

# Impact of Moisture Stress on Seed Yield in Tropical Maize

**Femi Emmanuel Awosanmi**

Seed Science laboratory, Department of Crop  
Production and Protection, Obafemi Awolowo  
University, Ile-Ife, Nigeria

Corresponding author. E-mail address: cedarfem@gmail.com

**Sunday Adesola Ajayi**

Seed Science laboratory, Department  
of Crop Production and Protection,  
Obafemi Awolowo University, Ile-Ife,  
Nigeria

**Abebe Menkir**

Maize Improvement Program,  
International Institute of Tropical  
Agriculture, IITA Headquarters,  
Ibadan, Nigeria

**Abstract** – Seeds of some tropical maize genotypes were produced under irrigated and moisture-stress conditions to examine and compare variations in flowering, morphology and seed yield traits under both moisture regimes. The seeds were planted at a spacing of 0.75 m between rows and 0.25 m within rows. The experiment was laid out in a randomised complete block design with four replications during the dry season and the crops were solely dependent on irrigation. All agronomic practices were adequately carried out from planting to maturity. All flowering and yield traits were significantly ( $P < 0.01$ ) affected by moisture-stress. Silking was delayed by 5 days in the moisture-stressed plots. Percentage variation was low ( $>20\%$ ) for pollen shed, days to silking, plant stand and root lodging; medium (21-40%) for plant height, ear height, stalk lodging, ears per plant, ears harvested and moisture content; high (41-60%) for plant aspect and ear aspect; very high ( $>60\%$ ) for anthesis-silking interval, field weight, grain weight and seed yield. Expectedly, seed moisture content at harvest was lower in the moisture-stressed plots with an average of 10.37% compared to the irrigated plot which was 13.54%. Low seed yield under moisture-stress condition was attributed primarily to delay in silking, thereby prolonging the anthesis-silking interval.

**Keywords** – Genotypes, Moisture Stress, Anthesis Silking Interval, Irrigation.

## I. INTRODUCTION

Stress is an external factor that exerts a deleterious physiological influence on plants and in most cases is measured in relation to plant survival, biomass accumulation, the primary assimilation processes ( $\text{CO}_2$  and mineral uptake) or crop yield, all of which are related to overall growth [1]. Stress can be caused by inadequate moisture, high temperature, soil salinity, among others. The major factor limiting crop productivity in the world which is also the earth's most abundant compound, is water. In recent times, rainfall pattern has been erratic and unreliable resulting in drought and this has been attributed to global warming and its associated effects [2]. Consequently, the likely timing of water deficit during crop growth in any given cropping seasons has become unpredictable. The Intergovernmental Panel on Climate Change (IPCC) identified decreases in grain yields, changes in runoff and water availability in the Mediterranean and Southern countries of Africa, increased stresses resulting from increased drought and floods, and significant plant and animal species extinctions and associated livelihood impacts as the likely manifestations of climate change and variability [3].

With the continuous increase in world population, mainly in the developing countries, and given the current level of productivity and projections of climate change, the production of maize will fall far short of future demands [4]. Maize is a crop that is sensitive to moisture with an average consumptive use of 2.5-4.3 mm/day [5]. This indicates that lack of water will significantly interfere with the normal metabolism of the plant. However, the response of plants to water stress is dependent on their metabolic activities, morphology and stages of growth [6]. Generally, moisture stress restricts plant developmental events which in turn reduces plant height and leads to stunted growth. When plants experience moisture stress at the beginning of the growing season their establishment will be severely affected and supplying thereafter is probably not possible because of lack of seeds and/or the limited financial resources of smallholder farmers. On the other hand, moisture stress during vegetative development results in marked reduction in height, biomass and delayed phenology in maize [7] due to a reduction in carbon assimilation through photosynthesis and thus grain yield. This effect is further extended into the flowering and dry matter accumulation period. [8]

Noted that maize is highly susceptible to drought at flowering and early seed development and this was further corroborated by [9] who reported that drought at flowering promoted the development of the male inflorescence which ensured pollen production and dispersion, but inhibited ear and silk development. The susceptibility of maize to drought during flowering and early seed development is manifested as a lack of synchrony between silk emergence and pollen shed, which reduces the rates of sexual fertilization and decreases kernel set [10]. In another similar study, [9] observed that each day delay between pollen shed and ear pollination leads to a delay of sexual fertilisation, an increase in barren plants and a significant yield reduction. A delayed rate of leaf senescence will increase the duration of photosynthetic activity and an improved partitioning of assimilates to the ear due to reduced plant height and/or reduced tassel size, and improves floret development and seed set in maize [11] [12].

