purposes of grain production, irrigation alone (M0W1) treatment would suffice or substitute the use of coir mulch and irrigation treatment in grain production under coastal conditions of Kenya. Comparative advantage in use of either irrigation alone (M0W1) or coir mulch and irrigation (M1W1) treatments over use of coir mulch alone (M1W0) treatments (if we ignore the value of biomass) was only 0.5 tons ha^{-1} (or 5.6 bags) of maize grain per ha.

However, since in season II, coir mulched (M1W0) and irrigation alone (M0W1) treatments increased grain yield by similar amounts (4.8 % than those of control),this suggests that under conditions of limited rainfall such as the relatively drier season II, coir mulching alone (M1W0) treatments could substitute irrigation alone (M0W1) treatment in grain production. It also implied that the amount of soil moisture conserved due to coir mulching treatments was comparable to the amount of soil moisture added under irrigation treatments. De *et al*. (1983) reported that maize yield increased with application of organic mulch and irrigation. The maize grain yield observed in this study are within the range reported by Wekesa *et al*. (2003) of 5.4 tons ha^{-1} for Pwani hybrid 4 maize variety.

5.12 Complementary relationship between coir mulch and irrigation treatments

Coir mulching treatments contributed to higher levels of conserved soil moisture and therefore improved soil moisture conditions in the root zones of between 10-15 % up to 49-66 DAS, which was comparable to that contributed by irrigation treatment. This suggest that coir mulching could substitute irrigation during this period, and irrigation should therefore be applied beyond 49 DAS when the conserved soil moisture starts declining especially at critical stages of maize growth.

Thus irrigation treatments would play a complementary and a supplementary role to coir mulch treatments by progressively increasing and maintaining favorable soil moisture conditions up to crop maturity.

5.13 Effect of June winds on maize yield of Pwani hybrid 4 maize

June winds occurrence, by their high velocities blew away most clouds resulting in decline in rainfall and increased atmospheric drought (and therefore vapor pressure deficit). This resulted in decline in soil moisture and therefore moisture stress in the maize crop. The June winds time of occurrence coincided with critical stages of maize growth and development which influenced levels of biomass and grain yield. Their sudden occurrence and change in velocity induced 'abrupt' decline in soil moisture and therefore moisture stress. Since the method of imposing and the rate at which water stress develops, fast or gradual, determines plant's sensitivity, response and osmotic adjustment to prevailing water conditions, the maize crop's sensitivity to water deficit conditions occasioned by June winds was high, and adversely affected yield formation (Steduto and Hsiao, 1998; Wiedenfeld, 2004; Muti and Kibe, 2009).

Since inadequate soil moisture at flowering results in none or poor pollination as tassels and ovules die out, and also increases asynchrony between pollen shedding and the time the stigma are receptive, resulting in limited or no fertilization (Salter and Goodness, 1967; Otegui *et al*. 1995), occurrence of June wind leads to poor yield. In addition occurrence of soil water deficit or termination of rains during the critical stages of maize growth and development such as in season II resulted in low biomass accumulation and low yield. This is what happened when coir mulching resulted in low biomass beyond 49 DAS during the wetter season I. The timing of the water deficit has more influence on crop yield than the magnitude of the deficit itself (Sing *et al*. 1987; Martinez-Cob and Tejero-juste, 2004). Based on this principle, this explains why occurrence of June winds in the middle of the growing season between floral initiation and grain-set ultimately results in poor maize yield in the region (Socias and Medrano, 1994).

Whereas application of irrigation was meant to maintain adequate soil moisture and counter the adverse effect of June winds on moisture deficit, interaction of coir mulching and irrigation treatments was not able to eliminate in total the decline in soil moisture occasioned by June winds. However, they only moderated the level of soil moisture reduction.

5.14 Ameliorative effect of coir mulch and irrigation interactions on June winds

The fact that there exists a strong relationship between % increases in evapotranspiration and 100 cm soil moisture on one hand, and the complementary relationship between amount of conserved soil moisture by coir mulch and irrigation treatments, makes it is possible to manipulate their interaction effects to counter and cushion the adverse effects of June winds on soil moisture and by extension, maize growth and yield.

The % changes in seasonal evapotranspiration fluxes in both seasons due to coir mulching alone (M1W0) treatments over the control treatments (M0W0) revealed that seasonal evapotranspiration fluxes were also modulated by other external factors such as occurrence of peak June winds and soil temperatures. Thus, the sharp decline and therefore 10-15 % depression in seasonal evapotranspiration fluxes observed at 49-66 DAS during the relatively wetter and drier seasons I and II respectively, coincided with and was attributed to occurrence of peak June wind velocities in the middle of growing season. Thus during the relatively wetter season I, the June winds occurrence resulted in 15-29 % depression in soil moisture.

A comparison of levels of soil moisture depression by June winds occurrence in coir mulched irrigated (M1W1) treatments and irrigation alone (M0W1) or coir mulch alone (M1W0) treatments revealed that interactions of coir mulch and irrigation (M1W1) treatments, rather than irrigation alone (M0W1) treatment, offered the best method of ameliorating the effects of June winds in terms of cushioning maize crop against the “abrupt drought” (i.e. drastic decline in soil moisture) at critical stages of growth, namely floral to grain-set stages of maize growth and development (Steduto and Hsiao 1998; Wiedenfeld, 2004). Therefore, commencement of supplementary irrigation at 49 DAS on coir mulched maize crop would maintain favorable levels of soil moisture for sustaining nutrient uptake and increased biomass and grain yield.

5.15 Interaction of coir mulch, irrigation and kaolin on seasonal evapotranspiration of Pwani hybrid 4 maize

The interactions of coir mulch, irrigation and kaolin contributed to significant increases or decreases in evapotranspiration of Pwani hybrid maize during early stages of maize growth. During seasons I and II, coir mulched and irrigated treatments, namely M1W0K1, M0W1K- and M1W1K- treatments contributed favorably to increased soil moisture that enhanced crop growth leading to higher levels of evapotranspiration for most of the growing season compared to non-mulched rainfed treatments. Kaolin enhanced evapotranspiration in non-mulched rainfed (M0W0K1) treatments during the wetter season I especially when applied early in the season at vegetative stages when soil moisture was not limiting. Generally, when kaolin was applied in either coir mulched rainfed or irrigated condition during season II when maize crop was experiencing moisture stress, the rates of evapotranspiration decreased. However when it was applied in combinations with coir mulch or irrigation when soil moisture was favorable, evapotranspiration was enhanced, since the treatments resulted in necessary soil moisture for sustaining the high levels of evapotranspiration.

