Der Tropenlandwirt, Beiträge zur tropischen Landwirtschaft und Veterinärmedizin,
98. Jahrgang, April 97, S. 95 - 109.

Phenological and Physiological Evaluation of the Potential of Tohono *O'odham* Z16 Maize as a New Crop for the Semi-Arid Areas of SE-Kenya

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1 Introduction

Maize (*Zea mays* L.), introduced to Africa by the Portuguese in the 16th Century, has become the most important staple crop in eastern and southern Africa (MIRACLE, 1966). Maize plays a staple food crop role in Kenya, where its proliferation and the resulting decline of indigenous cereals, e.g. millet and sorghum, was triggered by new genotypes introduced by settlers from South Africa at the beginning of the 20th century (ACLAND, 1971).

Tohono *O'odham* Z16[1] maize cultivar is also known by the name "*Papago*", i.e. it is named after the *Pima Papago* Indians who have domesticated the cultivar for centuries. The *Papago* Indians have lived in the Sonoran Desert of southern Arizona and northern Sonora, Mexico, where surface water is scarce and rain is infrequent (NABHAN, 1986). Because the *Papago* have adapted their crops and land management strategies to such marginal conditions, the agricultural botanist Anderson (1954, 26-28) has called them "... one of the world's most remarkable agricultural civilizations... they produce usable harvest on fewer inches of rainfall than are used anywhere in the world".

A number of researchers have proposed various strategies that need to be adopted in order to develop sustainable food production systems in these marginal areas and at the same time reduce the vulnerability of the small scale farmers to crop failures (JAETZOLD, 1979; JAETZOLD and SCHMIDT, 1983; HORNETZ, 1990). Some of the proposed agroecologically suitable farming strategies include: "water harvesting" sytems (e.g. *Matuta*), agroforestry and the introduction of drought resistant "minor crops". The urgent need for research on drought-adapted species of short cycle in Africa has been emphasized (DOW, 1989).

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1 The catalogue number Z16 is actually an accession number of the *Papago-Hopi* mix (MUENCHRATH, pers. comm.)

The search for drought-adapted species of short cycle, well adapted to the semi-arid environments is also at the top of the research agenda of Kenyan agricultural researchers (ODHIAMBO, 1989). The plants' phenological development and water requirements are important atrributes that need to be considered when evaluating their suitability for a given climatic environment (MUGAH and STEWART, 1982; ARNON, 1992). Besides phenology and crop water requirements, Hornetz (1988) notes the eco-physiological properties such as responses to high temperature and water stress need to be tested. The response of annual crops to water stress depends upon the developmental stage of the plants at the time water becomes limiting (LEVITT, 1972). Leaf water potential has proved to be one of the indicators of crop water stress (IDSO, 1982; OLUFAYO et al., 1993) and leaf water potential is a suitable index for screening crops for resistance to this abiotic stress (HORNETZ, 1990; OLUFAYO et al., 1993). This study intends to compare the phenology, crop water requirements and the diurnal behaviour of leaf water potential (LWP) of the new maize variety Tohono *O'odham* Z16 and of the locally grown varieties, i.e. Katumani Composite B (KCB) and Makueni Dryland Composite (MDLC) under different watering treatments (irrigated and rainfed). The objective was to evaluate the potential of the new maize variety in a semi-arid environment of SE-Kenya, with a view to making recommendations on its suitability for incorporation into the maize breeding programme at the National Dryland Farming Reseach Centre (NDFRC), Katumani, Kenya.