Maize yield can be reduced by as much as 90% if the crop is exposed to drought stress from a few days before tassel emergence to the beginning of grain filling [13]. In an evaluation of the performance of maize hybrids under moisture-limiting conditions, [14] noted that, days to silking, anthesis-silking interval, ears per plant and grain yield were negatively affected by moisture deficit. Water stress had little effect on timing of emergence and number

of leaves or total leaf per area per plant, but reduced the rate of leaf appearance [7]. It was also reported that moisture deficit reduced the number of ears per plant by 15% and grain yield by 40% while days to silk increased by 2% and anthesis-silking interval by 36% and less than 6% reduction in average days to anthesis, plant height, ear height, plant aspect and ear aspect [14]. The development of improved germplasm to meet the needs of future generations in light of climate change and population growth is of the utmost importance [4]. With a greater proportion of crop production in the tropics/sub-Saharan Africa being dependent on rainfall and the increasing frequency of drought as a result of climate change there is need to understand how newer cultivars of maize plants respond to drought. This study was conducted to investigate the effect of moisture stress on seed yield of some drought tolerant tropical maize genotypes.

## II. MATERIALS AND METHODS

Field trials were conducted at the International Institute of Tropical Agriculture outstation in Ikenne (latitude 6° 53' N and longitude 3° 42' E with an altitude of 60 m above sea level). The genotypes were planted in a single 3 m row with 0.75 m between rows and 0.25 m between hills. Two seeds were planted in a hill and later thinned to one after emergence to an approximate density of 53,333 plants per ha. The hybrids were arranged in a randomised complete block design with four replications. The experimental fields in the station were flat and fairly uniform. Planting was done in the dry season and the crops were completely dependent on irrigation. The field was divided into two blocks. The first block was watered adequately every week from planting till maturity while irrigation was withdrawn five weeks after planting in the second block to impose moisture stress. Weeds were controlled by applying both paraquat and atrazine at the rate of 5 l/ha of each formulation. NPK compound fertilizer at the rate of 60 kg N, 60 kg P and 60 kg K per ha was applied at four weeks after planting. Data were collected on:

- number of plants per stand (PLST) - This was determined as the number of standing plants at harvesting
- plant height (PHT) - This was measured as the distance from the base of the plant to the node bearing the flag leaf expressed in cm
- ear height (EHT) - This was measured as the distance from the base of the plant to the node bearing the upper ear expressed in cm
- number of roots lodged (RL) - This was the number of plants that fell from the root
- number of stalk lodged (SL) - This was determined as the number of plants with broken stalk below the ear or the stalk bending more than 45° from the upright position
- plant aspect (PASP) - This was scored on a 1 to 5 scale, where 1 = excellent overall phenotypic appeal and 5 = poor overall phenotypic appeal

- days to 50% pollen shed (PS) - This was obtained as the number of days from planting to when 50% of plants attained anthesis
- days to 50% silk (SK) - This was obtained as the number of days from planting to which 50% of plants showed emerged silks in a plot
- anthesis-silking interval (ASI) - This was computed as the interval in days between dates of tasseling and silking
- number of ears harvested (EHARV) - This was the number of ears counted in each plot at the time of harvest
- ear aspect (EASP) - This was scored on a 1 to 5 scale, where 1 = clean, uniform, large and well filled ears and 5 = rotten, viable, small and partially filled ears
- number of ears per plant (EPP) - This was calculated as the total numbers of ears at harvest divided by the total number of plants
- field weight (FWT) - This was obtained by weighing all ears
- grain weight (GWT) - All ears were shelled and weighed
- moisture content (MC) - The moisture content of the shelled grains was determined using the Dickey-John multi-grain digital moisture meter and was expressed in percentage; and
- seed yield (SY) - The yield per plot was adjusted to 15% moisture and the seed yield per hectare was calculated using the formula:

$$\text{Seed yield (kg/ha)} = (\text{Grain weight (kg/area (m}^2\text{))} \times (100 - \text{moisture}) / 85 \times (10000))$$

Seed yield was then converted to tons/ha by dividing by 1000.

