African Journal of Biotechnology Vol. 5 (13), pp. 1249-1253, 3 July 2006
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2006 Academic Journals

Full Length Research Paper

Simulated flooding and drought effects on germination, growth, and yield parameters of sesame (*Sesamum indicum* L.)

J. K. MENSAH[1], B. O. OBADONI[1], P .G. ERUOTOR[2] and F. ONOME-IRIEGUNA[1]

[1]Department of Botany, Ambrose Alli University, Ekpoma, Nigeria.
[2]Department of Agronomy, Delta State University, Asaba Campus, Nigeria.

Accepted 27 March, 2006

The effects of drought on germination of sesame seeds (*Sesamum indicum* L.) also known as benniseed were simulated in the laboratory using varying concentrations of sodium chloride, glucose and polyethylene glycol at 0 – 0.50 MPa water potential. Higher osmotic conditions (0.25 – 0.50 MPa) significantly reduced the percentage germination, radical and shoot development. The ability of the three chemicals to reduce germination and seedling development in sesame was of the order: polyethylene glycol < glucose < sodium chloride. Different irrigation regimes of water were used to induce flooding and drought effects on plants cultivated in pots in a green house. Both flooding and drought resulted in stunted growth, reduced dry matter, number of leaves per plant and seed yield per plant. Prolonged flooding reduced maturity time, and induced chlorosis and floral abortion. The growth and seed yield of sesame are adversely affected by continuous flooding and severe drought.

Key words: Drought, flooding, sesame plant, osmotic tension.

INTRODUCTION

Plants respond to fluctuations in environmental stress through a number of ways which enable them adjust in order to cope with such stresses. These include anatomical, morphological or physiological responses. Water is one of the major limiting resources in the semi-arid and regions of the world, and the available water resources also determine the extent to which other resources could be developed or efficiently utilized.

One of the measurements that relate directly to plant responses to water deficit is germination of seeds in solutions of high osmotic tension. A direct and inseparable relationship is known to exist between salts such as sodium chloride, calcium chloride and potassium sulphate and water stress. Solutions of glucose and polyethylene glycol have also been used widely to provide a range of water potentials to simulate osmotic stress (Sharma, 1973; Mensah and Okpere, 2000). Williams et al. (1967) have shown that germination of pasture species decreased in the order of polyethylene glycol > sodium calcium > glucose. In the field, plants respond to water deficit by decreasing stem number/branches, internode and leaf size but increase in root mass (Hall et al., 1988). Plants also adapt to water stress through changes in leaf area, chlorophyll content and relative water content of the leaves.

Generally, the capacity to respond to stress in order to cope with such variations as encountered in the Savanna regions confers higher survival potential on the plants (Sarmientol, 1984). In these regions, some plants are exposed to frequent episodes of drought and flooding conditions. Temporary and continuous flooding of soils is very common as a result of many factors including overflowing rivers, storm, over-irrigation, seepage from irrigation channels, movement of water by impounded aquifers and impoundment of flood control dams. The

*Corresponding authors E-mail: mensahmensah@yahoo.com.

Table 1. Effects of different osmotic solutions on germination and seedling growth of sesame seed.

Parameter	Osmotic tension (MPa)	Osmotic solutions		
		Glucose	NaCl	Poly ethylene glycol
Germination (%)	0 (control)	96.6 ± 0.3	96.6 ± 0.3	97.0 ± 0.3
	0.0625	90.0 ± 0.3	98.0 ± 0.2	96.6 ± 0.2
	0.1250	88.3 ± 0.4	88.3 ± 0.4	96.6 ± 0.3
	0.2500	55.6 ± 0.4	54.0 ± 0.4	74.3 ± 0.4
	0.5000	50.0 ± 0.6	35.3 ± 0.5	70.3 ± 0.4
LSD (0.05)	-	10.8	11.4	10.2
Root length (cm)	0 (control)	1.8 ± 0.3	1.7 ± 0.4	1.8 ± 0.3
	0.0625	2.6 ± 0.4	2.8 ± 0.3	2.5 ± 0.4
	0.1250	2.0 ± 0.4	2.5 ± 0.4	2.4 ± 0.5
	0.2500	1.8 ± 0.3	1.1 ± 0.2	2.0 ± 0.3
	0.5000	0.5 ± 0.2	0.5 ± 0.1	0.75
LSD (0.05)	-	0.68	0.72	0.60
Shoot length (cm)	0 (contol)	1.8 ± 0.5	2.0 ± 0.6	2.0 ± 0.4
	0.0625	1.7 ± 0.6	2.0 ± 0.5	1.9 ± 0.4
	0.1250	1.2 ± 0.4	0.9 ± 0.3	1.8 ± 0.3
	0.2500	0.7 ± 0.3	0.6 ± 0.2	1.6 ± 0.3
	0.5000	0.0	0.00	0.0
LSD (0.05)	-	0.60	0.50	0.45

aim of the present study is to fill the gap in our knowledge about the changes in agronomic and yield parameters of sesame in respect of flooding and drought stress. The sesame plant was selected for this study because it is an important oil and protein crop, which is indigenous to the cropping system of the semi-arid region of Nigeria and other West African countries.

