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Inter-seasonal Effects on Selected Maturity Parameters of DK8031 Maize Grown under Varying Irrigation and Nitrogen Levels in Embu County, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author CNO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AMK managed the analyses of the study. Author SM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Maize is a staple food and a source of carbohydrates to a large proportion of people in Kenya. The performance of crop plants such as maize depends on a number of factors such as climate, soil characteristics and plant species. The maturity parameters such time to tassel, milk stage, physiological maturity and biological maturity are consequently affected which in turn has an influence on crop performance. A study was carried out at University of Embu Demonstration Farm that lies at 03° 30′ S latitude, 37° 30′ E longitude, and altitude 1480 m above sea level, soils being Humic Nitisols. To evaluate the effects of seasonal weather variability on maturity parameters of DK8031 maize, a CRBD in a split plot experimental arrangement was set up in which four irrigation levels (I) and five nitrogen fertilizer rates (N) were allocated the main and subplot treatments in two seasons, respectively. The results revealed that the irrigation levels and nitrogen rates significantly

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(P<0.05) affected the time to reach the 50% tasseling, 50% milk stage and 50% physiological maturity, ranging from 69 to 73, 99 to 107 and 128 to 140 days after planting, respectively. In all cases, Season I (cool and less rainfall, 530.3 mm) crop took longer to reach any the three developmental stages, compared to Season II (warm and more rainfall = 605.6 mm). The time variation in reaching the developmental stages was attributed to the seasonal weather conditions. Farmers can opt to plant their maize crop in Season II to take advantage of the shorter period the crop takes to mature.

Keywords: Maize; tasseling; milk stage; physiological maturity; irrigation level; nitrogen rates; season.

1. INTRODUCTION

The need to be food secure worldwide receives critical priority as this determines the health and wealth of a country in the face of global warming that leads to prolonged drought and unpredictable weather patterns, declining soil fertility, ever increasing human population and limited natural resource base. Cereal grains such as maize (*Zea mays L.*) provide a staple source of food for many communities in the world [1]. The factors that influence the growth and early productive stages of cereal crops such as maize play a key role in determining the potential yield of field crops [2]. About double the nutrient inputs of nitrogen and phosphorus are applied in relation to that extracted by crops and this imbalance causes serious environmental concerns [2-6]. Estimating the time to tasseling, milk stage and physiological maturity is a good measure for farmers to decide the best input combination for that will be both cost effective and promote eventual crop productivity of maize as well as mitigate against these potential ecological disturbances. The effects of supplemental irrigation and nitrogen fertilizer rates on these crop parameters have not been investigated for Embu County, Kenya where some areas receive marginal rainfall. The time to tasseling, milk stage and physiological maturity have been reported to take18 to 22 and 55 to 65 days after silking and is influenced by such factors as cultivar type, soil characteristics and amount and distribution of rainfall as well as levels of inputs applied [2,7,8].

The effects of supplemental irrigation and nitrogen rates can be captured graphically through production functions to predict performance of the crop and estimate time required for the crop to mature. This becomes an important planning tool for farmers, researchers and policy makers in managing productivity and food security [9,10]. The work done at Iowa University Research and Demonstration farms representing different climates and regions showed that modeling inherently causes the modeler to assume certain factors such as yields exist. The hybrid maturities used were 105, 110 and 115 days with plant populations of 79,000 plants ha^{-1}. So, water-nitrogen relationships tools can be used to measure, optimize and manage maize crop productivity [11,12].

2. MATERIALS AND METHODS

2.1 Experimental Site, Soils and Weather

Embu District is in the Eastern Province of Kenya (latitude: 03° 30′ S, longitude: 37° 30′ E, and altitude 1480 m above sea level).The area receives a total annual rainfall of between 1200 and 1500 mm in two rainy seasons, ‘long rains’ (March to June) and ‘short rains’ (mid October to December). Mean monthly temperature ranges between 14℃ and 19.5℃.The soils are mainly HumicNitisols derived from basic volcanic rocks [13]. They are deep, well weathered with friable clay texture with moderate to high inherent fertility.

2.2 Experimental Design and Layout

The experiment was laid out in a split-plot in randomized complete block design. The irrigation levels (I) formed the main plots while the fertilizer levels (F) formed the subplots (Treatment Plots). Each treatment plot measured 4 x 3 m^2. A 1.0 m footpath was left between the subplots and 1.5m spacing between blocks to minimize percolation effects of water and fertilizer between blocks. Treatments were allocated to the subplots, which will be 1.0 m apart. Each subplot will have rows of cultivar maize having six rows each at a spacing of 75 x 30 cm. This gave a population of 37,500 plants/ha. A total plot area of 1,200 m^2 was used for the three blocks.

