Research Article

EFFECT OF WATER DEFICIT AT VEGETATIVE AND REPRODUCTIVE STAGES OF HYBRID, OPEN POLLINATED VARIETY AND LOCAL MAIZE (*Zea mays* L.)

S. K. Sah[1] and O. B. Zamora[2]
[1]Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal
[2] University of the Philippines at Los Baños

ABSTRACT

A pot experiment was conducted to study the effects of water deficit on vegetative and reproductive stages of Hybrid, Open pollinated (OPV) and Local varieties of maize. Water deficit at vegetative stage significantly reduced plant height, leaf area, shoot dry matter, root dry matter of the upper 25 cm depth, kernel number and grain yield per plant as compared to well watered plant. Water deficit at reproductive stage reduced more leaf area, kernel number and grain yield per plant than water deficit at vegetative stage. Water deficit at reproductive stage also reduced shoot dry matter, kernel size and harvest index. Leaf water potential and relative water content taken at 58 and 60 days after planting were also reduced by water deficit. The Local variety was taller with smaller kernel size and lower harvest index than Open pollinated and Hybrid varieties. There were no significant interactions among the varieties and water deficit treatments.

Key words: Leaf water potential, relative water content, vegetative and reproductive stages, harvest index

INTRODUCTION

Maize is the second important crop of Nepal after rice in terms of cultivated area and amount of production (CBS, 2004). Maize crop requires about 400 to 600 millimeters of water during its lifecycle (Singh, 1991). Water deficit at any growth stage reduces the growth and productivity of crops. Paudyal *et al.* (2001) identified water stress as one of the major problems of the spring season maize in most parts of Terai region of Nepal. The effect of water deficit on growth and yield depends upon time, intensity and duration of water deficit (Classen and Shaw, 1970a). It is necessary to know such effects of water deficit at different stages of crop growth in order to develop crop management strategies to minimize the risk in maize production. Therefore, this study was conducted to determine the effects of water deficit at vegetative and reproductive stages on growth and productivity of maize.

MATERIALS AND METHODS

The experiment was conducted from March to June 2003 in the Department of Agronomy, University of the Philippines at Los Baños. The experiment was laid out in two factors factorial randomized complete block design with three replications. The treatment combinations consisted of 3 levels of water stress, viz. W_1- well watered throughout the lifecycle, W_2 - water stress at vegetative stage, in which water was withheld from 32-40 days after planting (DAP), W_3 - water stress at reproductive stage, in which water was withheld from 52-60 DAP; and three varieties of maize, viz. V_1- Local variety (Tiniguib), V_2 - Open pollinated variety (IPB var 7), V_3 - Hybrid variety (IPB 911). The mean maximum temperature during crop growing period ranged from 32.3^0C to 34.9^0C and mean minimum temperature ranged from 22.1^0C to 24.5^0C. The relative humidity during crop growing period ranged from 77% to 85%. The pots were transferred to green house during rainy days. All the varieties were harvested in 95 days.

Total one hundred eight polyvinyl chloride (PVC) pots measuring 75 cm depth and 20 cm internal diameter lined with polythene sheet and filled with well pulverized soil up to brim of the pots were used in the experiment. Each pot was fertilized with 6 g complete fertilizer and 2 g urea. Each replication had four PVC pots planted with three seeds, which was thinned to one plant per pot after 15 days of planting. All pots were irrigated daily to maintain optimum moisture for 31 days. Irrigation was withheld from 32 to 40 DAP to impose water stress at vegetative stage. Similarly, irrigation was withheld from 52 to 60 DAP to impose water stress at reproductive stage. After water stress period, crop was irrigated daily to optimum moisture condition. Twenty-seven plants,

i.e. from each replication was sampled at 47 and 67 DAP for measuring plant height, leaf area, shoot dry matter and root dry matter. The remaining 54 plants, i.e. two from each replication were used for determining yield components. Leaf water potential was measured with pressure bomb apparatus in the second leaf from the youngest at 58 DAP at 10:00 hr. Leaf discs were taken at 60 DAP at 10:00 hr. to determine the relative water content of leaf.