At 100 DAS during the drier season II, non-mulched rainfed kaolin applied treatments had similar evapotranspiration to coir mulched rainfed kaolin applied treatments suggesting that when the conserved soil moisture got depleted at 49 DAS, the maize crop assumed comparable rates of evapotranspiration to that of rainfed. Similarly non-mulched irrigated kaolin applied maize crop had similar final evapotranspiration to coir mulched irrigated kaolin applied maize crop, suggesting that when the conserved soil moisture due to coir mulching got depleted, it is the moisture supplied by irrigation treatment that maintained the significant increases in evapotranspiration noted at the end of the season. These observations are in agreement with results by Yıldırım *et al*. (1996); Istanbulluoglu *et al*. (2002); Oktem *et al*. (2003); Çakir (2004); Igbadun *et al*. (2008) and Hayrettin and Ali, (2012), who observed that evapotranspiration increased markedly when soil moisture increased.

5.16 Interaction of coir mulch, irrigation and kaolin on biomass of Pwani hybrid 4 maize

Interactions of kaolin with coir mulch and irrigation resulted in either increased or depressed, biomass depending on soil moisture status and stage of maize growth. In general, application of kaolin in coir mulched or irrigated maize crop during the wetter season I resulted in relatively higher levels of biomass, with highest increases of being observed in non-mulched irrigated (M0W1); coir mulched irrigated (M1W1) and coir mulched rainfed (M1W0) treatments since these treatment maintained favorable soil moisture that led to higher rates evapotranspiration that led to the observed higher biomass. During the drier season II, non-mulched irrigated kaolin applied (M0W1-) treatments had similar biomass to the control treatment (M0W0K0), suggesting that most of the irrigation water was not used for biomass fixation, but lost in cooling the plants (Zhang *et al*. 2004).

The order of increase in biomass accumulation due to interaction effect of coir mulch, irrigation and kaolin was: M1W1K->M1W0K->M0W1K->M0W0K-, suggesting that coir mulched rain-fed-kaolin applied (M1W0K-) treatments could substitute non-mulched irrigated-kaolin applied (M0W1K-) treatments and still obtain higher final biomass and save on the limited water resource. De *et a*l. (1983) observed that maize yield increased with application of organic mulch and that mulched plots treated with kaolin or alachlor antitranspirants and receiving two or four irrigations yielded as much as untreated plots receiving four or six irrigations. Thus coir mulching could increase water use efficiency in water limiting environments.

5.17 Interactions of coir mulch, irrigation and kaolin on grain yield of Pwani hybrid 4 maize

In general, application of kaolin during the relatively wetter season I in combination with coir mulch or irrigation or both in increased grain yield by up to 41.9 %, except when applied at floral stages in rainfed conditions. This implied that kaolin enhanced grain yield under favorable soil moisture conditions. This is further confirmed by the observation that kaolin application in irrigated maize crop generally had highest average grain yield, with coir mulched irrigated (M1W1) treatments giving highest average grain yield of between 30.8-40.0 %, followed by its application in non-mulched irrigated treatments occasioning increases of 10.0 % - 41.9 %.

However the highest grain yield (of 6.7 tons ha^{-1}) in the study was obtained under coir mulch alone (M1W0K0) treatment, (increasing grains by 46 %),suggesting that coir mulching alone treatment provided the best conditions and micro-climate for enhanced grain yield and resulted in high water use efficiency.

Application of kaolin in combination with either coir mulch or irrigation during drier season II depressed grain yield, with foliar application of kaolin at floral stages of maize growth in coir mulched rain-fed conditions (M1W0K2 treatment) resulting in highest depression in grain yield of 46.3 %, suggesting that the sensitivity of the maize crop to kaolin application was highest at floral stages of growth. Coir mulched rainfed kaolin applied treatments gave similar grain yield to non-mulched irrigated kaolin applied treatments. This implies that coir mulching could substitute irrigation treatments and still obtain higher grain yield when compared to M0W1K0 and the control (M0W0K0) treatments. This observation further affirms that coir mulching conserved soil moisture that was later used mainly for grain yield formation, and that coir mulching provided best fit micro-climatic conditions in the root zone for the maize plants to invest and partition biomass assimilates towards maximum grain production. McMillen, (2013) reported that in hot and water limiting climatic conditions, mulching improved soil microclimate by lowering soil temperatures, reduced evaporation, and improved soil fauna activity and soil structure resulting in better infiltration, reduced run-off and improved evapotranspiration efficiency.

It was observed that in non-mulched conditions, application of irrigation and kaolin at floral stages of maize growth (M0W1K2 treatment) enhanced grain yield production during relatively drier seasons, while its application at floral stages in non-mulched rain-fed conditions (M0W0K2 treatment) depressed grain yield production. This therefore suggests that foliar application of kaolin on irrigated maize crop either improved water use and transpiration or enhanced grain-set resulting in increased grain yield. However its application in rain-fed maize crop resulted in either poor grain-set or diversion of evapotranspiration from grain yield formation. However, further research is required to establish these postulations.

5.18 Production functions relating above ground biomass to seasonal evapotranspiration

The high values of correlation coefficients of $R^2 = 0.92$ in wetter season I, and $R^2 = 0.96$ in season II suggests that the model equations obtained could be used to predict biomass production at any stages of Pwani hybrid 4 maize. Singh *et al.* (1987); Kumar *et al.* (1997); Allen *et al*. (1998) and Zhang *et al.* (2004), observed that production function could be used to forecast and predict yield in different environments.

5.19 Evapotranspiration-yield production functions based on Singh *et al.* (1987) and Kumar *et al*. (1997) model equations

The seasonal yield response factors (ky) of 2.0 and 1.33 obtained in this study for seasons 1 and II, respectively were within limits to those obtained Allen *et al*. (1998). They indicated the sensitivity of Pwani hybrid 4 biomass to soil moisture deficit and that, as the moisture deficit increased, the relative growth decreased by two-fold during season I. Allen *et al.* (1998) reported that the level of yield reduction due to increase in moisture deficit (yield response factor, Ky) are usually crop specific and vary over the growing season, being lowest during the vegetative and ripening period, and highest during the flowering and yield formation periods.

5.20 Production function of Pwani hybrid 4 maize grain yield

Coir mulching (M1) treatments had the highest significant effects ($p \leq 0.05$) on grain yield, and therefore was the most important factor determining the level of grain yield; followed by its interactions with irrigation treatments. Although kaolin had no significant contribution to grain yield, its application at vegetative stages (K1) had higher contribution to grain yield than its application during floral or grain-set/grain filling stages. During season II, only coir mulching treatments had significant ($p \leq 0.05$) effects on grain yield.