The data collected were subjected to analyses of variance using the General Linear Model [15]. The means, ranges and standard deviations of the field and vigour traits were calculated for both treatments. The difference in the means of drought treatment relative to the irrigated condition was calculated by expressing the difference as a percentage of the mean for irrigated treatment. The sum of squares attributed to the sources of variation for all traits were expressed as percentages of the total sum of squares.

## III. RESULTS

The range of values for days to silking, anthesis-silking interval, number of ears harvested and number of ears per plant obtained for moisture-stress plots were more than twice the corresponding values for the irrigated plot (Table I). Flowering was consistently earlier in the irrigated plots than in the moisture-stressed plots. The mean minimum and maximum plant heights recorded under irrigation were 155.00 cm and 210.00 cm, respectively while the respective values under moisture-stress were 95.00 cm and 175.00 cm. Ear height was reduced under drought to an average of 64.71 cm compared to that of plants in irrigated plot which was 87.54 cm. The mean field and grain weights for the moisture-stressed plots were reduced by about five times compared to the corresponding weights for the irrigated plots. While plant stand at harvest in

moisture-stressed plots was reduced by 2.6% over the mean for irrigated plots, both plant and ear heights were reduced by about 26%. Percentage variation was low (>20%) for pollen shed, days to silking, plant stand and root lodging; medium (21-40%) for plant height, ear height, stalk lodging, ears per plant, ears harvested and moisture content; high (41-60%) for plant aspect and ear aspect; very high (>60%) for anthesis-silking interval, field weight, grain weight and seed yield. Expectedly, seed moisture content at harvest was lesser in the moisture-stress plots with an average of 10.37% compared to the irrigated plot which was 13.54%.

The analysis of variance performed for all field traits combined for irrigated and moisture-stress plots revealed that with the exception of plant stand, root and stalk lodging,  $R^2$  values for all the traits were above 65% (Table II a & b). Only anthesis-silking interval, root and stalk lodging had coefficient of variation (CV) values that were above 20. The effect of moisture-stress was highly significant ( $P < 0.01$ ) for all the traits except for plant stand and stalk lodging. The genotypic effect was significant ( $P < 0.05$ ) for nearly all the traits except plant stand and

root lodging. Similarly, genotype  $\times$  treatment interaction was significant ( $P < 0.05$ ) for all traits except plant height, ear height, root lodging and moisture content. The genotypic means were separated for the traits with significant genotypic effect (Table III) which reveals the differences in their expression under the field traits measured.

The contribution of genotype to observed variabilities in the traits was higher than that of any other source for only one trait, pollen shed (Table IV). Treatment (moisture condition) alone contributed to more than 40% of the observed variabilities in days to silking, anthesis-silking interval, plant height, ear height, field weight, number of ears per plant, number of ears harvested, ear aspect, grain weight, moisture content and grain yield. The contribution of the interaction effect of genotype and treatment was higher than 10% for only 5 out of 15 traits, namely days to pollen shed, root lodging, stalk lodging, number of ears per plant and number of ears harvested. Unaccountable sources of variation (error) contributed to over 50% of the observed variations in root and stalk lodging but not in other traits (Table IV).

Table I: Mean, range and standard deviation values of the field parameters of maize under irrigated and moisture-stress conditions