2.3 Weather Data Collection and Graphs

The KARI-Embu in conjunction with the local Kenya Meteorological Department provided the following data over the experimental period: Rainfall, wind speed, daily maximum and mean temperatures, sunshine/radiation and relative humidity.

2.4 Crop Establishment and Management

Land was tilled to at least 20 cm depth and closed furrows made at 75 cm spacing by ridging. Two seeds per hole of DK8031 maize at an intra-spacing of 30 cm, giving a population rate of 44,444 plants per hectare of maize after thinning to one plant per hole for all treatment plots. The nitrogen nutrient fertilizer, calcium nitrate (CAN), was applied in incremental splits of 30 kg/ha at sowing then two weeks after sowing followed by other applications six, ten and fourteen weeks after sowing in subsequent applications. This coincided with the times of application of irrigation water, except for the last fertilization event, ,totaling to 4762 m^3 ha^{-1} [14] with increments of 119 mm starting at sowing. Two weed controls and other crop protection practices were carried out uniformly for all treatments.

2.5 Experimental Layout and Treatments

2.5.1 Irrigation levels

I_1:- Irrigation (1190.5 m^3 ha^{-1}) at sowing
I_2:- **I_1** and again two weeks later
I_3:- **I_2** then 6 weeks after sowing
I_4:- **I_3** then 10 weeks after sowing

2.5.2 Nitrogen nutrient levels (split applications)

N_0:- No fertilizer applied at sowing (total = 0 kg-N/ha)
N_1:- **N_0** with first split application of 30 kg-N/ha CAN two weeks after sowing (total = 30 kg-N/ha)
N_2:- **N_1** with second split application of 30 kg-N/ha CAN 6 weeks after sowing (total = 60 kg-N/ha)
N_3:- **N_2** with third split application of 30 kg-N/ha CAN 10 weeks after sowing (total = 90 kg-N/ha)
N_4:- $N_3$with fourth split application of 30 kg-N/ha CAN 14 weeks after sowing (total = 120 kg-N/ha)

2.6 Data Collection

2.6.1 Flowering (tasselling)

Observation for flowering or tussling was started once any one plant in any one treatment plot was observed and recorded in terms of days after sowing (DAS) and the number of flowered/tasseled plants recorded every week thereafter until when more than half of the sub-plot plants had flowered. Graphs of percent tussled plants against time of growth (DAS) were plotted to determine time for each sub-plot to attain 50% flowering.

2.6.2 Weather parameters

Daily weather parameters will be recorded from the Agro-Meteorological Station at KARI-Embu Regional Center. These included seasonal rainfall, wind speed, daily maximum and minimum temperature, solar radiation and percent relative humidity.

2.6.3 Analysis of data

Data collected was subjected to analysis of variance (ANOVA) using the GLM of SAS computer package (Version 9.1). Least significant difference (lsd) was used to separate means of study factors and Duncan's multiple range test (DMRT) used where interactions are observed.

3. RESULTS

3.1 Weather

There were two seasons spanning from April 19, 2012 to September 30, 2012 (Season I) and from October 13, 2012 to March 8, 2013 (Season II). The total amount of rainfall received was530.3 and 605.3 mm in two respective seasons, which was distributed differently (Fig. 1). The rainfall amount decreased progressively in Season I but increased in the first eight weeks of Season II before dipping thereafter. The distribution of the rainfall during the crop establishment stage would eventually affect its time to reach 50% tasseling, milk stage and physiological maturity. The minimum temperatures ranged from 12.9 to 15.8 and 14.1 to 15.4℃ while the maximum values varied from 20.1 to 25.8 and 24.1 to 29.0℃, in Season I and Season II, respectively. The mean wind run and relative humidity in the respective seasons were 67.7 and 11.7 km/day and 68.2 and 62.8%. There were no rains within two weeks before planting in either season; hence soils were wetted by initial irrigation at planting to ensure uniform germination.

3.2 Soil Characteristics

The soil characteristics of the experimental site are described below:

The soil was sandy loam with a bulk density of 1.3 g/cm3, soil pH = 5.43 and hydraulic conductivity 0f 330 mm/h. the carbon content was 2.46% while the nitrogen, potassium and potassium levels were 0.29, 0.17 and 0.13%, respectively.