5.21 Options for increased maize grains yield

This study was conceived to also find solutions into the problems associated with occurrence of high velocity June winds and high ambient temperatures at critical stages of maize growth and development. The study has found treatment interaction of coir mulch, irrigation and kaolin that when applied result in higher yield under conditions of high velocity June winds and high ambient temperatures. These treatment combinations provide farmers in coastal region of Kenya possible options of overcoming these environmental stresses during the growing season and increase maize production. Within these options are treatment interactions that give the higher grain yield during seasons of relatively higher rainfall and or during seasons of low rainfall. These are outlined in Table 4.12.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i) Coir mulching resulted in higher levels of conserved soil moisture during early stages of maize growth and also resulted in increased periodic evapotranspiration of Pwani hybrid 4 maize during the wetter and drier seasons I and II. However, the higher levels of conserved soil moisture and evapotranspiration did not result in significant increases in biomass and yield.

ii) Application of kaolin did not have any significant effect on evapotranspiration, biomass and grain yield of Pwani hybrid 4 maize.

iii) The interactions of coir mulch, irrigation and kaolin influenced levels of evapotranspiration, biomass and grain yield of Pwani hybrid 4 maize. Irrigation treatments increased evapotranspiration; biomass and grain yield more than rainfed treatments. However, higher irrigation or biomass levels did not necessarily lead to higher grain yield.

5.2 Recommendations

i) Further studies should be carried out to find out the physiological effect and mode of action of kaolin at molecular level on stomata and CO_2 absorption.

ii) Also studies should be carried out to find the optimal concentration of kaolin suspension for application on maize since the 6 % concentration used in this study was for wheat.

iii) Further studies are also necessary to determine whether coir dust mulch had other effect that resulted in formation of root-ball mass, and also determine the actual rooting depth of both non-mulched and coir mulched maize crop.

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APPENDICES

Appendix 1: Soil textural classes in the study site, in Kilifi during season I (2007)

Soil textural analysis (pipette method)

Soil depth	**Soil particle size composition, at Crop Sciences farm**			
(cm)	**% Sand**	**% Clay**	**% Silt**	**Texture classes**
0-8	50	34	16	SCL
8-16	58	34	8	SCL
20-28	64	30	6	SCL
30-38	66	30	4	SCL
46-54	64	32	4	SCL
45-53	56	38	6	SC
55-61	60	30	10	SCL
65-71	56	34	10	SCL
71-80	56	38	6	SC
80-88	50	40	10	SC
90-98	70	22	8	SL

Key: of soil textural classes

SCL----Sandy-clay loam

SC-----Sandy-clay

SL-----Sandy loam

Appendix 2: soil physical characteristics at different depth at the study sitein Kilifi during season I (2007)

	Soil moisture retention, bulk density, and hydraulic conductivity							
Depth (cm)	**Saturation (mm m^{-3})**	**Readily Available Water (mm m^{-3})**			**Difficult Available Water (mm m^{-3})**	**Permanent wilting point (mm m^{-3})**	**Bulk Density**	**hydraulic conductivity**
	pF 0	**pF 2.0**	**pF 2.3**	**pF 2.5**	**pF 3.7**	**pF 4.2**	**(g/cm^{-3})**	**cm/hr**
0-8	19.4	8.4	6.0	4.4	1.3	1.1	1.8	1.39
8.-16	18.7	8.8	7.0	6.1	1.6	1.2	1.8	1.28
20-28	18.3	10.3	8.5	7.5	1.9	1.5	1.9	1.33
30.38	17.1	12.3	10.0	8.9	3.2	1.4	1.9	2.31
46-54	18.0	12.2	9.0	7.4	4.1	4.0	1.8	3.79
45-53	18.1	12.6	10.2	9.2	4.6	4.1	1.8	3.42
55-61	19.9	15.0	12.6	11.5	6.3	5.6	1.8	4.54
65-71	37.7	30.6	28.5	27.3	5.5	4.3	1.6	3.71
71-80	25.7	19.2	17.3	16.2	8.4	5.1	1.6	6.39
80-88	20.7	17.1	15.7	15.0	5.5	3.2	1.9	3.37
90-98	23.2	17.9	16.1	15.2	6.4	2.4	1.8	4.25
100-108	17.9	9.6	8.4	7.2	4.5	3.8	1.9	3.22

Appendix 3: Soil chemical characteristics at different depths in the study site in Kilifi, during season I (2007)

Soil Depth	Soil PH-Acidity		Elect. Cond. ms^{-1} cm^{-1}		% Total Nitrogen		% Total org. Carbon		Phosphorus ppm		% Potassium-me	
0-15	6.39	slight	0.17	adequate	0.04	low	0.34	low	55	adequate	0.20	low
15-20	6.07	slight	0.10	adequate	0.03	low	0.31	low	30	adequate	0.22	low
20-35	5.57	medium	0.21	adequate	0.03	low	0.28	low	10	low	0.22	low
35-50	4.82	strong	0.24	adequate	0.03	low	0.22	low	10	low	0.28	adequate
50-60	4.75	strong	0.12	adequate	0.03	low	0.27	low	5	low	0.26	adequate
60-80	4.56	strong	0.12	adequate	0.03	low	0.25	low	5	low	0.24	adequate
80-100	4.38	extreme	0.11	adequate	0.03	low	0.21	low	5	low	0.22	low