MATERIALS AND METHODS

Laboratory studies

Seeds of *Sesamum indicum* L. were obtained from local farmers at Agbede in Edo State, Nigeria and used in this study. Two thousand five hundred (2,500) seeds were treated with 0.2% formalin solution and then washed thoroughly to remove all traces of the chemical as a measure to sterilize the seed coat. Batches of 50 seeds each were germinated in 0, 0.065, 0.125, 0.250 and 0.500 MPa of osmotic solutions prepared from polyethylene glycol, glucose and sodium chloride in triplicates following the methods of Ashraf and Abu-Shakra (1978) giving a total of 45 treatments. The emergence of radicle from the seeds was used to score for germination (ISTA, 1976), whereas measurements of radicle and shoot length were taken from 10 day old seedlings grown in vermiculite chips saturated with the test solutions.

Field studies

The experiments were carried out from September 2000 to February 2001 in a plastic greenhouse at Ambrose Alli University, Ekpoma (6^{o}44'N, 6^{o}04'E). Earthen pots of 25 cm diameter and 15 cm height filled with sandy loam soil were used for planting. Ten seedlings of 10 day old plants were subjected to different watering regimes:

(a) Watering every day (WD)
(b) Watering every 5 days (WF)
(c) Watering every 10 days (WTD)
(d) Watering every 15 days (WTHD)
(e) Flooding to depth of 1 cm above soil level

Plants subjected to drought/water stress conditions were watered to field capacity on each irrigation day until harvest. Two sets of the flooding experiments (FL) were carried out with plants of different ages (i.e. FLI plants were initially 15 days old and FL2 plants were 30 days old). Fifty day old plants at pre-flowering stage were used for all analysis except seed yield which was determined at harvest. The parameters studied in the field were: plant height; number of leaves per plant, leaf area (LA) by the methods of Gunkel and Mulligan (1953); relative water content (RWC) (Slatyer 1960); chlorophyll content (Arnon, 1949); dry weight, number of pods/plant and 1000 seed weight.

RESULTS AND DISCUSSION

The results obtained from the laboratory experiments are presented in Table 1. All the three chemicals, namely sodium chloride, glucose and polyethylene glycol, inhibited germination under the highest osmotic tension of 0.500 MPa used in this study. For a given seed, the first increase in the level of osmotic tension reduced the germination with no effect on the seedlings that came

Table 2. Effects of water stress on some agronomic and biochemical parameters of 50-day old sesame plants.

Parameter	Watering/Irrigation Regimes						
	WD	WO	WT	WTH	FL1	FL2	LSD(0.05)
Plant height (cm)	89.4±2.4	87.1±2.5	85.5±3.2	80.1±3.2	40.6±2.6	54.8±2.7	8.9
LVS	63.0±2.1	59.2±3.0	56.5±2.1	52.8±2.1	31.7±2.1	42.6±2.2	8.5
LA (cm^2)	13.3±0.8	10.2±0.7	10.4±0.6	11.0±0.8	8.3±0.9	9.5±1.1	3.2
SDW (g)	3.6 ± 0.4	4.0 ± 0.5	3.8 ± 0.3	3.0 ± 0.2	1.4 ±0.05	2.5 ± 0.1	0.7
RDW (g)	1.3 ± 0.5	1.4 ± 0.05	1.4 ± 0.04	1.3± 0.08	1.1± 0.05	1.3± 0.10	0.6
TDW (g)	4.9 ± 0.6	5.4 ± 0.7	5.2 ± 0.6	4.3 ± 0.4	2.5 ± 0.5	3.8 ± 0.4	0.9
RWC %	79.8±0.9	77.1±1.6	79.7±0.6	66.5±1.2	55.8±1.6	64.3±0.9	10.5
TC (mg/g of leaves)	4.4 ± 0.5	4.4 ± 0.3	5.3 ± 0.6	3.6 ± 0.6	1.6 ± 0.7	2.3 ± 0.5	0.9