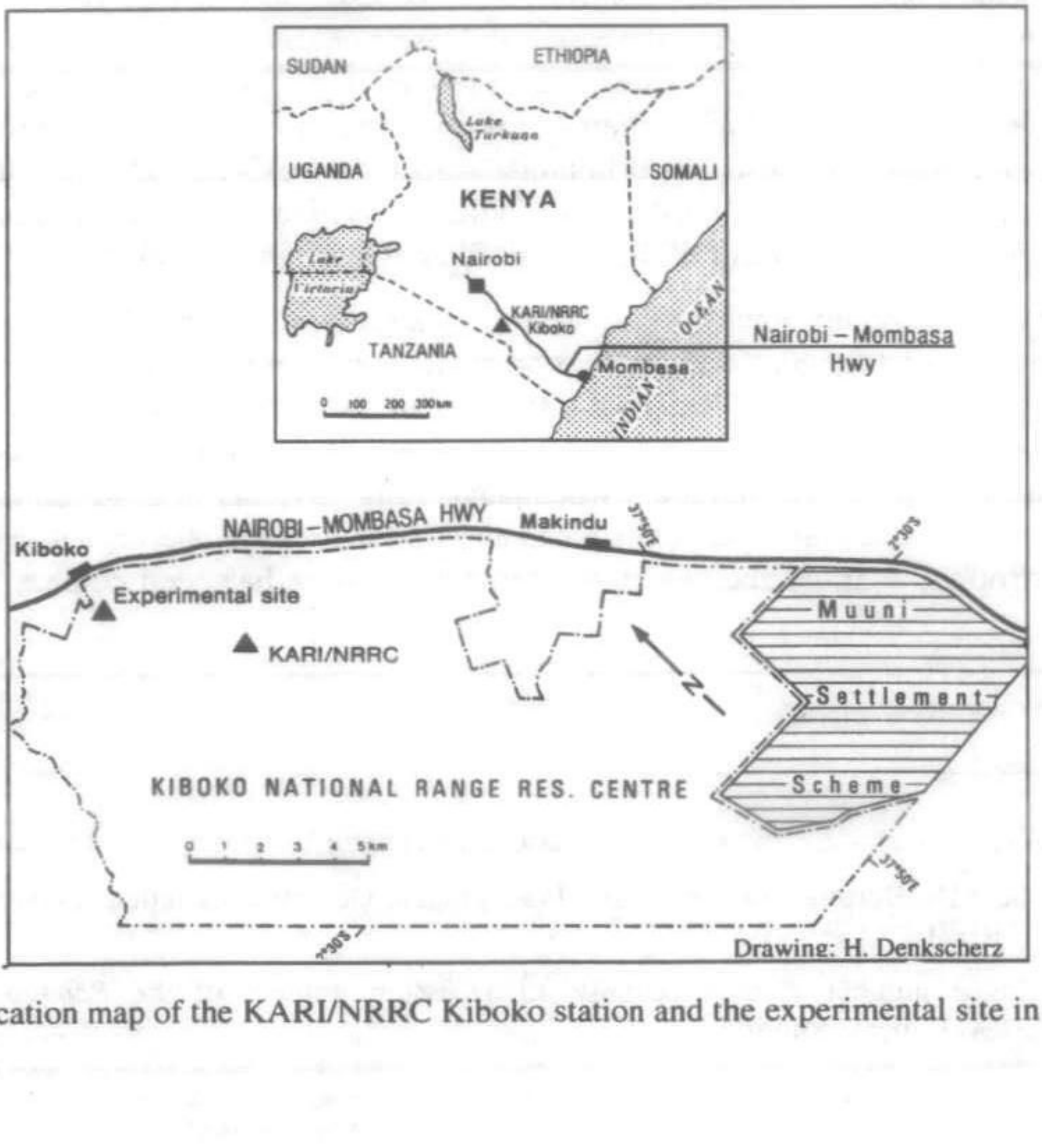

Fig. 1: Location map of the KARI/NRRC Kiboko station and the experimental site in SE-Kenya

2 Experimental site characteristics

The soil on the experimental field site at the National Range Research Centre (KARI/NRRC/ICRISAT) Kiboko, Kenya (2° 10' S, 37° 40' E) (see Fig. 1) is classified as an acri-orthic Ferralsol (TOUBER, 1983). The soil is well drained and texturally is a sandy clay loam overlaying a sandy clay (PILBEAM et al., 1995, 135). The soil chemistry indicates in particular a deficiency in nitrogen (N_{min}) such as ammonium and nitrate (0.07 and 0.04 mg/100 g of soil, respectively; soil profile depth = 60 cm) (C. ANTOINE, unpublished data). Rainfall is bimodally distributed, with mean monthly maximum in April (113 mm) and November (145 mm); mean annual rainfall is about 562 mm year. The short rains (October to January) generally have more rainfall and are more reliable than the long rains (March to June) (MUSEMBI and GRIFFITHS, 1986). The lengths of the (agro)humid periods for drought adapted crops as calculated by WATBAL.Module 1 computer program (KUTSCH and SCHUH, 1983) are 50 - 55 days (long rains) and 65 days (short rains). Average monthly temperatures are highest in February (24.3° C) and October (23.4° C) (KMD, 1984), prior to the onset of the rains in March and November, respectively.

3 Materials and methods

3.1 Materials

Tohono *O'odham* Z16 maize seeds were obtained from the Native Seeds/SEARCH[2] Institute in Tucson, Arizona, USA. They export Tohono maize seeds in packets each containing 50 certified and treated seeds. A total of 20 packets (1000 seeds) were imported and later screened and re-certified by the Crop Plant Genetic Resources Centre at Muguga, Kenya. Certified seeds of the locally grown maize varieties (Katumani Composite B and Makueni Dryland Composite) were purchased from the Kenya Seeds Company Ltd, Nairobi, Kenya.

3.2 Methods

Land preparation was carried out by disc ploughing followed by disc harrowing. The maize seeds were sown in 6 x 4 m plots at Kiboko experimental site before the onset of the short rains in October 1993. These plots were replicated four times per treatment in a random block design. Maize was sown in rows 75 cm apart with a spacing of 30 cm between plants in the row. Subsequently, the two maize seedlings per hole were thinned to one leaving an expected population density of 4.4 plants m^{-2}. At sowing, the plots received farm-yard manure to give minimal nutrient supplement to the plants after preliminary soil analysis data of the plot indicated plant nutrient deficiencies. The plots were top-dressed with calcium ammonium nitrate fertilizer (CAN: 26 % N) at an equivalent rate of 20 kg ha^{-1} 3 weeks after germination. The fertilizer was top-dressed

[2] Native Seeds/SEARCH is an institute concerned with the collection and preservation of ancient seeds of Southwestern USA for modern needs

between plant rows. Furadan chemical (active ingredient 5 % carbofuran) was applied at a rate of 2 grammes m^{-1} in the maize rows at sowing to control cutworms (*Agrotis ipsilon*). Maize stalk borer was controlled by applications of Diptrex (active ingredient 2.5 % Trichlorphon) to each whorl.

All the plots were irrigated at the time of emergence in order to ensure good germination. The irrigated plots were thereafter supplied with water whenever soil moisture levels at the 15 and 40 cm soil depths fell below 80 % of field capacity . Irrigation was done on the following dates: 10.11., 17.11., 8.12., 14.12, 23.12.1993 and 5.1.1994, respectively (see Fig. 2). Each irrigation amounted to approximately 57.6 mm of rainfall. Crop water requirements were estimated using the water balance approach (LENGA and STEWART, 1983) and the Penman's approach (MUGAH and STEWART, 1982), while soil moisture monitoring was done using gypsum block electrodes (SOILMOISTURE, Sta. Barbara, California/USA, see HARTMANN, 1993). The gypsum blocks had earlier been calibrated for the soils at the experimental site. The soil moisture monitoring was done in 15, 40 , 60 and 80 cm soil depth based on the assumption that the maize rooting depth in this area is about 80 cm (NADAR, 1984). For illustrative purposes of monitoring soil moisture, plots of short duration Tohono maize variety were used in this respect (Plots 1.11 and 2.2) (see Figs. 2 and 3). Potential evapotranspiration (ETo) was estimated using the modified PENMAN formula (MCCULLOCH, 1965).