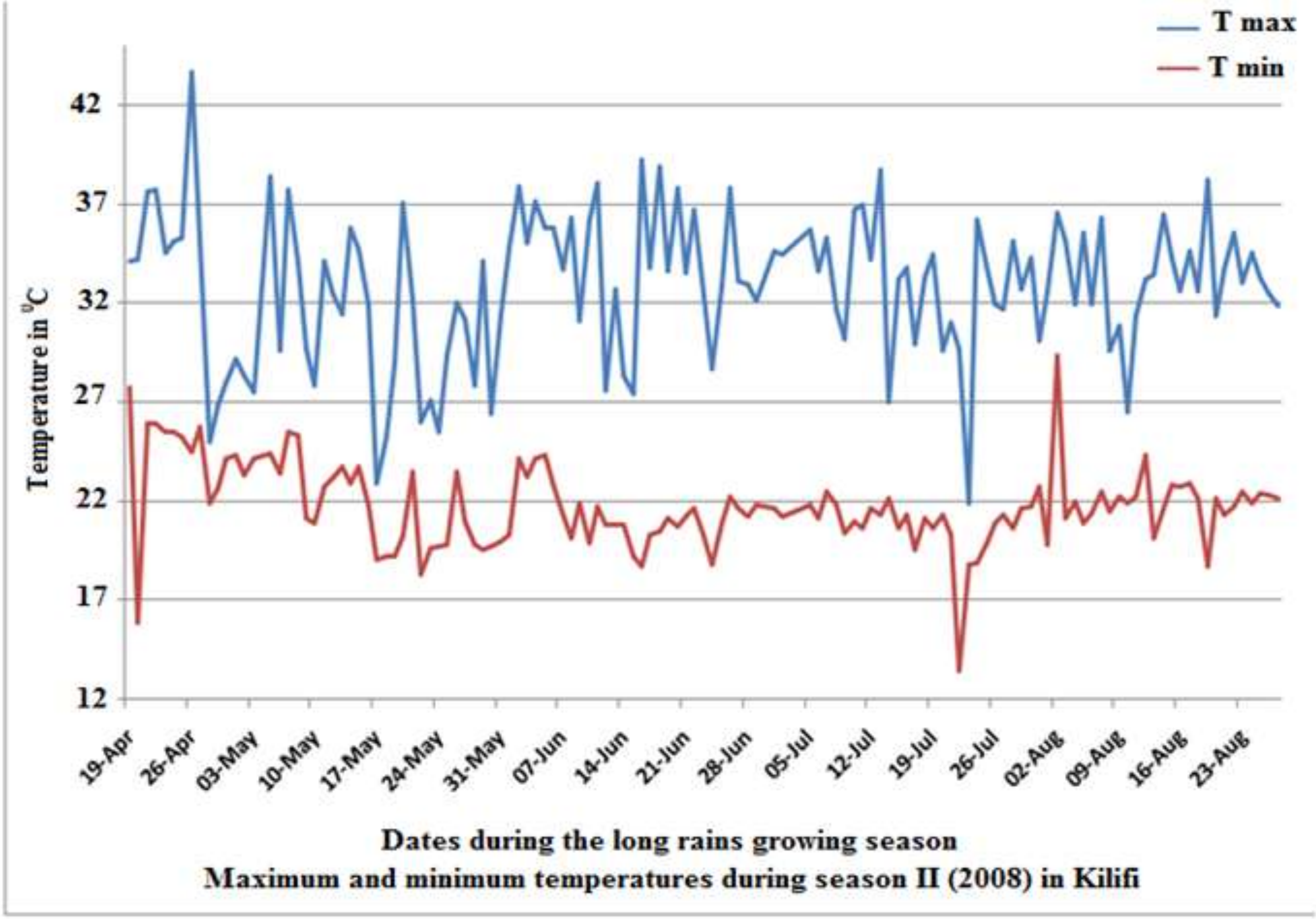
Soil	% Magnesium-me		% Manganese- me		% Calcium- me		Copper		Iron		Zinc		Na
0-15	2.61	adequate	0.33	adequate	2.1	adequate	0.83	low	16.1	adequate	1.88	low	0.20
15-20	1.00	adequate	0.25	adequate	2.7	adequate	0.84	low	12.3	adequate	1.09	low	0.22
20-35	1.29	adequate	0.26	adequate	1.2	low	0.37	low	14.3	adequate	2.30	low	0.18
35-50	1.45	adequate	0.19	adequate	2.1	adequate	0.35	low	10.7	adequate	1.96	low	0.26
50-60	1.85	adequate	0.10	adequate	1.7	low	0.30	low	10.7	adequate	1.98	low	0.20
60-80	2.68	adequate	0.12	adequate	1.5	low	0.34	low	15.1	adequate	2.41	low	0.20
80-100	2.69	adequate	0.12	adequate	1.3	low	0.28	low	13.9	adequate	2.66	low	0.16

Note: ppm= parts per million; me= milli-equivalent

Appendix 4: Analysis Of Variance of Pwani hybrid 4 maize grains

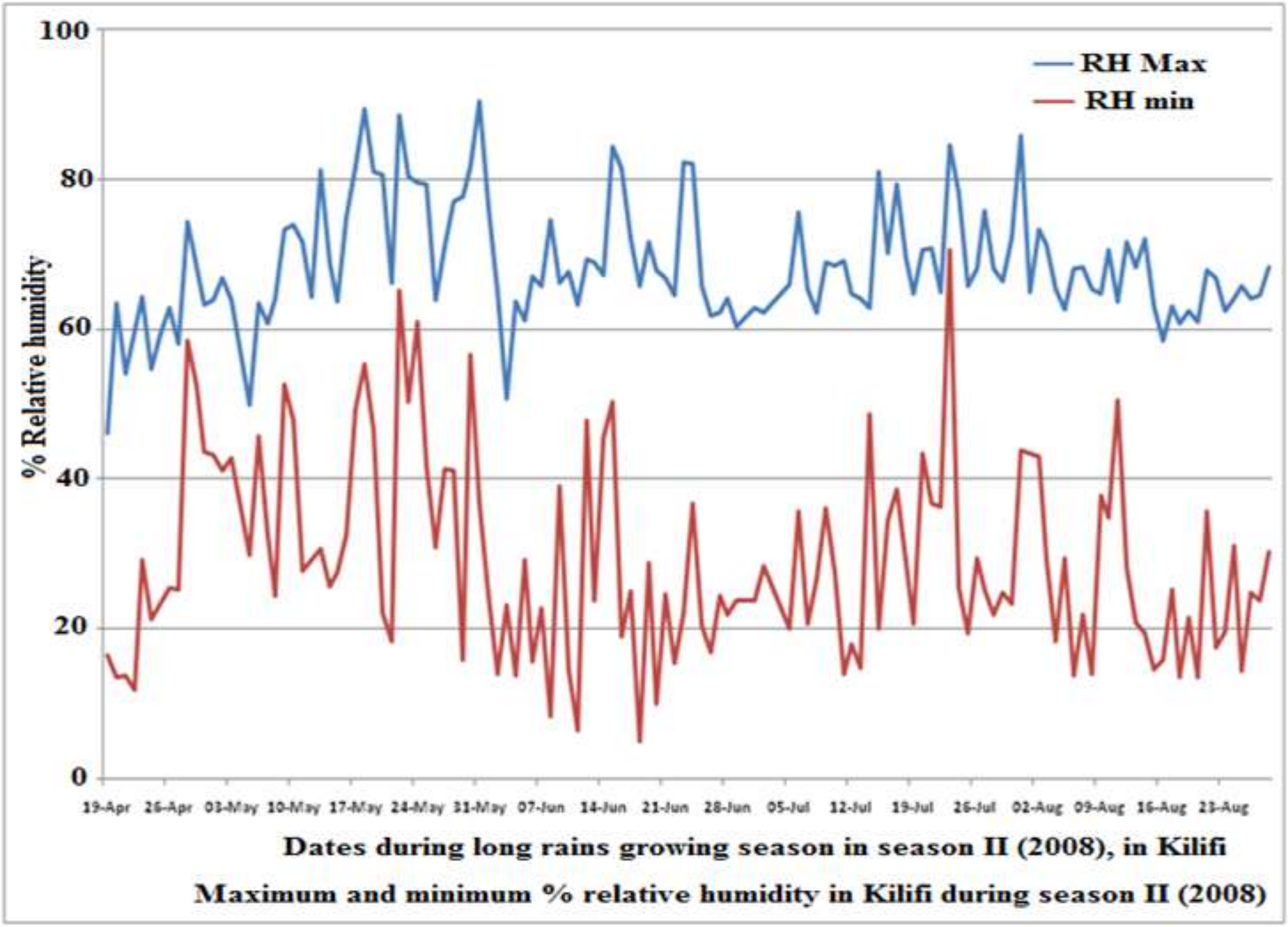
Source of variation	**d.f.**	**(m.v.)**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
BLOCK stratum	2		20.925	10.462	6.3	
BLOCK.*Units* stratum						
MULCH	1		2.535	2.535	1.53	0.227
IRRIGATION	1		12.122	12.122	7.29	0.011
KAOLINE	3		6.042	2.014	1.21	0.323
MULCH.IRRIGATION	1		2.142	2.142	1.29	0.266
MULCH.KAOLINE	3		4.745	1.582	0.95	0.429
IRRIGATION.KAOLINE	3		15.128	5.043	3.03	0.045
MULCH.IRRIGATION.KAOLINE	3		14.383	4.794	2.88	0.053
Residual	29	-1	48.197	1.662		
Total	46	-1	121.81			