Polythene lining with soil and roots was removed from each pot during each sampling. The soil with roots was cut with sharp knife from 0-25 cm, 25- 50 cm, and 50- 75 cm depth. The mass was passed through 2.5 mm sieve and washed with water. The extracted roots of each layer were oven dried at 60^0C for one week and dry matter of each layer was determined.

RESULTS AND DISCUSSION

Plant height

There was significant difference in plant height among the varieties (Table 1). Local variety (Tiniguib) was taller than OPV (IPB var 7) and Hybrid variety (IPB 911) at both dates of observation. The OPV was also significantly taller than Hybrid at 47 DAP.

Water stress at vegetative stage significantly reduced the plant height as compared to well-watered treatment, whereas water stress at reproductive stage did not influence the plant height significantly as compared to well-watered treatment (Table 1). The reduction in plant height is common with consistent reaction to water stress. Nesmith and Ritche (1992) also observed decline in the extension of stem and leaf, and reduction in inter nodal length of corn in response to pre- anthesis water deficit.

Leaf area

Leaf area per plant was the highest in the Hybrid variety followed by the Local variety and the OPV but it was not significantly different among the varieties at both dates of observation (Table 1). Water stress at vegetative as well as reproductive stage significantly reduced the leaf area per plant as compared to well-watered plant (Table 1). The reduction in leaf area per plant due to water stress at vegetative stage was 15% and it was 33% due to water stress at reproductive stage as compared to well-watered plants. The reduction of leaf area in response to water stress at vegetative stage is due to decrease in turgor pressure, which is necessary for cell enlargement. Acevedo *et al.* (1971) reported that elongation of maize leaves was highly sensitive to slight reduction in soil and leaf water potential. Higher reduction of leaf area per plant due to water stress at reproductive stage might be due to accelerated leaf senescence at low leaf water potential. Aparicio- Tejo and Boyer (1983) also observed accelerated leaf drying in maize due to low water potential.

Shoot dry matter

Shoot dry matter of the Local variety was significantly higher than the OPV but it was not different from the Hybrid variety at 47 DAP. Similarly, shoot dry matter of the Hybrid variety was significantly higher than the OPV but it was not different from the Local variety at 67 DAP. The shoot dry matter at harvest (95 DAP) was not significantly different among the varieties (Table 1).

Water stress at vegetative as well as reproductive stage reduced the shoot dry matter significantly as compared to well-watered plants. Final shoot dry matter at harvest (95 DAP) was also significantly reduced due to water stress at vegetative and reproductive stages. The reduction of final shoot dry matter was 17% due to stress at vegetative stage and 15% due to stress at reproductive stage as compared to well-watered plants.

Water stress influenced the height and leaf area per plant, which ultimately influenced the shoot dry matter of plants. Reductions of photosynthetic surface by water stress decreased the ability of plants to produce dry matter. This result is similar to the results obtained by Classen and Shaw (1970a).

Root dry matter

There was significant difference in root dry matter per plant among the varieties in the 25-75 cm depth but not in 0- 25 cm depth at 47 DAP. Local variety (Tiniguib) had significantly higher root dry matter per plant in 25-75 cm depth as compared to Hybrid (IPB 911) but at par with OPV (Table 2). At 67 DAP, the root dry

matter of Hybrid was higher than OPV but at par with Local variety in the 0-25 cm depth. The root dry matter of Local variety was higher than both Hybrid and OPV in 25-75 cm depth at 67 DAP. Gardner *et al.* (1985) mentioned the large genotypic difference in the rooting ability of crop. Higher root content at lower depth provides the ability of crop to survive under drought by acquiring more water.

Table 1. Effects of treatments on vegetative growth

Treatments	Plant height (cm)		Leaf area per plant (cm²)		Shoot dry matter (g)		
	47DAP	67DAP	47DAP	67DAP	47DAP	67DAP	95DAP
Varieties							
Hybrid (IPB 911)	145.00c	160.66b	3687.4a	2536.8a	68.52ab	99.65a	120.68a
OPV (IPB var 7)	161.68b	165.00b	3209.1a	2224.7a	63.29a	86.16b	120.09a
Local (Tiniguib)	180.30a	189.44a	3510.8a	2399.3a	73.28a	89.56ab	116.50a
Water Stress							
Water stress (32-40DAP)	144.90b	160.66b	3053.1b	2818.2a	54.18b	82.86b	110.87b
Water stress (52-60DAP)	170.67a	172.66ab	3738.7a	1739.1b	76.99a	85.02b	113.49b
Well watered (Control)	171.44a	181.55a	3615.6a	2603.4a	73.92a	107.5a	132.91a