Traits	IRRIGATED				MOISTURE-STRESSED				% Variation
	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	
Days to pollen shed	56.00	65.00	<b>59.46</b>	1.90	55.00	66.00	<b>60.90</b>	2.25	2.42
Days to silking	56.00	65.00	<b>59.83</b>	2.15	56.00	73.00	<b>65.06</b>	3.12	8.74
Anthesis-silking interval	-2.00	3.00	<b>0.38</b>	0.89	0.00	9.00	<b>4.17</b>	1.98	997.37
Plant stand	9.00	15.00	<b>12.15</b>	1.05	10.00	13.00	<b>11.90</b>	0.91	2.60
Plant height	155.00	210.00	<b>179.29</b>	10.85	95.00	175.00	<b>131.88</b>	16.91	26.49
Ear height	65.00	105.00	<b>87.54</b>	7.77	40.00	85.00	<b>64.71</b>	10.12	26.08
Root lodging	0.00	0.00	<b>0.00</b>	0.00	0.00	1.00	<b>0.08</b>	0.25	-
Stem lodging	0.00	13.00	<b>0.81</b>	1.80	0.00	5.00	<b>0.56</b>	1.01	30.86
Plant aspect	1.50	3.50	<b>2.32</b>	0.52	1.50	5.00	<b>3.32</b>	0.84	-43.10
Field weight	1.20	3.40	<b>2.12</b>	0.37	0.10	0.70	<b>0.40</b>	0.15	81.13
Ear harvested	9.00	13.00	<b>11.83</b>	1.16	4.00	12.00	<b>9.08</b>	1.93	23.25
Ear aspect	1.50	3.00	<b>2.19</b>	0.37	2.00	4.50	<b>3.45</b>	0.61	57.53
Grain weight	0.93	2.48	<b>1.50</b>	0.27	0.04	0.67	<b>0.28</b>	0.13	81.33
Ears per plant	0.77	1.10	<b>0.98</b>	0.06	0.33	1.00	<b>0.78</b>	0.15	20.41
Seed yield	3.96	10.20	<b>6.26</b>	1.10	0.18	2.86	<b>1.19</b>	0.56	80.99
Moisture content	10.90	15.70	<b>13.54</b>	0.82	8.40	12.90	<b>10.37</b>	1.12	23.41

S.D. – Standard Deviation

Sources of Variation	Traits								
	PS	SK	ASI	PLST	PHT	EHT	RL	SL	PASP
Replication (df = 3)	6.05*	17.69**	3.34	3.01*	738.17**	207.02*	0.03	7.52**	0.38
Genotype G (df = 15)	17.76**	23.96**	7.25**	0.94	379.23*	217.41**	0.04	3.52**	1.84**
Treatment T (df = 1)	66.13**	875.01**	460.06**	2.00	71946.89**	16683.56**	0.22**	2.00	32.00**
G x T (df = 15)	5.08**	9.71**	4.17**	1.64*	67.99	26.07	0.04	3.75**	0.51*
Error (df = 93)	2.01	3.72	1.24	0.80	177.56	64.36	0.03	1.47	0.27
Mean	60.18	62.45	2.27	12.02	155.58	72.13	0.04	0.69	2.82
CV (%)	2.36	3.09	49.04	7.43	8.56	10.54	400.0	176.4	18.32
$R^2$ (%)	69.52	80.57	84.76	40.15	83.04	77.78	38.82	49.42	73.35

**Table IIb: Mean squares for maize yield traits combined for genotype and moisture regimes**

Sources of Variation	Traits						
	EHARV	FWT	EASP	GWT	EPP	SY	MC
Replication (df = 3)	0.51	0.12	0.07	0.05	0.00	0.69	3.22**
Genotype G (df = 15)	4.49**	0.23**	1.05**	0.14**	0.03**	2.35**	1.57*
Treatment T (df = 1)	242.00**	94.99**	50.84**	48.18**	1.34**	824.73**	322.13**
G x T (df = 15)	4.43*	0.13**	0.25*	0.07**	0.02*	1.12**	1.23
Error (df = 93)	1.98	0.05	0.14	0.03	0.01	0.45	0.74
Mean	10.46	1.26	2.82	0.89	0.88	3.73	11.96
CV (%)	13.47	16.88	13.07	18.57	11.12	18.50	7.21
R <sup>2</sup> (%)	67.16	95.99	84.83	95.30	69.60	95.43	84.40

\*P<0.05, \*\*P<0.01. PS – Pollen shed, SK – Days to silking, ASI – Anthesis-silking interval, PLST – Number of plants per stand, PHT – Plant height, EHT – Ear height, RL – Root lodging, SL – Stem lodging, PASP – Plant aspect, EHARV – Number of ears harvested, FWT – Field weight, EASP – Ear aspect, GWT – Grain weight, EPP – Number of ears per plant, SY – Seed yield, MC – Seed moisture content