3.3 Tasseling of Maize

There were significant interactions between irrigation application and nitrogen rates only in Season I (April to September, 2012) during tasseling of the DK8031 maize (Table 1). The longest and shortest interactive time taken by the Season I crop to attain 50% tasseling was observed under $I_{119}N_0$ and $I_{476}N_{90}$ treatment combinations, respectively. Similar results were noted in Season II (October 2012 to March 2013) for the same treatment combinations although they were not statistically different. This shows that low input combinations delayed crop maturity of maize to tassel by about five days in Season I which was cooler and drier compared to the Season II weather conditions. Under irrigation treatments the time to tasseling was significantly different (73.6 DAS) when 119 mm additional water was applied compared to when 476 mm was added over and above the seasonal rainfall, a one day delay (Table 1). In Season II, the time to tasseling was statistically similar but shorter by about 2 days compared to the Season I crop under irrigation treatments. Increasing the rate of nitrogen rates significantly decreased the time to tasseling in both season (Table 1).

Under nitrogen application rates of the crop took 75.4 and 70.9 days compared to 72.4 and 68.6 days after sowing with 0 kg-N/ha and 120 kg-N/ha in the respective seasons. Availing higher rates of N fertilizer thus appears to reduce the time to flowering (tasseling) of the DK8032 probably because the N to promote productive development of crops. The crop takes more time to gather sufficient N from other sources, thereby taking longer to mature under limited supply of the fertilizer N. It has been reported that adjustments for dealing with the effects of climate variations include changes in sowing dates and cultivars, changes in material inputs such as irrigation and nitrogen fertilizers and techniques to conserve soil water [15]. This can be investigated for the Kenyan conditions at Embu to compare the current finings over the years.

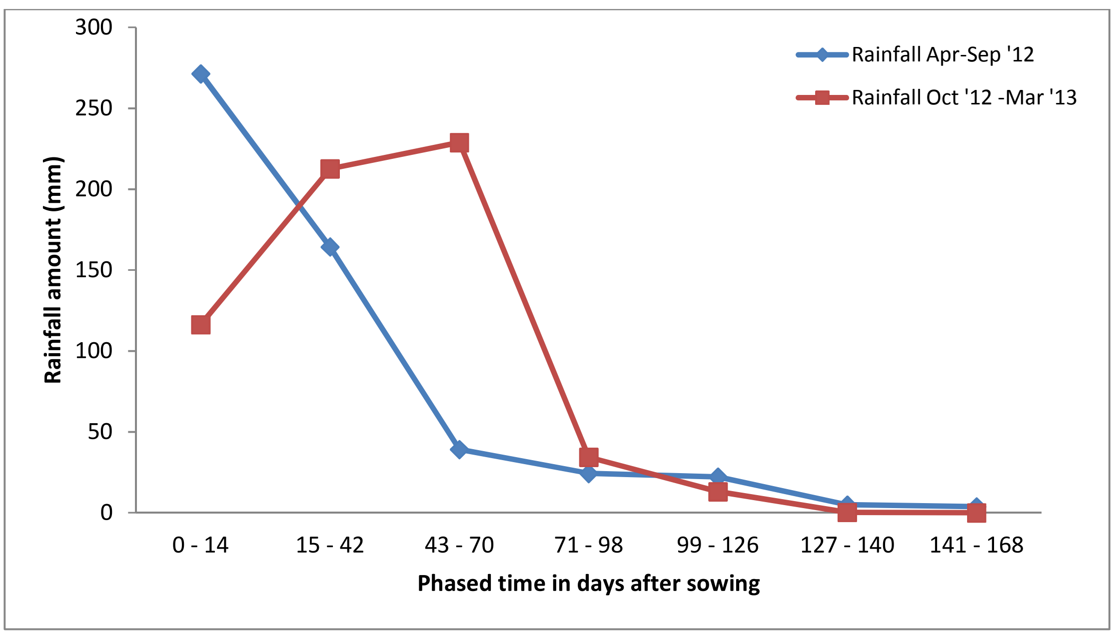

Fig. 1. Rainfall distribution in the two seasons at experimental site in Embu

Regression analysis showed that the level of reliability for irrigation treatments were low (R^2 = 0.4) and very low (R^2 = 0.0182) in Seasons I and II, respectively (Fig. 2). The functions were thus not able to sufficiently explain the variations occasioned by added water through irrigation. On the other hand, irrigation treatments produced moderate (R^2 = 0.43) to high (R^2 = 0.8766) linear regression relationships in Seasons I and II, respectively (Fig. 3). These would be used to predict the time to tasseling of the maize at 43 and 88% reliability. For instance, the time to tasseling would be about 74 and 71 DAS and 71 and 69 DAS for the 0 and 120 kg-N/ha nitrogen treatments in Season I and Season II, respectively. The model predictions are thus more comparable to measured values in Season II than Season I and that nitrogen rates had greater impact on tasseling compared to irrigation application under similar growing seasonal conditions.