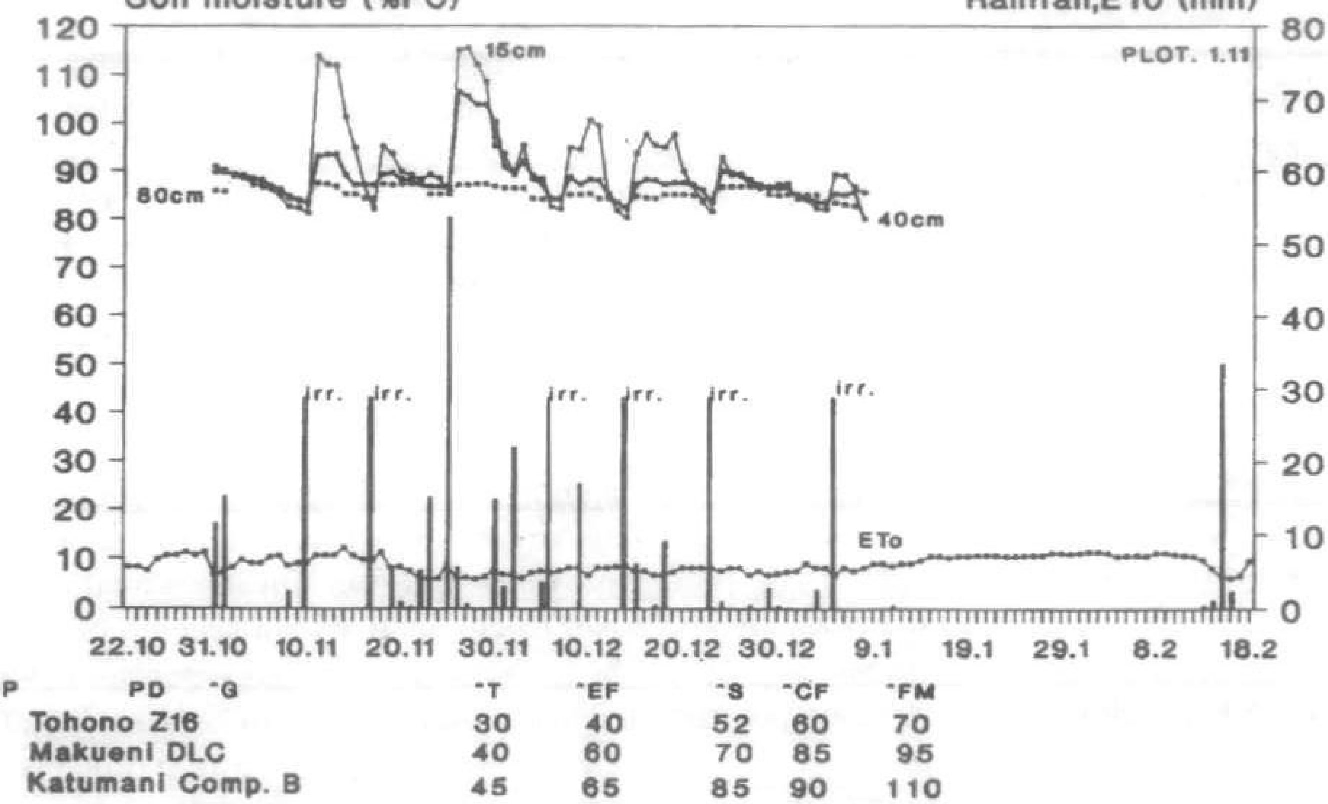

Fig. 2: Rainfall, soil moisture, ETo and phenol. phases of maize varieties during the 1993/94 short rains

The diurnal leaf water potential in-situ was measured with a hygrometer probe (WESCOR Inc. Logan, Utah/USA; Model C-52) on leaf discs punched from the middle part of either the last expanded leaf or the one next below it in each of the treatments.

The sampled leaves were healthy and fully exposed to sunlight. Leaf discs were allowed to equilibrate in the hygrometer chamber for 15 minutes (SORIANO and GINZO, 1975, 275) before taking the microvolt (µV) reading using the HR-33T dew point microvoltmeter (WESCOR Inc.). The µV-readings were converted to megapascale (MPa). Leaf water potential measurements were done between 52 to 85 days after emergence, when most of the plants were silking. This stage has been generally accepted as one of the most water-sensitive in crop development (DOORENBOS and PRUITT, 1977). The phenological developmental changes were observed and recorded on a daily basis from germination to full maturity. A phenological phase was taken to have occured when 75 % of the plants had attained the characteristics of the respective phase (LENGA and KEATING, 1990). The following phenological phases (PP) of the maize varieties were distinguished: planting date (PD), germination (G), tasselling (T), ear formation (EF), silking (S), cob formation (CF) and full maturity (FM).

4 Results and discussion

4.1 Rainfall, soil moisture profiles and phenological development during 1993/94

During the 1993/94 short rainy season, the experimental site received a total of 240.5 mm of rainfall. This was about 68 % of the long term mean seasonal rainfall for NRRC Kiboko station. The ETo during this season averaged 5.0 mm day^{-1}. It can be seen from Figure 2 that rainfall was poorly distributed during this season. This season represented a typical example of an Anti-ENSO[3] season, i.e. below a Normal season in terms of rainfall amount, according to the classification by Willems (1993). Figure 2 further shows the relationship between rainfall, soil moisture, ETo, irrigation and the respective phenological phases of Tohono Z16, Makueni DLC and Katumani Comp. B maize varieties, while Fig. 3 shows this relationship under rainfed treatment for Tohono Z16. From Fig. 2, it can be seen that the season began with soil moisture content of over 80% FC at all depths. This moisture content was maintained almost throughout the season largely because of the efficiency of the five irrigations that were applied.

Using Tohono Z16 maize (Fig. 3), under the rainfed treatment, it can be seen that the season began with soil moisture content of about 80 % FC at all soil depths. This soil moisture amount, however, decreased rapidly to about 55 % and 65 %, at depths of 15, 40 cm and 80 cm, respectively, following a 2 week dry spell after germination. Around the tasselling stage, there was an increase in soil moisture content at all depths (80% FC) following a heavy rainfall event of 53.6 mm on 25.11.93 (Fig. 3). Soil moisture content was, however, rapidly depleted following intermittent dry spells that characterized this season, particularly at silking. For example, the moisture content level at the 15 cm soil depth decreased to a low of about 40 % FC and that at 40 cm depth to about 60 % FC during the silking stage (Fig. 2). These soil moisture deficiencies had

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[3] ENSO = El Niño Southern Oscillation (see FRENKEN et al., 1993; Anti-ENSO: opposite; ca. 30-35 % of all short rainy seasons)

an extremely negative effect on the maize crop yield during this season (see SHISANYA, 1996).