LVS = Number of leaves/plant
SDW = Shoot dry weight
RDW = Root dry weight
WD = Watering daily
WO = Watering every 5 days
WT = Watering every 10 days
WTH = Watering every 15 days
FL1 = Flooding of 15 day old plants
FL2 = Flooding of 30 day old plants
LA = Leaf area
TDW = Total dry weight
RWC = Relative water content
TC = Total Chlorophyll

out. The rate of germination was enhanced by sodium chloride (NaCl) at osmotic tension of 0.0625 MPa by reducing the time for germination. However, higher levels of osmotic stress delayed the emergence of the radicle and further development of the seedling, similar to the report of Maliwal and Paliwal (1970). In the present study, it has been observed that osmotic tensions of 0.0625 and 0.125 MPa do not have significant ($P < 0.05$) effects on germination. Higher osmotic tensions of 0.250 and 0.500 MPa significantly reduced the percentage germination compared to the control. The few seeds that germinated at 0.500 MPa were weak and chlorotic and did not proceed with radicle elongation and shoot development.

The sesame seeds had a higher potential to germinate in polyethylene glycol (PEG) than glucose or NaCl at higher osmotic tensions of 0.25 and 0.50 MPa. The retardation of germination by the chemicals may be due to their osmotic or ionic effects or a combination of both (Greenway and Munns, 1980). PEG and glucose are organic compounds which do not appreciably ionize in water, thus their effects are mainly osmotic. Sodium chloride on the other hand is inorganic and exerts both ionic and osmotic effects. Based on the effects of the chemicals on germination of sesame seeds, the order of their effects of retarding germination is given as NaCl > glucose > PEG. The present results are contrary to the findings of Mensah and Okpere (2000) who gave the order of potency of the three chemicals as PEG > Glucose > NaCl in peanuts. The effects of the chemicals on radicle and shoot growth recorded 10 days after planting in vermiculite chips are also shown in Table 1. The chemicals enhanced root growth at lower osmotic tension of 0.0625 MPa. However at higher osmotic tensions of 0.125 and 0.250 MPa, the radicle lengths were reduced. The effects of the chemicals on shoot length/development were uniform, with decreasing shoot length as the osmotic tension increases. At the highest tension of 0.500 MPa, no growth was recorded after the germination of the seeds.

The effects of simulated drought on sesame plant are shown in Table 2. Generally, water deficit adversely affected vegetative growth as indicated by changes in plant height, leaf area and dry weight. The results are comparable to those of Rahman et al. (2000). The decrease in plant height was proportional to the extent of drought conditions imposed on the plant. David and Park (1979) had earlier observed decreases in dry weight of *Phaseolus vulgaris* under drought conditions, which is similar to the results of this present study. Extensive investigations of the effect of water deficit on leaf area

Table 3. Effects of different irrigation regimes on yield parameters.

Parameter	Watering/Irrigation Regimes						
	WD	WO	WT	WTH	FL1	FL2	LSD(0.05)
Pods/plant	32.4±3.1	32.1±2.0	31.1±2.6	22.5±2.6	18.3±1.2	20.1±1.3	3.9
Seeds/plant	72.6±3.8	74.8±4.1	75.8±4.3	75.8±4.3	35.8±2.6	51.1±2.1	11.2
1000 seed wt (g)	2.5 ± 0.6	2.7 ± 0.3	2.7 ± 0.4	2.9 ± 0.4	2.5 ± 0.4	2.5 ± 0.3	N.S.
Yield/plant (g)	5.9 ± 0.7	6.4 ± 0.8	6.9 ± 0.7	6.9 ± 0.7	1.6 ± 0.3	4.9 ± 0.4	1.6

WD = Watering daily
WO = Watering every 5 days
WT = Watering every 10 days
WTH = Watering every 15 days
FL1 = Flooding of 15 day old plants
FL2 = Flooding of 30 day old plants

have been reported by Brouwer (1963) in *P. vulgaris* and peanuts by Rao et al. (1988). These studies had established that leaf area decreased under severe water stress and that on the removal of the stress, the rate of growth of the leaf is restored to a value comparable to that of the control. It had been recorded in the present studies (Table 2) that the leaf area decreased with increasing drought conditions.

The relative water content (RWC) of the leaves has been proposed as a better indicator of water stress than other growth/biochemical parameters of the plant (Sinclair and Ludlow, 1985). The RWC is usually higher in plants, which are adapted to dry conditions, and similar observations had earlier been reported by Carter and Paterson (1982) in soybean. Sesame plants exposed to drought maintained high RWC (Table 2) indicating that the plant is adapted to drought and hence its importance in the cropping system of the semi-arid zone of Northern Nigeria.