Table 1. Time to 50% flowering, milk stage and physiological maturity of DK8031 maize

Factor	50% Tasseling		50% Milk stage		50% Physiological maturity	
	Season I	Season II	Season I	Season II	Season I	Season II
I_{119}	73.6a	70.3a	107.1a	100.0a	140.9a	129.0a
I_{238}	73.2ab	70.3a	107.0a	99.9ab	140.5ab	129.3a
I_{357}	73.2ab	69.5a	107.0a	99.6ab	140.3ab	129.1a
I_{476}	72.8b	69.5a	106.7a	99.2b	140.0b	128.3b
LSD	0.6297	1.334	0.5411	0.7933	0.7727	0.6111
N_0	75.4a	70.9a	110.0a	101.3a	143.8a	131.2a
N_{30}	72.8b	70.3a	106.8b	100.1b	140.5b	129.4b
N_{60}	72.8b	70.0ab	106.2bc	99.5bc	139.4c	128.5c
N_{90}	72.5b	69.9b	106.1c	99.0cd	139.3c	128.1cd
N_{120}	72.4b	68.6b	105.8c	98.5d	139.2c	127.4d
LSD	0.7040	1.4914	0.6049	0.8869	0.8639	0.6832
R^2	0.8664	0.7275	0.9074	0.8083	0.8769	0.8603
Mean	73.2	69.9	107.0	99.7	140.4	128.9

Legend: I_{119} = Irrigation application at 119 mm level; LSD = Least significant difference; N_0 and N_{30} = Nitrogen rate at 0 and 30 kg-N/ha; R^2 = Coefficient of determination. Values with the same letter indicate that they are statistically not significant from each other, i.e. a, b, c and d

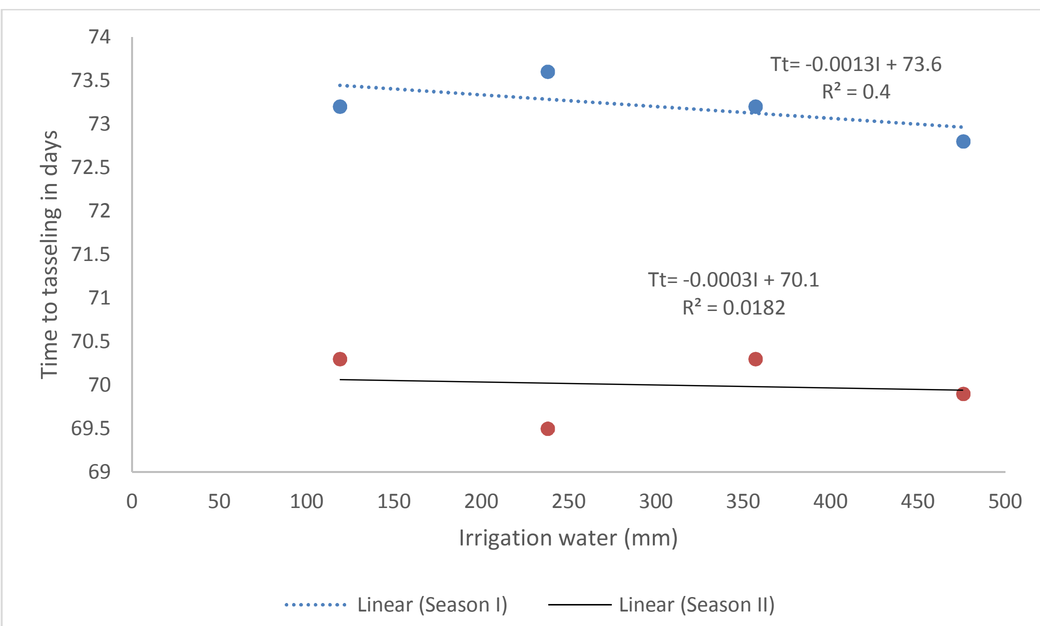

Fig. 2. Effects of applied irrigation water on time to tasseling of DK8031 maize in two seasons