Appendix 5: Maximum and minimum temperatures at study site in Kilifi during season II (2008)



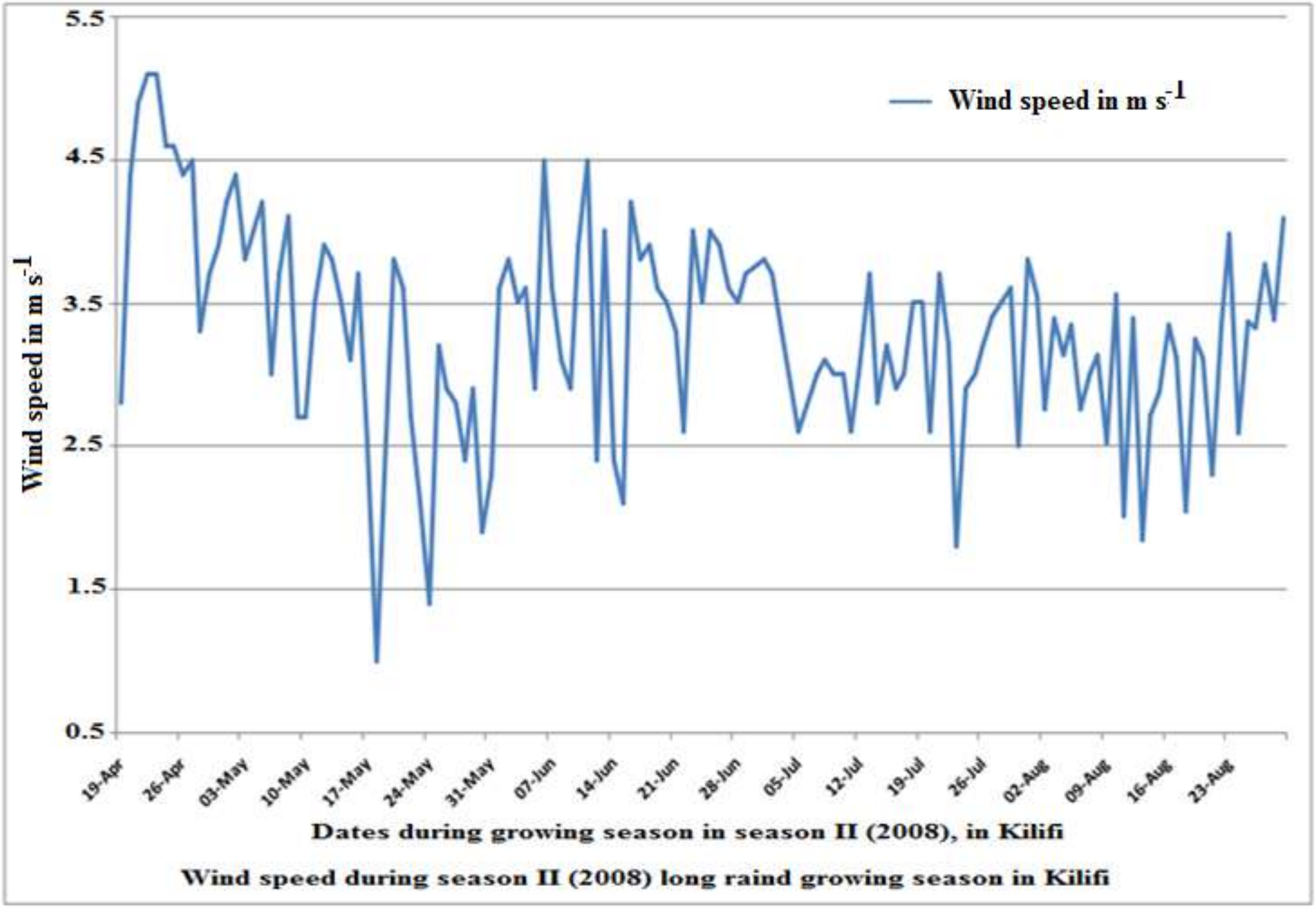
Maximum and minimum temperatures during season II (2008) in Kilifi

Appendix 6: Maximum and minimum % R.H at study site in Kilifi during season II (2008)