In the present studies, similarities and differences have been recorded in the effects that flooding and drought have on sesame plant. Due to the generation of hypoxia, flooding reduces water absorption and stomatal conductance, causing plants such as sesame to wilt in a similar way as if it is under drought conditions. The chlorophyll content of the plant has been observed to increase and remain unchanged under drought and this is similar to what was recorded by Jensen (1985) in onions. According to Poljakoff-Mayber and Gale (1975), the ability to synthesize more chlorophyll under water stress is a good measure of the species tolerance to drought. On the contrary, the chlorophyll content of the leaves under flooding was significantly (P>0.05) reduced. Furthermore, it has been observed that under flooding, the leaves of sesame plants turn yellow, senescence early and are shed, with abscission occurring in older basal leaves and subsequently in younger upper leaves. Thus, on the basis of chlorophyll content under both drought and flooding conditions, it could be inferred from the present study that sesame is drought resistant but unable to withstand flooding.

Both severe drought (watering every 15 days) and continuous flooding resulted in low yield in terms of pods/plant and seed yield/plant. Some plants did not flower at all under flooding while others showed high abortion rate of floral parts. The effects were however more prominent in 15 – day old plants subjected to flooding that 30 – day old plants. Consequently, it could be concluded that sesame plants are adversely affected by continuous flooding conditions or environments severe drought.

REFERENCES

Arnon DI. (1949) Copper Enzyme in Isolated Chloroplasts. *Plant Physiol,* 24, 1 – 5
Ashraf CM, Abu-Shakra S. (1978). Wheat Seed Germination under Low temperature and Moisture Stress. Agron. J. *70* 135 – 139.
Brouwer R. (1963). The influence of suction tension of nutrient solutions on growth, transpiration and diffusion pressure deficit on bean leaves (*Phaseolus vulgaris*) *Neerlantica* 12:248 – 267.
Carter JE Jr, Paterson RP. (1985). Use of Relative Water Content as a Selection Tool for Drought Tolerance in Soyabeans. Argon J. Abstr. ASA Madison 21:77
David JIN, Park SN. (1979). Salinity effects on leaf anatomy. *Plant Physiol.* 63: 700 – 703.
Greenway H, Munns R. (1980). Mechanism of Salt Tolerance in Non-Halophytes Annu Rev. of Plant Physiol. 31:49 – 90.
Gunkel WW, Mulligan CW. (1953). Leaf Punch for Foliage Samples. Farm Res. 193.
Hall MH, Sheaffer CC, Heichel GH (1988). Partitioning and Mobilization of Phytoassimilates in Alfalfa Subjected to water deficit. Crop Sci. 8: 879 – 1 59.
ISTA, (1976). Int. Rules for Seed Testing Assoc. Norway Seed Sci. Technol 4: 2 – 49.
Jensen A. (1985). On the Ecophysiology of *Halimieme portulacoides* In: Ecology of Coastal Vegetation (Beeflink WG, Rozema J, Huiskes, AEL, eds) Vegetation 61/62: 309 – 317.
Maliwal GL, Paliwal KV. (1970). Salt Tolerance Studies in some Varieties of Wheat and Barley at Germination Stage. Ind. J. Plant Physiol 10:26 – 35.
Mensah JK, Okpere VE. (2000). Screening of four groundnut cultivars

from Nigeria for drought resistance. Legume Res. 23: 37 – 41.

Poljakoff Mayber, Gale J. (1975). Plants in Saline Environments. Springer Verlag, Belin, 178p.

Rahman LSM, Nawata E, Sakuratoni T, Uddiu ASM. (2000). Ecological Adaptation of Chicken pea *Cicer arichnum* L. to water stress. Legume Res. 23:145 – 2000.

Rao NRC, Williams JA, Sirakumas MUK, Wadia KDR. (1988). Effects of water deficit at different growth phases of peanut. H. Responses to drought during pre-flowering phase, Agron. J. 80: 431 – 438.

Sarmiento G. (1984). The Ecology of Neo-tropical Savanna. Cambridge. Harvard University Press.

Sharma ML. (1973) Stimulation of drought and its effects on germination of five pasture species. Argon. J 68:619 – 622.

Sinclair TR, Ludlow NM. (1985) Who taught Plants thermodynamics? The unfulfilled potential of plant water potential. Aust. J. Plant Physiol. 12: 213 – 217.

Slatyer RO (1960). Aspects of the tissue water relationship of an important arid zone species *(Acacia aneura* F Muel) in comparison with two mesophytes. *Bull. Res*. Counc. Isr. Sec. D. 8: 675 – 680.

Williams TC, Snell RS, Ellis JE (1967). Methods of Measuring Drought Tolerance in Corn. Crop. Sci. 7, 179 – 182.