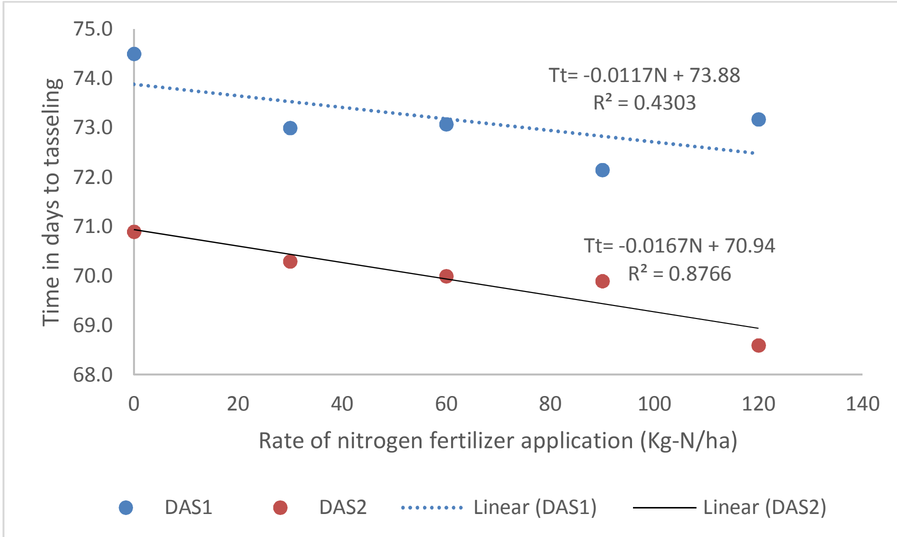

Fig. 3. Effects of nitrogen fertilizer application on time to tasseling of DK8031 in two seasons

3.4 Milk Stage

The results shown in Table 1 indicate that the time to milk stage (R3) was significantly different under irrigation treatments only in Season II (Table 1). The crop needed between 107 and 99 days after sowing to reach milk stage in Seasons I and II, respectively. The crop was observed to reduce time to this stage with increasing irrigation water in both seasons because it needed more time to attain critical kernel mass under water limited conditions. The effects of nitrogen rates on the time to physiological maturity were significant in both seasons (Table 1). This varied from 110 to 105.8 and 101.3 to 98.5 days after sowing in Season I and II, respectively. Increasing the rate of nitrogen application from 0 to 120 kg-N/ha hastened the time to physiological maturity by about 4 and 3 days in these respective seasons. Like for tasseling, additional nitrogen promotes growth and development of the crop, thereby reducing time to the respective maturity stage. This stage is reported to occur when the kernels turn yellowish with a 'milk' white fluid 8 to 22 days after silking [16,8] and accelerated by warm and drier conditions [17]. This explain why the DK8031 took about seven to eight days longer to reach milk stage in Season I (April to September, 2012) compared to the Season II (October 2012 to March 2013) under irrigation and nitrogen treatments, respectively.

A linear relationship had the best fit when the irrigation levels were regressed against the time to milk stage in both seasons but the reliability (R^2 being ≈0.47 and 0.37) was only fair (Fig. 4 and Fig. 5). The time to milk stage reduced with increasing amounts of inputs. The estimated times to milk stage by the functions without irrigation water are 108 and 100 days after sowing in Seasons I and II, respectively. Under nitrogen rates, the functions were good (R^2 = 0.69) and very good (R^2 =0.96) in the respective seasons. The regressions show that the season two crop had predictable better consistence that under N rates which also had a greater impact on the time to milk stage compared to irrigation treatments.

3.5 Physiological Maturity

The physiological maturity (growth stage 9) of maize is attained when the kernel has reached its maximum dry weight and a layer of black cells develop at the kernel base [18]. In the current study, it took the DK8031 maize about 140 and 130 days after sowing to reach physiological maturity in Seasons I and II, respectively (Table 1). There were significant differences in maturity times under both irrigation levels and nitrogen rates and the time to maturity declined with increasing amounts of the two inputs (Fig. 6 and Fig. 7).

When regression relations were developed for irrigation treatments, the fit was very high (R^2 ≈ 0.98) and low (R^2 ≈ 0.32) under irrigation treatments in the two respective seasons. The production function estimated the time to physiological maturity to be 141 and 129 days after sowing in case the crop was grown under rainfed conditions. The linear functions developed for the effects of nitrogen rates were quite good at 71% and 93% reliability and indicate that the time to reach maturity by the DK3031 maize was hastened with increasing nitrogen rates (Fig. 7). In case the crop was to be grown without nitrogen output, it would have taken about 143 and 131 days after sowing. This is best summarized by Fig. 8. Farmers can utilize this observation not only to increase potential yields but also reduce time to maturity.