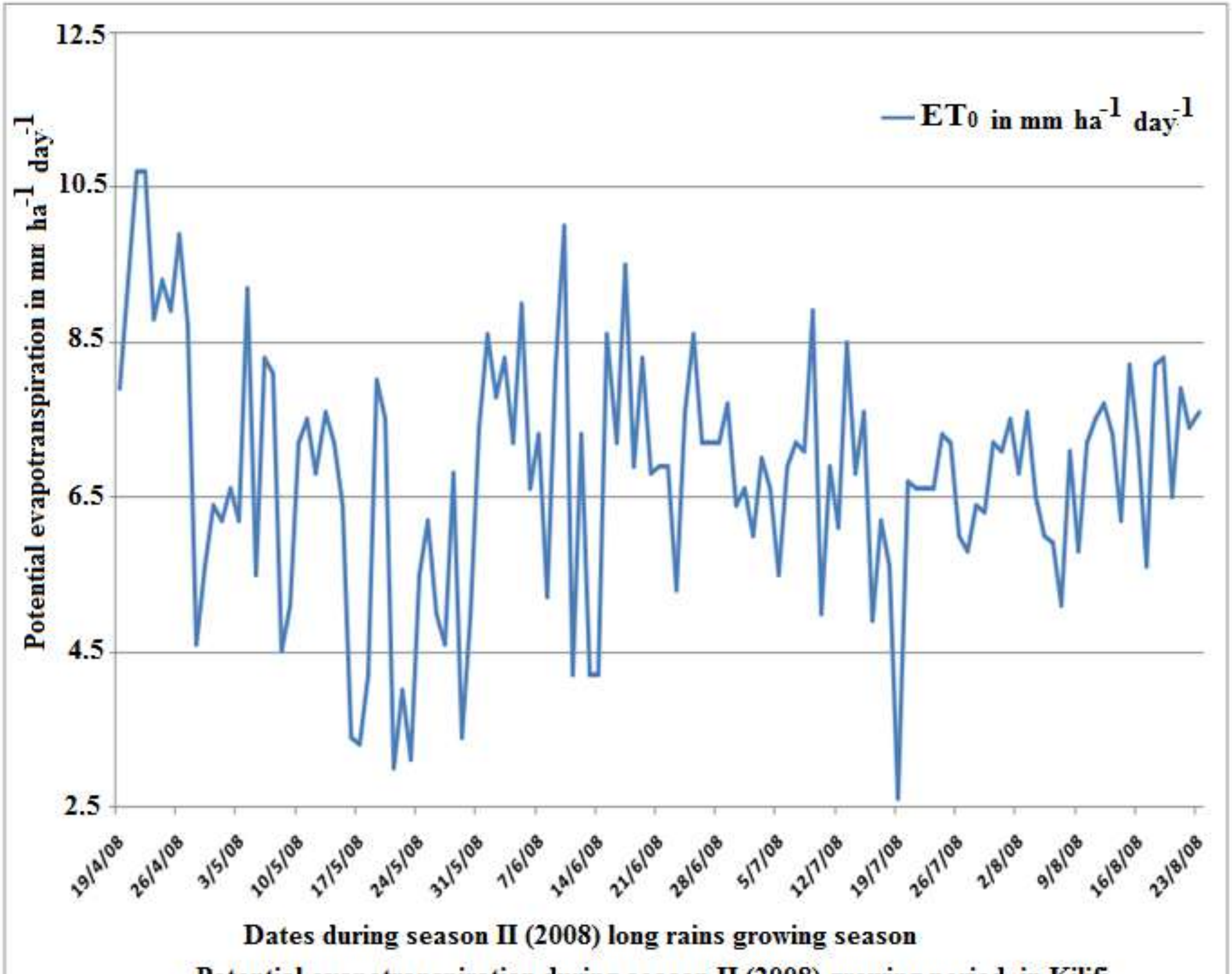
Maximum and minimum % relative humidity in Kilifi during season II (2008)

Appendix 7: Wind speed at study site, in Kilifiduring season II (2008)



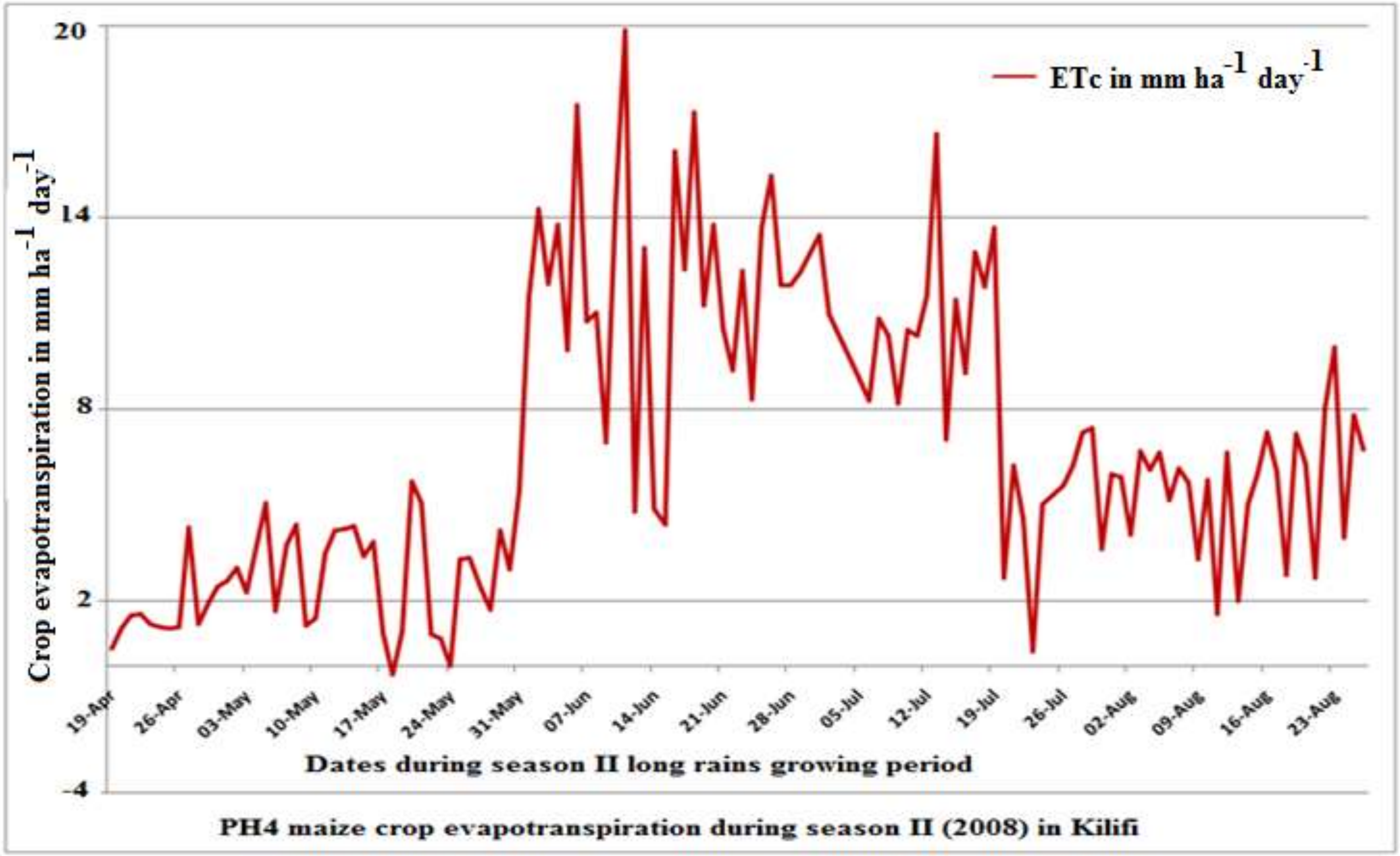
Wind speed during season II (2008) long raind growing season in Kilifi