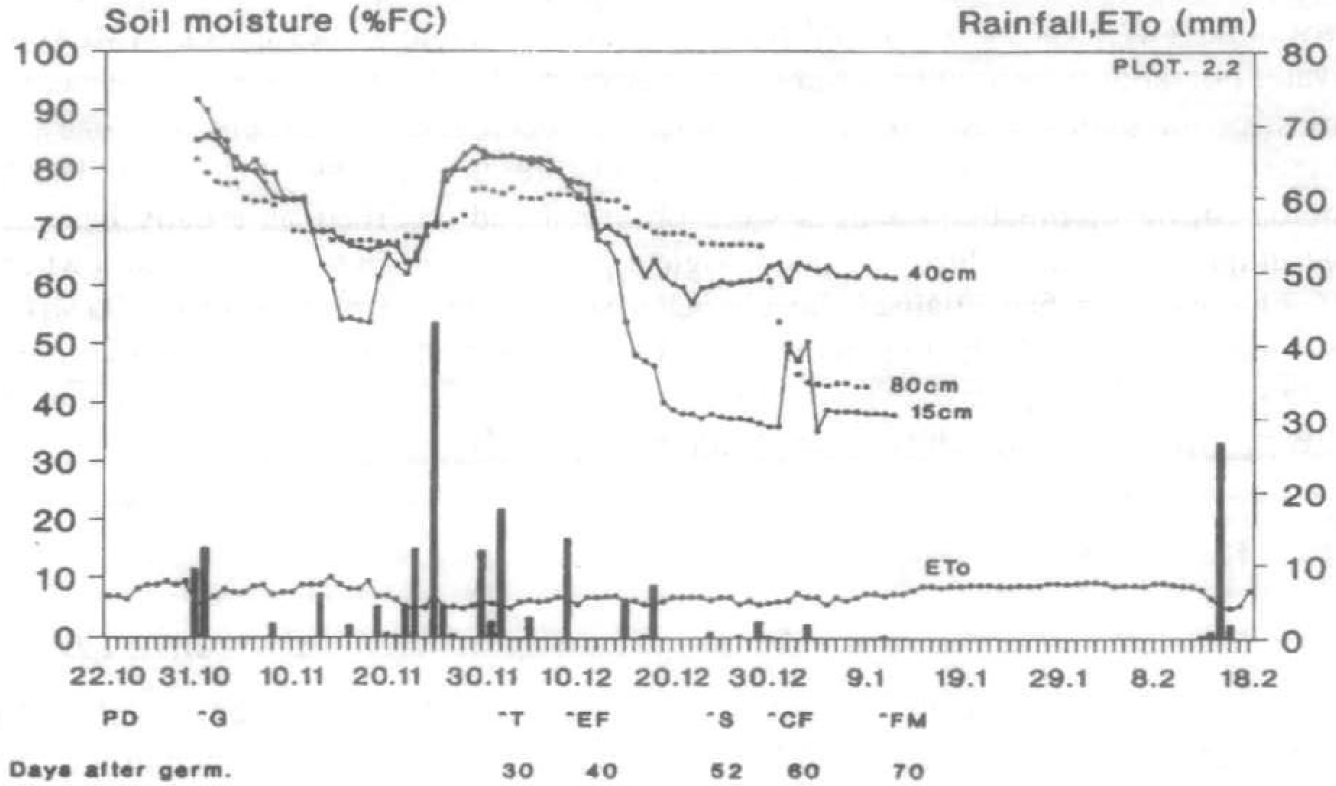

Fig. 3: Rainfall, soil moisture, ETo and phenol. phases of Tohono Z16 maize during 1993/94 short rains

From Fig. 2, it can be seen that under optimum conditions, Tohono Z16, Makueni DLC and Katumani Comp. B maize varieties took about 30, 40 and 45 days to tasselling, respectively, 52, 70 and 85 days to silking and 70, 95 and 110 days to full maturity. Similar phenological observations on Makueni DLC and Katumani Comp. B have been documented (NADAR, 1984; LENGA and KEATING, 1990). It should be pointed out here that the differences in days to maturity between Tohono Z16, Makueni DLC and Katumani Comp. B were 25 and 40 days, respectively.

The introduction of the Tohono Z16 maize in the marginal areas of SE-Kenya may be interpreted as a step forward in the dryland maize breeding research programme and not as an alternative to the locally grown maize varieties. Tohono Z16 will accelerate the search for a maize variety that matures quickly within the relatively short growing periods, typical of these areas (JAETZOLD and SCHMIDT, 1983), without compromising the final yield output.

Under rainfed treatment, a false start in silking was observed on some of the stressed maize plots. This was more pronounced on the Makueni DLC and Katumani Comp. B plots and could be observed particularly around 20.12.93, when the soil moisture reserves were almost depleted (Fig. 3). Water stress has been found to markedly alter hormone levels within the plant (HSIAO and BRADFORD, 1983, 250). Thus, early flowering or silking in plants under water stress can be attributed to the increased production of abscisic acid (ABA) and ethylene, which tend to inhibit growth but instead promote senescence during water stress (HSIAO and BRADFORD, 1983). On the other hand, there was pronounced leaf rolling among the stressed Tohono Z16 maize plants. Leaf rolling is a common response to stress and results in a marked reduction in effective leaf area and a more vertical leaf orientation, thus reducing the radiation load (BEGG, 1980, 39).

4.2 Crop water requirements

The data in Table 1 show the crop water requirement estimates of the three maize cultivars grown at KARI/NRRC Kiboko experimental field station during the 1993/94 short rainy season using the water balance and Penman approaches. From Table 1, it can be observed that Makueni DLC and Katumani Comp. B maize varieties required about 41 % and 52 % more water than the Tohono Z16 variety during this season, respectively. These results, with respect to Katumani Comp. B maize variety are in agreement with those obtained by Mugah and Stewart (1982), though the slight differences between them could be attributed to site geographic differences.

Table 1: Crop water requirement estimates of three maize cultivars grown at KARI/NRRC Kiboko experimental field station during the 1993/94 short rainy season using the Water balance and Penman approaches

Maize cultivar	Crop water requirement estimates		
	Water balance method (mm)	Penman method (mm)	Mean estimate (mm)
Tohono Z16	295.5	290.5	293.0
Makueni DLC	405.6	418.7	412.2
Katumani Comp. B.	435.2	458.0	446.6

4.3 Diurnal leaf water potential (LWP)

The diurnal course of LWP in the three maize varieties under irrigation and rainfed treatments, 52 to 85 days following emergence, is presented in Figures 4-a and 4-b, respectively. These graphs confirm the usual patterns found in literature (e.g. SHARRAT et al., 1983; EHLER et al., 1978; OLUFAYO et al., 1993). The LWP was high at day break, i.e. 7.00 h morning local time (-0.30 MPa to -0.40 MPa) under irrigation treatment (Fig. 4-a) and slightly lower (-0.42 MPa to -0.50 MPa) under stressed rainfed treatment (Fig. 4-b). The LWP decreased during the course of the day, reaching a minimum of about -1.50 MPa to -1.98 MPa under irrigation treatment (Fig. 4-a) and about -2.38 MPa (Tohono Z16), -2.80 MPa (Makueni DLC) and -3.00 MPa (Katumani Comp. B) under stressed rainfed treatment, between 15.00 h and 16.00 h local time (Fig. 4-b). The decrease in LWP in the maize plants under irrigation treatment is due to an atmospheric evaporative demand with rising radiative energy and saturation deficit indicating good hydration (OLUFAYO et al., 1993). For the maize plots under rainfed treatment, the decrease was largely due to water stress. Most of the maize plants under rainfed treatment exhibited leaf enrolling. This phytodynamical phenomenon (TURNER and KRAMER, 1980) is a common response to water stress and tends to reduce leaf temperatures and transpiration rates (FORSETH and EHLERINGER, 1983).