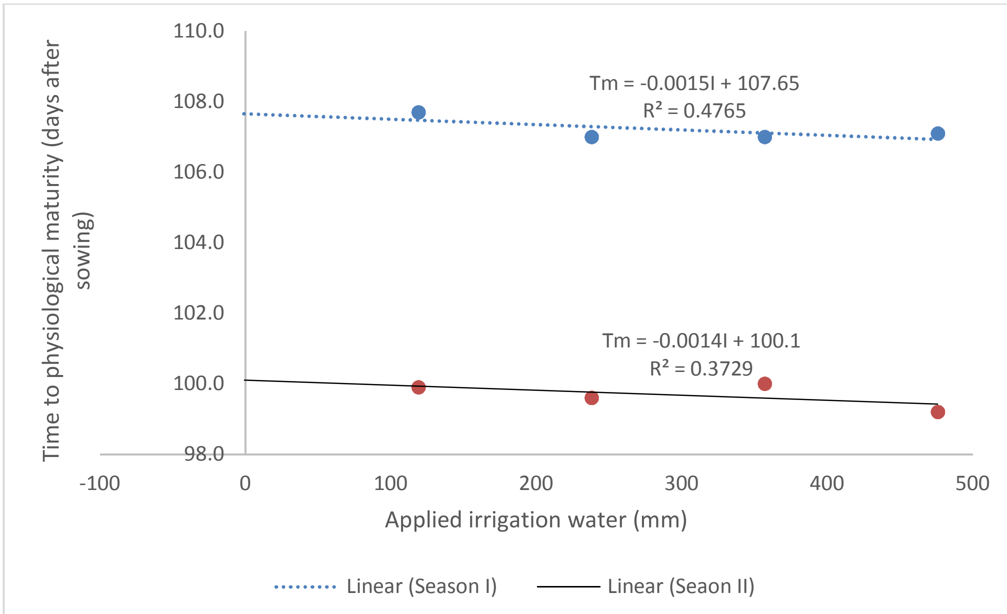

Fig. 4. Effect of applied irrigation water on the time to milk stage of DK8031 maize grown in Embu, Kenya

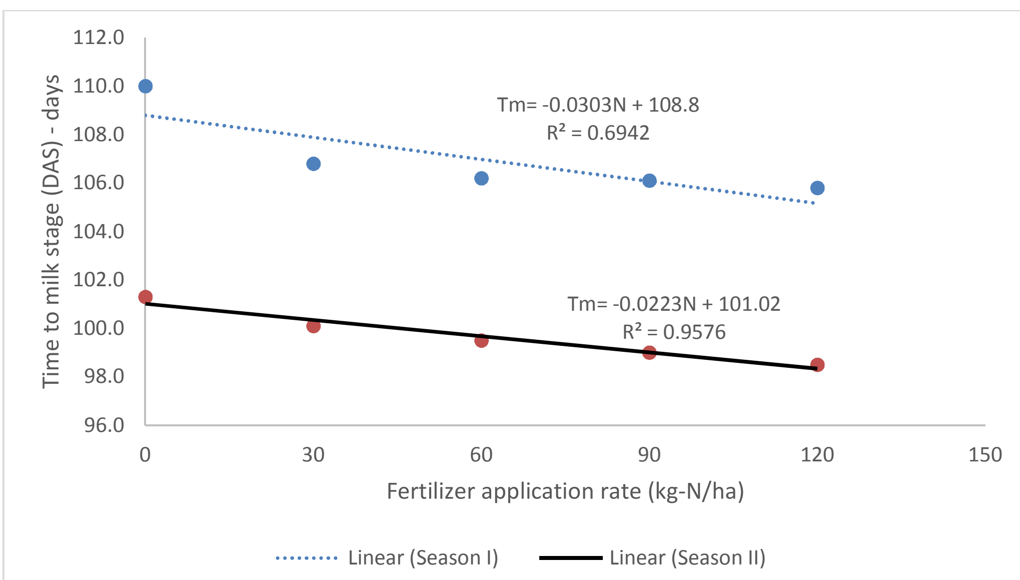

Fig. 5. Effect of nitrogen application rates on the time to milk stage of DK8031 maize grown in Embu, Kenya