Appendix 8. Potential evapotranspiration at study site in Kilifi during season II (2008)



Potential evapotranspiration during season II (2008) growing period, in Kilifi

Appendix 9: Pwani hybrid 4 maize crop evapotranspiration at study site in Kilifi during season II (2008)



PH4 maize crop evapotranspiration during season II (2008) in Kilifi

Appendix 10: Effect of kaolin on above ground biomass and grain yield of Pwani hybrid 4 maize during seasons I and II, in Kilifi

Seasons	Season I							Season II						
Stages (DAS)	0	31	49	66	83	100		0	31	49	66	83	100	
Treatments	Above ground biomass (**tons ha^{-1}**)						Grain yield (**tons ha^{-1}**)	Above ground biomass (**tons ha^{-1}**)						Grain yield (**tons ha^{-1}**)
K0	0	1.0	2.9	6.9	10.3	13.7	5.4	0	0.6	4.9	6.5	8.1	9.6	4.5
K1	0	1.0	2.7	7.3	11.2	15.1	5.3	0	0.9	4.7	6.5	7.8	9.1	4.3
K2	0	1.0	2.6	6.9	11.0	15.6	4.5	0	0.7	4.9	6.6	8.1	9.5	4.3
K3	0	1.0	2.6	6.2	10.7	13.7	4.9	0	0.9	5.0	6.5	8.0	9.5	4.5
Mean	0	1.0	2.7	6.8	10.8	14.5	5.0	0	0.8	4.9	6.5	8.0	9.4	4.4
LSD (5%)		0.179	0.58	1.15	1.50	1.94	1.08		0.37	1.35	1.17	1.15	1.32	0.46
SED		0.087	0.28	0.56	0.72	0.94	0.53		0.18	0.65	0.57	0.56	0.64	
		NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS

Appendix 11: Rates of biomass accumulation of Pwani hybrid 4 maize due to kaolin during seasons I and II

Season I (2007)	**Daily rates of biomass accumulation in kg day^{-1} ha^{-1}**				
Stages of growth (DAS)	31	49	66	83	100
Treatment					
K0	31.0	114.7	235.3	197.6	201.8
K1	31.6	100.6	270.6	231.2	228.2
K2	30.6	97.1	254.7	237.1	272.9
K3	31.0	98.2	211.8	260.0	179.4
Mean	31.0	102.6	243.1	231.5	220.6
Season II (2008)					
K0	18.4	254.7	92.9	92.4	91.2
K1	28.1	225.3	102.9	78.8	77.1
K2	21.9	248.2	99.4	85.9	85.3
K3	28.7	241.8	87.1	88.2	89.4
Mean	28.0	164.8	177.5	167.0	160.7
Overall Mean	27.7	172.6	169.3	158.9	153.2

Appendix 12: Rates of evapotranspiration of Pwani hybrid 4 maize as influenced by coir mulch and irrigation treatments in seasons I and II

Season I	**Daily rates of evapotranspiration in mm day^{-1} ha^{-1}**				
Growth stages (DAS)	31	49	66	83	100
Treatments					
M0 W0-07	21.4	15.5	6.4	2.8	14.3
M0 W1-07	21.3	13.4	9.0	1.8	15.9
M1 W0-07	21.7	12.9	8.0	3.7	15.5
M1 W1-07	21.9	11.6	9.2	2.7	17.3
Mean-07	21.6	13.3	8.2	2.7	15.7
Season II					
M0 W0-08	10.1	12.7	10.0	1.6	10.2
M0 W1-08	9.9	11.7	10.3	5.0	13.7
M1 W0-08	9.6	12.3	10.4	2.5	10.2
M1 W1-08	9.2	13.0	10.6	5.0	13.9
Mean-08	9.7	12.4	10.3	3.5	12.0
Overall Mean	16.3	12.9	9.1	3.1	14.1

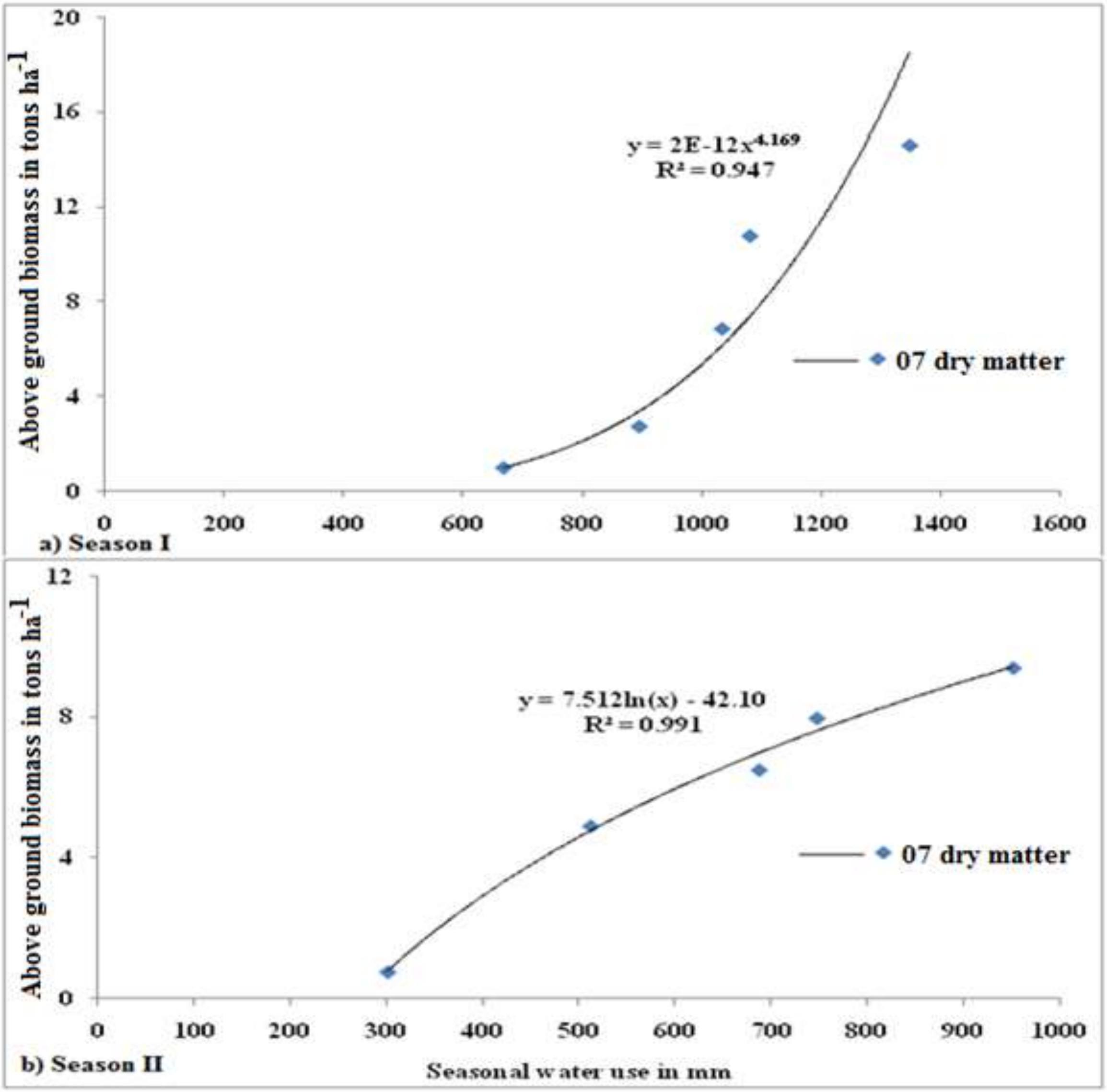
Appendix 13: Daily rates of evapotranspiration of Pwani hybrid 4 maize as influenced by coir mulch, irrigation and kaolin treatments in seasons I and II, in Kilifi