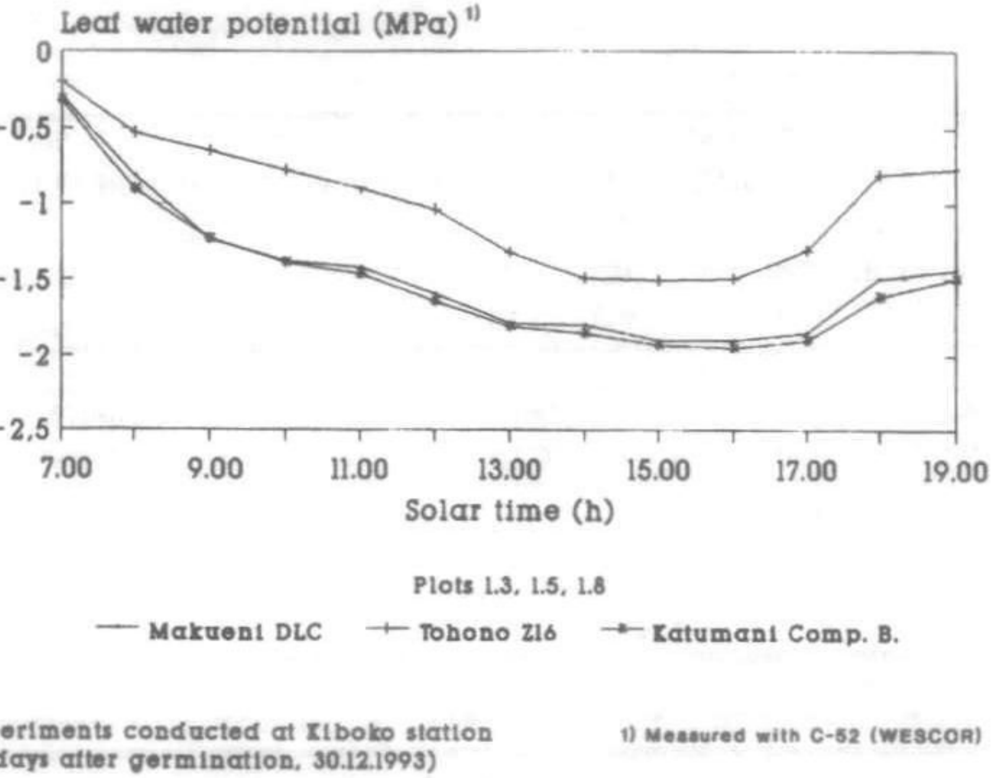

Fig. 4-a: Leaf water potential measurements of three maize vars. at opt. water conditions, 1993/94 short rains

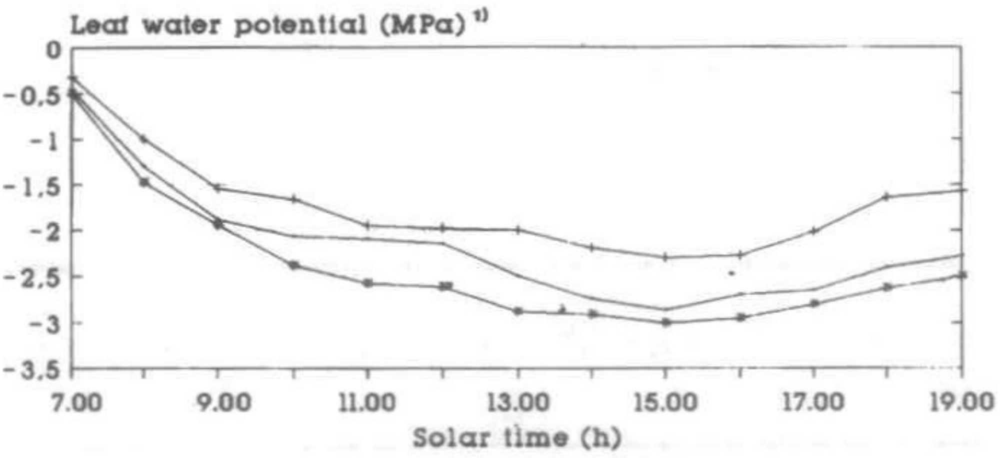

Fig. 4-b: Leaf water potential measurements of three maize vars. under rainfed conditions, 1993/94 short rains

Table 2: Comparison of block and treatment effects on three maize cultivars planted at KARI/NRRC Kiboko experimental field station during the short rainy season of 1993/94

Treatments	Adjusted mean grain yield (kg/ha)
Plot 1.1 (IRR-KCB)	4500.5 a
Plot 1.8 (IRR-KCB)	4890.8 a
Plot 2.5 (RF-KCB)	747.8 c
Plot 2.10 (RF-KCB)	519.2 c
F-Ratio (T)	4.123 *
F-Ratio (B)	NS
CV (%)	91.8
Plot 1.2 (IRR-MDLC)	4400.0 a
Plot 1.3 (IRR-MDLC)	4804.0 a
Plot 2.8 (IRR-MDLC)	742.3 c
Plot 2.9 (IRR-MDLC)	692.4 c
F-Ratio (T)	3.879 *
F-Ratio (B)	NS
CV (%)	84.6
Plot 1.5 (IRR-TZ16)	1875.5 b
Plot 1.11 (IRR- TZ16)	1927.5 b
Plot 2.2 (RF- TZ16)	653.4 c
Plot 2.7 (RF- TZ16)	717.6 c
F-Ratio (T)	3.654 *
F-Ratio (B)	NS
CV (%)	54.3

Notes:

a, b, c, d Yields with the same column followed by the same letter are not significantly different at P<0.95 and 0.99 according to DNMR test

***** Significant at both levels

NS Not significant at both levels

****** Individual plants of Tohono Z16 were very inhomogenous due to original seed material; yields of homogenous crop stands will be much higher (breeding programme!)