Treatment means followed by common letters in column are not significantly different within varieties and water stress treatments, respectively, by LSD at 0.05

Water stress at vegetative stage significantly reduced the root dry matter per plant in 0-25 cm depth but there was no influence on root dry matter per plant due to water stress at reproductive stage (Table 2). Cruz *et al.* (1986) observed in rice that mild water stress at vegetative stage significantly reduced the total root dry matter as well as root length density. In this experiment, root dry matter per plant of stressed plant was similar to well watered plant in the lower depth. Plant generally maintains its root growth to acquire water from lower depth under water stress condition. Sharp and Davis (1979) observed significant accumulation of solutes in the root tips of un-watered plants which resulted in the maintenance of root turgor for the duration of water stress treatment. Water stress at reproductive stage did not influence the root dry matter per plant either at 0-25 cm depth or at 25-75 cm depth. When water was reapplied after stress at vegetative stage, the root dry matter per plant recovered at the second date of observation. In determinate crops, active growth of roots and leaves takes place in the vegetative stage. This might be the reason for no influence on root dry matter per plant due to water deficit at reproductive stage.

Leaf water potential (LWP) and relative water content (RWC)

LWP and RWC were taken at 58 and 60 DAP, respectively, to understand plant water condition during water deficit period. There was no difference in LWP and RWC among the varieties. Water stress at reproductive stage significantly lowered the LWP and RWC as compared to well-watered plants (Table 3). LWP and RWC were similar in well-watered plants and water stress at vegetative stage because at the time of observation both treatments were equally supplied with water.

Low LWP, which is developed due to water deficit, has been reported to decrease the leaf growth rate and leaf area development (Acevedo *et al.*, 1971), inhibit dry matter accumulation and accelerate leaf senescence (Aparicio- Tejo and Boyer, 1983), decrease photosynthesis (Westgate and Boyer, 1985), decrease the synchronization of male and female floral development (Herrero and Johnson, 1981), increase frequency of zygotic abortion (Zinselmeir *et al.*, 1995), decrease grain number, size and yield (Saini and Westgate, 2000). RWC is integrated measure of plant water status. Higher RWC is necessary for proper growth and function of plant (Blum, 1999). In the present experiment, low RWC due to water stress inhibited growth and plant function, which were reflected in lower leaf area, shoot dry matter and lower yield.

Table 2: Effect of treatments on root dry matter

Treatments	Root dry matter per plant (g)			
	47 DAP		67 DAP	
	0-25 cm depth	25-75cm depth	0-25cm depth	25-75 cm depth
Varieties				
Hybrid (IPB 911)	18.56a	5.27b	18.77a	6.43b
OPV (IPB var 7)	18.43a	6.11ab	14.31b	6.62b
Local (Tiniguib)	17.10a	7.79a	16.35ab	9.04a
Water stress				
Water stress (32 - 40 DAP)	11.37b	5.74a	17.42a	6.97a
Water stress (52 – 60 DAP)	20.65a	6.67a	17.08a	8.03a
Well watered (control)	22.07a	6.76a	14.93a	7.01a

Treatment means followed by common letters in column are not significantly different within varieties and water stress treatments, respectively, by LSD at 0.05.

Table 3: Effects of treatments on leaf water potential at 58 DAP and relative water content at 60 DAP

Treatments	Leaf Water Potential (Mpa)	Relative Water Content (%)
Varieties		
Hybrid (IPB 911)	- 1.43 a	76.61 a
OPV (IPB var 7)	- 1.46 a	79.69 a
Local (Tiniguib)	- 1.37 a	80.79 a
Water stress		
Water stress (32-40 DAP)	- 1.30 b	82.53 a
Water Stress (52- 60 DAP)	- 1.70 a	72.39 b
Well watered (Control)	- 1.26 b	82.15 a