	Season I (2007)					Season II (2008)				
DAS	31	49	66	83	100	31	49	66	83	100
Treatments	Daily rates of evapotranspiration in mm day^{-1} ha^{-1}									
M0W0K0	21.0	16.2	6.6	3.3	14.6	10.0	13.0	10.0	1.6	10.2
M0W0K1	21.6	15.5	6.2	2.7	14.0	9.6	13.8	10.0	1.6	10.1
M0W0K2	21.4	15.9	5.8	3.0	14.3	10.3	11.7	10.2	1.8	10.2
M0W0K3	21.4	14.4	7.1	2.1	14.2	10.6	12.3	9.8	1.5	10.3
M0W1K0	21.2	14.3	8.3	1.3	15.5	9.9	11.4	10.5	5.0	13.9
M0W1K1	21.3	12.5	10.2	1.7	15.7	9.8	12.1	10.3	4.9	13.7
M0W1K2	21.0	14.1	7.9	2.0	16.8	10.4	9.6	11.0	5.5	13.7
M0W1K3	21.7	12.9	9.5	2.1	15.6	9.6	13.1	10.1	4.7	13.6
Mean	21.3	14.5	7.7	2.3	15.1	10.0	12.1	10.2	3.3	12.0
M1W0K0	21.6	12.4	8.0	3.4	15.7	10.5	9.7	10.2	4.0	10.0
M1W0K1	22.1	12.9	7.9	3.6	14.8	9.8	12.3	10.4	2.1	10.2
M1W0K2	21.4	13.4	8.2	3.4	14.9	8.9	13.8	10.4	2.0	10.3
M1W0K3	21.7	12.7	8.0	4.5	16.4	9.4	13.4	10.3	1.9	10.3
M1W1K0	21.9	10.5	9.7	3.0	17.8	9.3	12.0	10.8	5.3	13.9
M1W1K1	22.3	9.6	10.3	3.0	17.8	9.2	14.4	9.8	4.3	14.0
M1W1K2	21.7	13.4	9.2	1.7	14.9	8.8	14.3	10.3	4.9	13.7
M1W1K3	21.6	12.8	7.5	3.2	18.7	9.3	11.8	11.0	5.5	13.9
Mean	21.8	12.2	8.6	3.2	16.4	9.4	12.7	10.4	3.7	12.1

Appendix 14: Daily rates of biomass accumulation of Pwani hybrid 4 maize as influenced by coir mulch, irrigation and kaolin treatments in seasons I and II, in Kilifi

	Season I (2007)					Season II (2008)				
DAS	31	49	66	83	100	31	49	66	83	100
Treatments	Rates of above ground biomass accumulation in kg day^{-1} ha^{-1}									
M0W0K0	38.7	104.7	232.4	176.5	174.7	11.0	197.6	70.6	113.5	115.9
M0W0K1	32.3	85.9	251.2	217.6	210.0	20.6	185.9	111.8	80.6	84.1
M0W0K2	28.7	87.1	242.9	211.8	270.6	31.3	178.2	70.6	95.9	98.2
M0W0K3	32.9	94.7	231.8	248.8	147.1	30.6	102.9	113.5	83.5	85.3
M0W1K0	24.5	138.8	250.0	232.9	233.5	23.2	163.5	113.5	87.1	87.6
M0W1K1	21.6	77.6	263.5	270.6	278.2	34.8	160.0	86.5	76.5	72.4
M0W1K2	32.3	112.4	285.9	319.4	323.5	19.7	281.8	81.2	67.1	63.5
M0W1K3	27.1	111.2	215.9	233.5	237.1	42.9	239.4	62.9	59.4	60.0
Mean	29.8	101.5	246.7	238.9	234.3	26.8	188.7	88.8	82.9	83.4
M1W0K0	28.7	108.8	207.6	172.4	200.0	24.8	331.2	121.8	66.5	64.7
M1W0K1	39.4	124.1	258.8	202.4	201.8	14.8	255.3	107.6	94.1	92.4
M1W0K2	32.3	87.6	265.3	195.9	280.6	14.2	297.6	119.4	64.7	68.8
M1W0K3	33.2	94.1	192.4	321.8	107.6	16.5	287.6	115.9	80.0	80.6
M1W1K0	31.9	107.6	250.0	207.6	205.9	14.8	325.9	64.7	102.9	102.9
M1W1K1	33.2	115.3	308.2	237.6	231.2	42.3	299.4	105.9	63.5	65.9
M1W1K2	28.7	102.4	225.9	217.6	219.4	22.6	247.1	113.5	117.6	121.8
M1W1K3	30.3	92.9	206.5	233.5	235.3	24.5	349.4	42.9	131.8	131.2
Mean	32.2	104.1	239.3	223.6	210.2	21.8	299.2	99.0	90.1	91.0
Overall	30.9	102.8	243.2	231.7	223.0	24.3	243.9	93.9	86.5	87.2

Appendix 15: Best fit production function relating evapotranspiration to biomass accumulation



Best-fit production function relating evapotranspiration to above ground biomass during seasons a) I and b) II in Kilifi