IRR Irrigated treatment; RF: Rainfed treatment

KCB Katumani Composite B; MDLC: Makueni Dryland Composite; TZ16: Tohono *O'odham* Z16

The Tohono Z16 maize variety appeared to maintain a higher LWP compared to Makueni DLC and Katumani Comp. B varieties. For example, under rainfed treatment Tohono Z16 maize attained a minimum LWP of about -2.38 MPa compared to -2.85

and -3.00 MPa attained by Makueni DLC and Katumani Comp. B, respectively (see Fig 4-b). This gives evidence that Tohono Z16 possesses drought resistance mechanisms (NABHAN, 1986). With regard to Makueni DLC and Katumani Comp. B, their extremely low LWP is an indication of their unsuitability for the semi-arid environments of Kenya, particularly when the season is deficient in rainfall. Their susceptibility to water stress is also documented by the fact that they quickly leave their optimum hydrature level early in the morning (see Figs. 4-a and 4-b). As it has been shown earlier, these two maize varieties required more water than Tohono Z16 variety during this season (i.e. 41 % and 52 % more water, respectively). Yield reductions from the optimum yields[4], resulting from the water stress during this season for Tohono Z16, Makueni DLC and Katumani Comp. B maize varieties were 64 %, 87 % and 90 %, respectively (see Table 2).

From a practical point of view, it would be recommended that Tohono Z16 maize variety be planted by farmers, particularly during exceptionally dry seasons, i.e. Anti-ENSO (classification according to WILLEMS, 1993). All the maize varieties can be planted during seasons with good rainfall amounts, with Makueni DLC and Katumani Comp. B being the "high yielding" varieties. An actual atmosphere-ocean-teleconnection has already been presented by Frenken et al. (1993), with reference to South-East Kenya.

4.4 Conclusions

The 1993/94 short rainy season was characterized by extreme moisture deficiencies. The season was a typical example of what Willems (1993) classified as Anti-ENSO. Tohono Z16 attained full maturity within 70 days. This short maturity period fits well within the mean length of agrohumid periods of about 40/45 to 85/105 days (JAETZOLD and SCHMIDT, 1983), which are typical of these semi-arid areas. Due to the short maturation period, Tohono Z16 requires less water compared to Makueni DLC and Katumani Comp. B. Tohono Z16 maize variety showed its ability to withstand extreme moisture stress as indicated by its higher LWP and the phytodynamical responses compared to the other two maize varieties, resulting in less yield reductions. As a result of this study, it is strongly recommended that Tohono Z16 maize variety be incorporated into the maize breeding programme at NDFRC, Katumani. The genetic material of earliness to maturity and drought adaptation present in Tohono Z16 could be exploited by maize breeders with a view to develop new maize cultivars. However, the immediate task of the breeders would be to select particular production traits of Tohono Z16 maize in order to minimize heterogeneity within it.

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[4] Optimum yield for each maize variety represents the average yield from irrigation treatment plots over 2 seasons at Kiboko experimental site. For details, see SHISANYA (1996)

5 Summary

This study intends to compare the phenology, crop water requirements and the diurnal behaviour of leaf water potential of the new maize variety Tohono *O'odham* Z16 and of the locally grown varieties, i.e. Makueni DLC and Katumani Comp. B. under different watering treatments. The major objective of this study was to evaluate the potential of the new maize variety in a semi-arid environment of SE-Kenya, with a view to making recommendations on its suitability for incorporation into the maize breeding programme at NDFRC, Katumani, Kenya. The results of this study showed that:

a) Under optimum water requirements, Tohono Z16 attained full maturity within 70 days compared to 95 and 110 days for Makueni DLC and Katumani Comp. B, respectively.

b) Makueni DLC and Katumani Comp. B maize varieties required about 41 % and 52% more water than Tohono Z16.

c) Under rainfed treatment, leaf enrolling was more pronounced among the Tohono Z16 maize plants as compared to the other two maize varieties. This has been shown to be evidence for plant adaptation to water stress and results in a marked reduction in effective leaf area thus reducing the radiation load.

d) Under rainfed treatment, Tohono Z16 maize attained a minimum LWP of about -2.38 MPa compared to -2.85/-3.00 MPa attained by Makueni DLC and Katumani Comp. B, respectively. The susceptibility of these latter two maize varieties to water stress is documented by the fact that they quickly leave their hydrature level early in the morning compared to Tohono Z16 maize which tends to maintain its level for a relatively longer period of time.

As a result of this study, it is strongly recommended that Tohono Z16 be incorporated into the maize breeding programme at NDFRC, Katumani. It has been shown that Tohono Z16 maize possesses physiological characteristics which could be positively exploited by plant breeders at NDFRC, Katumani, in the search for drought adapted maize cultivars for the semi-arid areas of SE-Kenya.

Zur phänologischen und physiologischen Bewertung der Anbaumöglichkeiten von Tohono O'odham Z16 Mais für die semi-ariden Gebiete SE-Kenyas

Zusammenfassung

In der vorliegenden Studie werden phänologische und physiologische Eigenschaften (Wasserbedarf/-verbrauch, Hydraturverhalten) der in SE-Kenya neue eingeführten, kurzzyklischen Maisvarietät Tohono *O'odham* Z16 mit denen von zwei lokal angebauten, aber streßempfindlichen Hochertragsmaissorten (Makueni DLC, Katumani Comp.B.) unter Bewässerungs- und Regenfeldbaubedingungen ausgetestet. Dabei steht im Vordergrund die Bewertung der Anbaumöglichkeiten dieser neuen Varietät unter den semiariden Bedingungen SE-Kenyas, auch im Hinblick auf die Verwendung im

"Maize Breeding Programme" des National Dryland Farming Research Centre (NDFRC) in Katumani/Kenya.