**Table IIa: Mean squares for maize morphological traits combined for genotype and moisture regimes**

GEN	PS	SK	ASI	PHT	EHT	SL	PASP	EHARV	FWT	EASP	GWT	EPP	SY	MC
1	60.67	63.33	2.67	166.00	83.33	2.33	2.42	10.17	1.35	2.75	0.97	0.88	4.03	12.57
2	62.67	64.17	1.50	162.50	75.50	0.00	2.50	9.33	1.53	2.42	1.13	0.81	4.62	12.76
3	60.67	64.50	3.83	164.50	80.83	0.00	2.83	10.83	1.37	2.83	1.02	0.88	4.25	11.97
4	59.17	60.50	1.33	156.67	77.50	1.50	2.92	10.67	1.28	2.83	0.89	0.90	3.71	12.12
5	61.00	62.33	1.33	157.00	81.17	0.33	2.50	11.00	1.33	2.75	0.97	0.89	4.05	12.28
6	58.83	63.00	4.17	158.33	79.17	0.33	3.17	11.00	1.33	3.00	0.96	0.91	4.04	11.32
7	59.33	61.00	1.67	155.83	74.17	0.50	2.58	10.00	1.25	2.67	0.81	0.83	3.42	11.53
8	59.17	61.50	2.33	160.33	79.00	0.33	2.00	11.17	1.45	2.17	1.03	0.98	4.32	12.48
9	59.00	60.50	1.50	157.17	70.83	1.83	2.42	11.67	1.47	2.42	0.99	0.94	4.14	12.03
10	58.67	61.83	3.17	138.67	62.83	0.33	3.58	10.83	0.95	3.33	0.67	0.93	2.80	11.47
11	60.00	61.83	1.83	149.17	78.67	0.50	2.42	9.67	1.23	2.58	0.88	0.80	3.68	12.20
12	58.67	60.17	1.50	153.00	77.50	1.00	2.92	11.17	1.28	2.58	0.91	0.89	3.80	11.93
13	60.83	62.00	1.17	151.00	79.17	0.17	2.58	10.17	1.00	2.92	0.74	0.86	3.11	11.68
14	64.00	66.67	2.67	147.00	68.50	0.50	3.42	8.83	1.00	3.33	0.64	0.75	2.71	11.25
15	59.67	62.00	2.33	158.33	74.17	0.67	3.25	10.67	1.15	3.00	0.84	0.88	3.52	11.90
16	60.50	63.83	3.33	153.83	75.67	0.67	3.67	10.17	1.20	3.50	0.81	0.90	3.41	11.83
<b>Mean</b>	60.18	62.45	2.27	155.58	76.13	0.69	2.82	10.46	1.26	2.82	0.89	0.88	3.73	11.96
<b>LSD<sub>0.05</sub></b>	1.41	1.91	1.11	13.23	7.97	1.20	0.51	1.40	0.21	0.37	0.16	0.10	0.67	0.86

**Table III: Mean values of the field traits of the 16 maize genotypes.**
**Table IV: Percentage of the total sum of squares for maize agronomic traits measured on the field accounted for by various sources of variation**

Traits	Rep	Genotype	Treatment	G X T	Error
Days to pollen shed (days)	3.0	43.38	10.77	12.42	30.43
Days to silking (days)	2.98	20.21	49.19	8.19	19.43
Anthesis-silking interval	1.32	14.38	60.79	8.27	15.24
Plant height (cm)	2.27	5.84	73.88	1.04	16.96
Ear height (cm)	2.31	12.10	61.92	1.45	22.22
Root lodging	1.97	15.88	5.21	15.88	61.14
Stalk lodging	8.34	19.54	0.74	20.79	50.58
Plant aspect	1.21	29.63	34.29	8.22	26.65
Field weight (kg)	0.35	3.29	90.45	1.89	4.01
Ears per plant	0.23	13.06	46.05	10.31	30.58
Ear harvested	0.27	11.99	43.08	11.83	32.84
Ear aspect	0.26	18.87	61.15	4.53	15.17
Grain weight (kg)	0.26	3.84	89.35	1.85	4.71
Seed yield (t/ha)	0.23	3.83	89.56	1.82	4.57
Moisture Content (%)	2.18	5.31	72.76	4.16	15.59