Means followed by common letter in column are not significantly different within varieties and water stress treatments, respectively, by LSD at 0.05 level

Table 4: Effect of treatments on yield attributes and harvest index

Treatments	Kernel Per cob	100 kernel weight (g)	Grain yield per plant (g)	Harvest index
Varieties				
Hybrid (IPB 911)	184.22a	19.29a	38.68a	0.286a
OPV (IPB var 7)	185.11a	19.16a	35.56a	0.312a
Local (Tiniguib)	195.22a	14.06b	26.33b	0.224b
Water stress				
Water stress (32- 40 DAP)	191.44b	18.07a	34.89b	0.308a
Water stress (52-60 DAP)	139.33c	15.90b	22.30c	0.193b
Well watered (Control)	233.78a	18.54a	43.38a	0.321a

Means followed by common letters are not significantly different within the varieties and water stress treatments, respectively, by LSD at 0.05 level

Kernel number

Water stress treatments significantly influenced the kernel number per cob (Table 4). Water deficit at vegetative and reproductive stage reduced the kernel number per cob by 18% and 40%, respectively, as compared to well-watered plants. There was no significant difference in kernel number per cob among the varieties.

Water stress reduces the kernel number per cob well before the onset of reproductive stage. Nesmith and

Ritchie (1992) also observed a decline in kernel number per cob due to pre-anthesis water deficit. Kernel number per cob is the most sensitive to water deficit at reproductive stage. Reproductive stage drought can cause asynchrony between pollen shedding and silk emergence, and thus, results failure of pollination (Herrero and Johnson, 1981). Lower water potential at early silk emergence stage reduces the assimilate supply because of inhibition of photosynthesis, which may cause low seed number (Westgate and Boyer, 1985). It may also cause zygotic abortion (Westgate and Boyer, 1986) resulting in lower grain number per cob.

Kernel size

Hundred kernel weight was significantly different among the varieties (Table 4). The kernel size of Local variety was significantly lower than Hybrid and OPV, which did not differ significantly from each other. Water deficit at reproductive stage significantly reduced the kernel size as compared to well watered plants (Table 4). The reduction in kernel size was 14% due to water deficit at reproductive stage.

Water deficit at reproductive stage accelerates the leaf senescence, inhibits photosynthesis, reduces the assimilate supply, and thus, decreases the rate and duration of grain filling. Setter *et al.* (2001) also reported that pre-pollination and post-pollination water deficit reduce the kernel number and kernel size of the corn.

Grain yield

Grain yield per plant differed among the varieties and was affected by water deficit (Table 4). The grain yield per plant of the Local variety was significantly lower than OPV and Hybrid variety. The lower yield of Local variety was due to smaller grains and lower harvest index as compared to OPV and Hybrid variety. Water deficit at vegetative as well as reproductive stages significantly reduced the grain yield per plant as compared to well-watered plant (Table 4). The reduction was 19.5% and 48.5% due to water deficit at vegetative and reproductive stages, respectively, as compared to well watered plants. The reduction in grain yield was due to loss of grain number in vegetative stage drought, whereas it was due to less grain number and lower grain size in water deficit at reproductive stage. Classen and Shaw (1970b) also observed significant grain yield reduction (12-15%) due to water deficit at vegetative stage and 53% grain yield reduction due to water deficit at 75% silking stage.

Harvest index

The harvest index of the Local variety was significantly lower than OPV and Hybrid varieties (Table 4). The genotypic differences in harvest index exist. Traditional varieties generally have lower harvest index. Water deficit at reproductive stage significantly reduced the harvest index, whereas there was no significant difference in the harvest index between plants having water deficit at vegetative stage and well watered plants (Table 4). The lower harvest index due to drought at reproductive stage indicates less partitioning of dry matter towards the grain. Sinclair et al. (1990) reported that under moderate water stress, harvest index was stable but decreased under severe water stress, where accumulated biomass was less than about 1100 g m^{-2}.

CONCLUSIONS

Water deficit at reproductive stage was more sensitive than water deficit at vegetative stage. The reduction in grain yield per plant was higher in water deficit at reproductive stage because of higher reduction of leaf area, kernel number and kernel weight as compared to water deficit at vegetative stage.

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