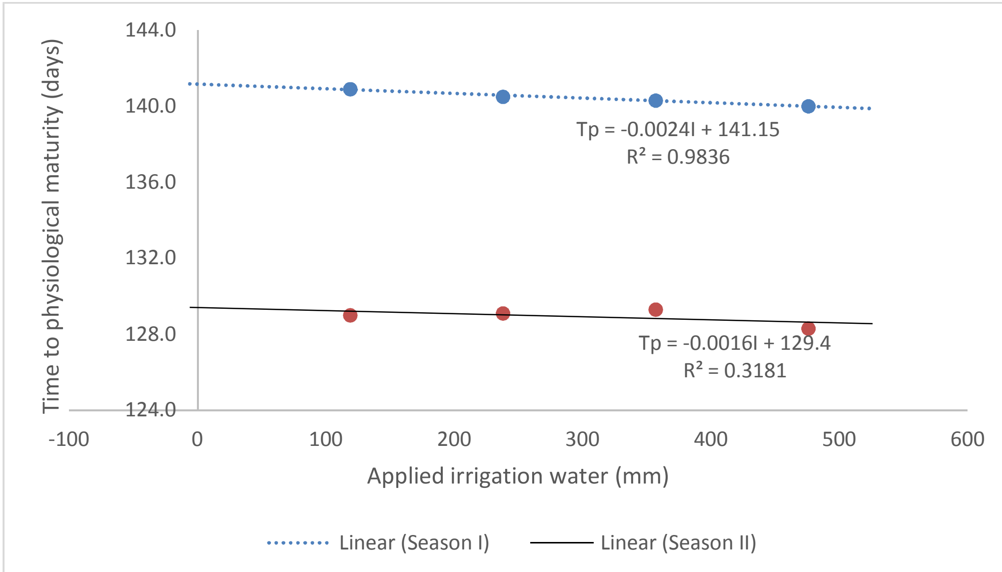

Fig. 6. Effect of applied irrigation on the time to physiological maturity of DK8031 grown in Embu County, Kenya

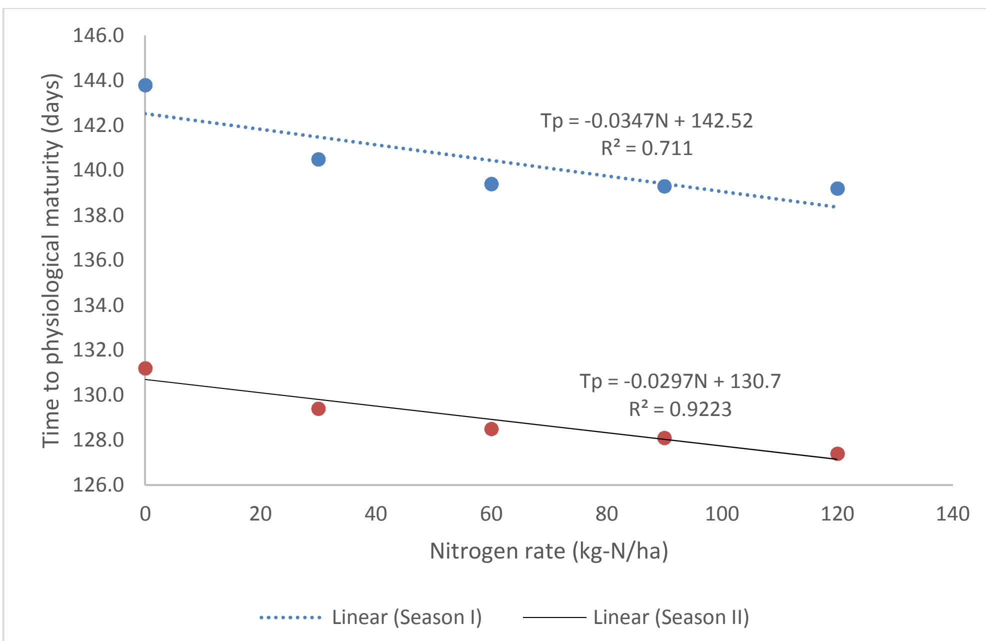

Fig. 7. Effect of nitrogen fertilizer rates on the time to physiological maturity of DK8031 grown in Embu County, Kenya

4. DISCUSSION

The findings in this study reveal that the three maturity parameters were affected by irrigation levels and nitrogen rates at different levels in both seasons. It has been indicated that better yields and efficient use of resource inputs are critical if agriculture is to be sustained in crops such as maize [19]. Determining the most effective input combination is thus important. The amount of available water for the crop (rain and irrigation) and the nitrogen fertilizer rate that guarantees optimal production under the current study was 357 mm and 90 kg-N/ha and 238 mm and 120 kg-N/ha in Seasons I and II. The lower irrigation level in Season II was attributed to the higher amounts of rainfall received in this season which was well distributed, especially in the early time of crop establishment (Fig. 1). There were hardly any significant interactions reported between irrigation levels and nitrogen rates on the selected maturity parameters of the DK8031 maize except for the time to tasseling in Season I. The effects of nitrogen rates were observed to be more paramount on the maturity parameters than those for irrigation/water supply. It has been noted that nitrogen uptake is more dependent on applied N than water supply although N uptake decreased with greater water and N deficits and both inputs affect crop maturity at varying degrees [20].