Die Untersuchungen erbrachten, daß

a) bei optimaler Wasserversorgung Tohono Z16 innerhalb von 70 Tagen zur Vollreife gelangt, im Gegensatz zu 95 bzw. 110 Tagen für Makueni DLC und Katumani Comp.B.;

b) Makueni DLC und Katumani Comp.B. ca. 41 bzw. 52% höhere Wasseransprüche als Tohono Z16 aufweisen;

c) in Wasserstreßsituationen Tohono Z16 wesentlich effektivere morphologische und physiologische Anpassungsmuster als die beiden Hochertragssorten zeigt. Dabei gelingt es der kurzzyklischen Varietät, die Tagesminimumwerte der Hydratur bei ca. -2,38 MPa zu stabilisieren, während die der beiden weniger angepaßten Sorten auf -2,85 bzw. -3,0 MPa abfallen. Deren geringere Anpassungsfähigkeit gegenüber Trockenstreß wird auch dadurch dokumentiert, daß sie ihr günstiges Hydraturniveau am frühen Morgen sehr schnell verlassen, während Tohono Z16 dieses über einen längeren Zeitraum noch aufrechterhalten kann.

Als wichtige Empfehlung aus diesen Ergebnissen der Studie kann herausgestellt werden, daß Tohono Z16 in das "Maize Breeding Programme" des NDFRC Katumani involviert werden sollte, da die Pflanze sehr günstige physiologische Eigenschaften für den Trockenfeldbau in den zunehmend durch Neuansiedlungen geprägten ASAL-Gebieten Kenyas aufweist.

Acknowledgements

The authors would like to thank the Director KARI (Kenya Agricultural Research Institute), NDFRC, Katumani for the provision of a field site at Kiboko. This work was funded by the Deutscher Akademische Austauschdienst (DAAD), Bonn, and the Deans Research Funds Committee of the Faculty of Arts, Kenyatta University, Kenya.

Résumé

Cette étude présente les résultats d'un test des qualités phenologique et physiologique sous les conditions d'irrigation et la cultivation sèche (par exemple besoin et consommation d'eau; résistance à la sécheresse) d'une sorte de maïs a cycle court (Tohono *O'odham* Z16), nouvelle introduite au SE du Kenya, contre les qualités de deux sortes de mais cultivé localement (Makueni Dryland Composite/MDLC, Katumani Composite B./KCB). Ces deux sortes apportent un rendement haut (HYV), mais sont aussi très sensible au sécheresse. Au premier plan on a évalué les possibilités de cultivation de cette nouvelle variété sous la condition semi-aride au SE du Kenya, aussi en vue de l'utilisation dans le "Maize Breeding Programme" du "National Dryland Farming Research Centre (NDFRC)" à Katumani/Kenya.

L'examen a rapporté, que

a) le Tohono Z16 devient avec une alimentation d'eau optimale entier mûre dans 70 jours, au contraste de 95 respectivement 110 jours pour le MDLC et le KCB;

b) MDLC et KCB ont besoin 41% respectivement 52% plus d'eau que Tohono Z16;

c) Tohono Z16 montre dans une situation de sécheresse (stress d'eau) un modèle d'adaptation morphologique et physiologique plus effective que les deux sortes de rendement haut.

De plus la variété de cycle court réussi que l'estimation du potentiel d'eau minimum du jours s'élève a environ -2,38MPa, pendant que les deux sortes moins adapter tombent sur -2,85 respectivement -3,0MPa. Leur petit souplement envers le stress sec se documente par le fait, qu'elles quittent leurs favorable niveau du potentiel d'eau tôt le matin, pendant que Tohono Z16 peux maintenir son niveau pour une période plus longes.

Comme recommandation importante de ses résultats peux etre mis en evidence, que Tohono Z16 devrais être involvé dans le „Maize Breeding Programme" du NDFRC Katumani, parce que la plante a des qualités physiologique tres favorable pour la cultivation sèche sur le territoire du ASAL au Kenya.

Resumen

En el presente estudio se someten a ensayos comparativos las propiedades fenológicas (necesidad y consumo de agua, comportamiento de potential de agua) del Tohono *O'odham* Z16, variedad de maíz de certo ci do recién introduciada en Kenia, con las de otras dos especies de alto rendimiento, cultivadas en la región, pero sensibles a condiciones climaticas adversas (Makueni DLC, Katumani Comp. B), observando su comportamiento en régimen de regradío y en régimen de precipitationes. Nuestro objectivo es la valoración de las posibilidades de culturo de esta nueva variedad en las condiciones semiáridas de Kenia, con miras a su aplicación en el "Maize Breeding Programme" del NDFRC en Katumani/ Kenia.

Las investigaciones han dado como resultado que:

a) en condiciones de agua óptimas, la variedad Tohono O'odham Z16 consiguió su plena sazón en 70 días, frente a los 95 y 110 días de los tipos Makueni DLC y Katumani Comp. B respectivamente.

b) los tipos Makueni DLC y Katumani Comp.B necestitan aproximadamente un 41% y un 52% respectivamente más de agua que la variedad Tohono Z16.

c) en situaciones de escasez de lluvia el Tohono Z 16 muestra una capacidad morfológica y fisiológica de aclimatación mucho más efectiva que los otros dos de alto rendimiento. Además la variedad de ciclo corto consigue establizar su valor mínimo diurno de potencial de agua en -2,38 MPa aproximadamente, mientras que las otras dos clases peor aclimatadas descienden a -2,85 y -3,0 MPa. La menor capacidad de adaptación de estos últimos, en época de seguía, queda asimismo documentada por el

hecho de que se aleja muy rápido de su nivel de potencial de agua muy temprano por la maZana, mientras que el Tohono Z16 puede mantenerlo por mayor tiepo.

De acuerdo con los resultados de este estudio se puede recomendar vivamente que el Tohono Z16 sea incluido en el "MBP" del NDFRC de Katumani, ya que la planta muentra unas propiedades fisiologicas muy positivas para el cultivo de secano en las cada vez más pobladfas áreas ASAL de Kenia.