#### IV. DISCUSSION

Moisture and temperature are two important climatic factors affecting crop distribution and production. As a consequence of climate variability over time, one-third of the people in Africa live in drought-prone areas and are vulnerable to the impacts of droughts [16]. Moisture-stress caused delayed flowering with its effect being progressively severe on the interdependent and sequential flowering stages - tasseling, pollen-shed (anthesis) and silking. Maize silks have high water content and depend largely on a favourable water status to emerge and grow

from the husk as earlier observed by [14]. The differences between the two treatments in the mean values for pollen-shed and silking were less than 10% because of the relatively large denominator. However, the practical and economic significance of a six-day delay in silking under moisture stress far more outweighs the seemingly low magnitude of the differences. In addition, the measures of dispersion clearly suggest that seedlots from moisture-stress plots will not be uniform because of the wide differences in the dates of silking and by inference, dates of pollination and fertilization. The 23% lower moisture content at harvest of seeds from moisture-stress plots

provided an indication that accumulation of assimilates terminated much earlier in plants growing in the moisture-stress plots and this might have been enhanced by high atmospheric temperature which alongside with drought led to early desiccation of seeds on the mother plant. Higher temperatures shortens the life cycle of grain crops resulting in a shorter grain filling period and the production of smaller and lighter grains, culminating in lower crop yields and poor grain quality [17] [18]. This is because increase in temperature is associated with higher respiration rates, shorter periods of seed formation and consequently lower biomass production [19]. [20] also reported that drought affected both the rate and length of time dry matter is accumulated in soybeans noting that the length of time is affected to a greater extent. According to [21], the physiological explanations for producing smaller seeds may be the loss of current assimilate supply due to accelerated leaf senescence, decreased sink capacity, possibly resulting from fewer cells or less cell volume, or inhibition of storage product synthesis due to premature desiccation.

The above observations on the maize plant explain the significantly four times higher seed weight and yield from irrigated plots compared with moisture-stress plots arising largely from the observed significant negative impact of moisture on productivity traits like the number of ears per plant (EPP) and number of ears harvested (EHARV). These observations were contrary to what [8] reported that number of ears per plant was not affected by moisture-stress. This was because contrary to our imposition of moisture long before flowering, [8] imposed moisture-stress on maize plants at the seed filling stage after the reproductive primordia had developed. Not only were the number of ears reduced under moisture-stress, a visual appraisal of the ears produced were rated lower than those of the irrigated produced ears in this study. The ears from moisture-stress plots were partially filled, forming nubbins, which could be attributed to poor pollination resulting from the delay in silking and poor seed set as was also reported by [22].

The genotypes showed a differential yield response to drought. The effect of moisture-stress resulted in significant reduction in seed yield suggesting that the physiological processes associated with the formation of yield is highly dependent of water status of the mother plant as [13] and [23] have earlier noted. The severe reduction in seed number and weight was largely due to accelerated leaf senescence resulting in the shortening of the seed filling period [23] [24]. The results clearly suggest that moisture-stress was the greatest single contributor to variabilities in flowering, plant and ear heights as well as yield-related traits.

## V. CONCLUSION

The role of moisture is significant in all stages of crop growth from seed germination to the production of seeds for the perpetuation of its life. In as much as there are no alternative to moisture, then, supplemental irrigation is inevitable in areas where rainfall is erratic to ensure

sustainable crop growth and food security. However, the performances of the genotypes varied under the two moisture conditions revealing the capability of some to be more tolerant than others. These can be developed and made available to farmers in drought-prone areas.