The period from sowing to maturity has been reported to increase by 2 to 38 days in maize grown attributable to effects of climate change between 1981 and 2007 [21]. The ambient temperatures have increase over the years due to climate chance, a factor that hastens biological activity of crop plants including maize. The seasonal variation in the current study attest to this in that the crop in the warmer Season II (October 2012 to March 2013) took relatively shorter periods to tassel, reach milk stage and attain physiological compared to the cooler Season I (April 2012 to September 2012) for between three to 10 days (Fig. 8). These change in crop growth mechanisms are better explained by use of models which can effectively predict and estimate maturity times and, by extension, yields of the crop. This is useful information for farmers and other stakeholders such as policy makers and researchers to adopt strategies that can mitigate against effects of seasonal variations by incorporating other factors that influence growth and development of maize [22] [23,24].

The Season I was generally cooler with weaker wind run and received less rainfall (<70 mm) compared to Season II. This may have reduced photosynthetic rates, slowing down growth and development of the DK8031 maize. The time to attain 50% tasseling, milk stage and physiological maturity were thus relatively longer for all these parameters compared to the Season II crop. In the second season, the crop received more rainfall, stronger winds and temperatures were was warmer (up to 29℃) and received higher PAR compared to Season I crop. This caused some leaves to curl to reduce transpiration rate and promote carbon dioxide uptake, thereby increasing photosynthesis and assimilate partitioning. The maize crop thus took shorter periods to reach tasseling, milk stage and physiological maturity compared to the Season I crop (Fig. 8). The different crop responses would thus be attributed to the inter-seasonal weather variation that was thus reflected in the different times to attain respective maturity stages. Similar observations were made for the growth variables of the same crop [25].

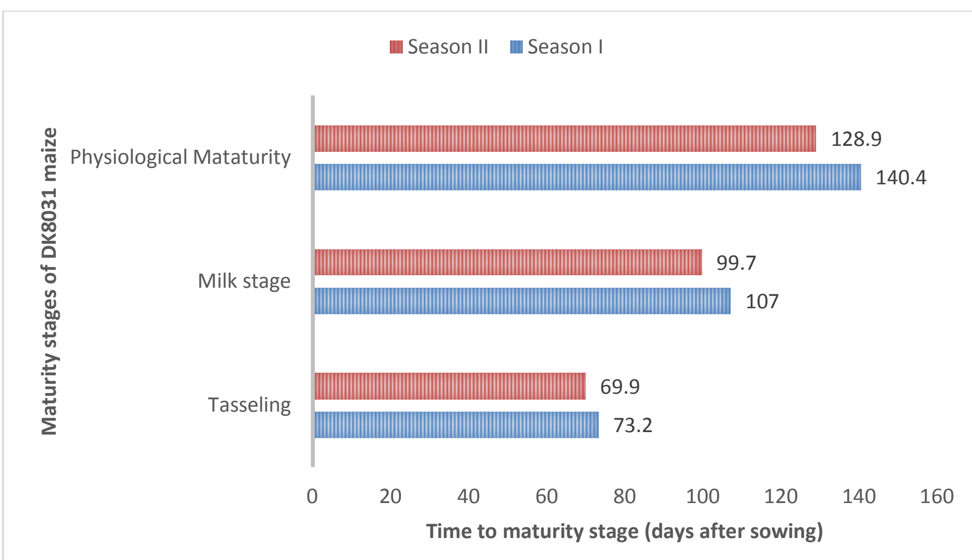

Fig. 8. Seasonal comparison of the time to tasseling, milk stage and physiological maturity of DK8031 maize grown under varying irrigation levels and nitrogen rates in Embu County, Kenya

5. CONCLUSIONS

The least time for the DK8031 maize to reach tasseling, milk stage and physiological maturity was under the 476 mm level of irrigation in both seasons, implying that rainfall alone was insufficient to reduce the maturity times. Under nitrogen application, an average of 60 kg-N/ha in Season I and at least 90 kg-N/ha in Season II were sufficient to significantly reduce the time to the respective maturities of the maize.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

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