References

1. ACLAND, J. D., 1971: East African crops. 1st edition, London
2. ANDERSON, E. A., 1954: Maize in Southwest. Landscape 3, 26-28
3. ARNON, I., 1992: Agriculture in drylands: Principles and practice.- (Development in Agricultural and Managed Forest Ecology, 26), Amsterdam, 3-39
4. BEGG, J. E., 1980: Morphological adaptations of leaves to water stress. In: TURNER, N.C. and KRAMER, P.J. (eds.), 1980
5. DOORENBOS, J. and PRUITT, W. O., 1977: Guidelines for predicting crop water requirements.(FAO Irrigation and Drainage Paper, 24), Rome
6. DOW, M., 1989: Issues in research and institutional development related to drought, desertification and food deficit in Africa. In: Proceedings of the International Conference on Drought, Desertification and Food Deficit in Africa, ASS, Nairobi, Kenya, 3-6 June, 30-56
7. EHRLER, W. L., IDSO, S.B., JACKSON, R. D. and REGINATO, R. J., 1978: Diurnal changes in plant water potential and canopy temperature of wheat as affected by drought. Agronomy Journal 70, 999-1004
8. FORSETH, I. N. and EHLERINGER, J. R., 1983: Ecophysiology of two solar tracking desert annuals VI. Effects of leaf orientation on calculated daily carbon gain and water use efficiency. Oecologia 58, 10-18
9. FRENKEN, G., HORNETZ, B., JAETZOLD, R. and WILLEMS, W., 1993: Actual landuse advice in marginal areas of SE-Kenya by atmosphere-ocean-teleconnection. Der Tropenlandwirt 94, 3-12
10. HARTMANN, B., 1993: Managing soil moisture with gypsum block method - An old measuring method and modern technique. Zeitschrift für Bewässerungswirtschaft 28(1), 59-72
11. HORNETZ, B., 1988: Ecophysiological experiments for improving landuse patterns in the drylands of South-East Kenya by means of drought resistant leguminous crops (Tepary beans, Bambara groundnuts). Der Tropenlandwirt 89, 107-129
12. HORNETZ, B., 1990: Vergleichende Streßphysiologie von Tepary-Bohnen als "Minor-Crop" und Mwezi Moja-Bohnen als Hochleistungsleguminose im tropischen Landbau. Journal of Agronomy and Crop Science 164, 1-15
13. HSIAO, T. C. and BRADFORD, J. K., 1983: Physiological consequences of cellular water deficits. In: TAYLOR, H. M., JORDAN, W. R. and SINCLAIR, T. R., (eds.): Limitations to efficient water use in crop production. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc., 227-256
14. IDSO, S. B., 1982: Non-water-stressed baselines: A key to measuring and interpreting plant water stress. Agricultural Meteorology 27, 59-70
15. JAETZOLD, R., 1979: Agro-climatic conditions for landuse in settlement areas East of Thika. (= Materialien zur Ostafrika-Forschung, 1), Trier
16. JAETZOLD, R. and SCHMIDT, H., 1983: Farm management handbook of Kenya. Vol.II/East Kenya, Nairobi
17. KMD (Kenya Meteorological Department), 1984: Climatological statistics for Kenya. Nairobi
18. KUTSCH, H. and SCHUH, H. J., 1983: Simplified computer-based modelling of water balance in defined crop stands. In: REINER, L. and GEIDEL, H. (eds.), 1983: Informationsverarbeitung Agrarwissenschaft, München

19. LENGA, F. K. and KEATING, B. A., 1990: Use of thermal time to predict phenology of Kenyan maize germplasm. East African Agricultural and Forestry Journal 55(3), 103-123

20. LENGA, F. K. and STEWART, J. I., 1983: Crop water requirement of beans.- (= Record of Research Annual Report 1981. Kenya Agricultural Research Institute, Agricultural Research Department), Nairobi, 27-30

21. LEVITT, J., 1972: Responses of plants to environmental stresses, New York, London

22. LUDLOW, M. M. and BJÖRKMAN, O., 1984: Paraheliotropic leaf movement in Siratro as a protective mechanism against drought-induced damage by excessive light and heat. Planta 161, 505-518

23. MCCULLOCH, J. S. G., 1965: Tables for the rapid computation of the Penman estimate of evaporation. East African Agricultural and Forestry Journal 30, 286-295

24. MIRACLE, M. P., 1966: Maize in tropical Africa. Madison, London

25. MUGAH, J. O. and STEWART, J. I., 1982: Water use of Katumani Composite B. maize as determined from climatic data. East African Agricultural and Forestry Journal 45, 92-102

26. MUSEMBI, D. K. and GRIFFITHS, J. F., 1986: The use of precipitation data to identify soil moisture patterns and the growing seasons in Eastern Kenya. Agricultural and Forest Meteorology 37, 47-61

27. NABHAN, G. P., 1986: Papago Indian desert agriculture and water control in the Sonoran desert, 1697-1934. Applied Geography 6, 43-59

28. NADAR, H. M., 1984: Matching rainfall patterns and maize growth stages under Machakos area conditions. East African Agricultural and Forest Journal 44 (Special Issue), 52-56

29. ODHIAMBO, T., 1989: Statement of the problem. In: Proceedings of the International Conference on Drought, Desertification and Food Deficit in Africa, AAS Nairobi, Kenya, 3-6 June, 1986, 16-29

30. OLUFAYO, A., BALDY, C., RUELLE, P. and KONATE, J., 1993: Diurnal course of canopy temperature and leaf water potential of sorghum (*Sorghum bicolor* L. Moench) under a Mediterranean climate. Agricultural and Forest Meteorology 64, 223-236

31. PILBEAM, C. J., DAAMEN, C. C. and SIMMONDS, L .P., 1995: Analysis of water budgets in semi-arid lands from soil water records. Experimental Agriculture 31, 131-149

32. SHARRAT, D. C., REICOSKY, S. B., IDSO, S. B. and BAKER, D. G., 1983: Relationship between leaf water potential, canopy temperature and evapotranspiration in irrigated and non irrigated alfalfa. Agronomy Journal 75, 891-894

33. SHISANYA, C. A., 1996: Chances and risks of maize and beans growing in the semi-arid areas of SE-Kenya during expected deficient, normal and above normal rainfall in the short rainy season. (Materialien zur Ostafrika-Forschung, 14), Trier

34. SORIANO, A. and GINZO, H. D., 1975: Yield responses of two maize cultivars following short periods of water stress at tasselling. Agricultural Meteorology 15, 273-284

35. TOUBER, L., 1983: Soils and vegetation of the Amboseli-Kibwezi Area. (Reconnaissance Soil Survey Report No. R6), Kenya Soil Survey, Nairobi, Kenya

36. TURNER, N. C. and KRAMER, P. J. (eds.)., 1980: Adaptation of plants to water and high temperature stress. New York

37. WILLEMS, W., 1993: El Niño und die "short rains" in SE-Kenya - Saisonale Niederschlagsvorhersage für einen Trockenraum auf der Basis eines Modells für tägliche Niederschläge. (Materialien zur Ostafrika-Forschung, 10), Trier