## REFERENCES

- [1] Taiz L. and Zeiger E. 2002. Plant Physiology. Third Edition. Sinauer Associates Inc. 591-593.
- [2] IITA. 2007. Doubling maize production in Nigeria in two years. [www.iita.org/cms/details/agric\\_health\\_project\\_details.aspx](http://www.iita.org/cms/details/agric_health_project_details.aspx) [Retrieved: April, 2008]
- [3] Boko, M., Niang I., Nyong A., Vogel C., Githeko A., Medany M., Osman-Elasha B., Tabo R. and Yanda P. 2007: Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.
- [4] Cairns J. E., Sonder K., Zaidi P. H., Verhulst N., Mahuku G., Babu R., Nair S. K., Das B., Govaerts B., Vinayan M. T., Rashid Z., Noor J. J., Devi P., San Vicente F. and Prasanna B. M. 2012. Maize production in a changing climate: Impacts, adaptation and mitigation strategies. *Advances in Agronomy*, Vol. 114: 1 – 58.
- [5] Maize Water Management. 2000. [Online] Available: [www.ikisan.com](http://www.ikisan.com) [Retrieved: December 2007].
- [6] Ribaut, J. M., Hoisington D. A., Deutsch J. A., Jiang C. and DeLeon D. G. 1996. Identification of quantitative trait loci under drought conditions in tropical maize I. Flowering parameters and the anthesis-silking interval. *Theor Appl Genet* 92: 905-914.
- [7] Abrecht D. G and Carberry P. S. 1993. The Influence of water deficit prior to tassel initiation on maize growth, development and yield. *Field Crops Research* 31 (1-2), 55-69.
- [8] Westgate, M. E. 1994. Water status and development of the maize endosperm and embryo during drought. *Crop Science* 34: 76-83.
- [9] Sangoi L. and Ricardo J. S. 1998. Maize susceptibility to Drought at flowering: A new approach to overcome the problem. *Ciencia Rural*, Santa Maria 28 (4): 699-706.
- [10] Bolanos J. and Edmeades G. O. 1996. The importance of the anthesis-silking interval in breeding for drought tolerance in tropical maize. *Field Crops Research* 48: 65-80.
- [11] Johnson, E. C, Fischer K. S., Edmeades G. O., Palmer A. E. F. 1986. Recurrent selection for reduced plant height in lowland tropical maize. In: Evaluation of the performance of maize hybrids, improved open-pollinated and farmers' local varieties under Irrigated and drought stress conditions, Menkir A and A.O.Akintunde. *Maydica* 46: 227-238.
- [12] Evans L.T and Fischer R. A. 1999. Yield potential: Its definition, measurement and significance. In: Evaluation of the performance of maize hybrids, improved open-pollinated and farmers' local varieties under Irrigated and drought stress conditions, Menkir A and A.O. Akintunde. *Maydica* 46 (2001): 227-238.
- [13] Nesmith D. S. and Ritchie J. T. 1992. Effects of soil water-deficits during tassel emergence on development and yield components of maize (*Zea mays* L.). *Field Crops Res.* 28: 251-256.
- [14] Menkir A and Akintunde A. O. 2001. Evaluation of the performance of maize hybrids, improved open-pollinated and farmers' local varieties under Irrigated and drought stress conditions, *Maydica* 46, 227-238.
- [15] SAS Institute. 2003. SAS/STAT Software. SAS Institute Inc., Cary, NC.
- [16] World Water Forum. 2000. The Africa Water Vision for 2025: Equitable and Sustainable Use of Water for Socioeconomic Development. UN Water/Africa, 34.
- [17] Wolfe D. W. 1995. Potential Impact of Climate change on Agriculture and food supply. Proceedings of Sustainable Development and Global Climate Change: Conflicts and Connections. A Conference sponsored by the Centre for Environmental Information, 4-5 December, 1995.

- [18] Adams R. M, Hurd B. H, Lenhart S., Leary N. 1998. Effects of global climate change on Agriculture: An interpretative review. *Climate Research*, 11: 19-30.
- [19] Amthor J. S. 1989. *Respiration and Crop Productivity*. Springer-Verlag, New York Inc.
- [20] Ron S. and Kent K. 1998. Effects of drought on Soybeans. *Drought Information*.
- [21] Wayne S. C., Javier B. and Runge E. C. A. 2004. *Corn: Origin, History, Technology and Production* [Retrieved online: [www.google.books.com](http://www.google.books.com)].
- [22] Ajayi S. A. 2003. Physiological and biochemical basis of maize seed quality. Ph.D Dissertation, Curvillier Verlag, Göttingen 143.
- [23] Abdelmula, A. A. and Sabiel, S. A. 2007. Genotypic and differential responses of growth and yield of some maize (*Zea mays* L.) genotypes to drought stress. Conference on International Agricultural Research for Development. University of Kassel-Witzenhausen and University of Gottingen, October 9-11.
- [24] De Souza O. I., Egli D. B. and Bruening W. P. 1997. Water stress during seed filling and leaf senescence in soybean. *Agronomy Journal*, 89 (5): 807 – 112.