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Effect of Polyethylene glycol 6000, mannitol, sodium and potassium salts on the growth and biochemical characteristics of oat (*Avena sativa* L.)

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Abstract:

A study was conducted to evaluate the effects of different osmotica on a variety of oat by subjecting it to various treatments of salts of sodium and potassium and water stress (using Polyethylene glycol '6000' and Mannitol). It was observed from the study that oat variety (JHO-822) stressed osmotically when subjected to treatments with polyethylene glycol '6000' and mannitol. Both osmotic and drought stress were found to influence different aspects of metabolic processes, resulting in a decline of photosynthetic efficiency and disrupted carbohydrate metabolism. Increased shoot/root length was observed along with increased fresh/dry weight in case of PEG 5%. In 10% mannitol and 15% mannitol solution, the shoot and root length of Avena sativa L. was totally inhibited. However, at higher concentration, i.e. 0.1M NaCl, the shoot/root length as well as their fresh /dry masses shows maximum reduction compared with lower

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concentrations, i.e. 0.01M and 0.001M NaCl. Seedlings in higher concentrations, i.e. 0.1M of NaCl and 0.1M K_2O treatments show reduced contents of chlorophylls and carotenoids, whereas in lower concentration of NaCl, KCl and K_2O (0.01M and 0.001M) differences in growth were not found so obvious in this cultivar (JHO-822) of oat.

Key words: Oat Variety (JHO-822), osmotic stress/ water stress, sodium and potassium salts, chlorophyll and carotenoids

Introduction

Oat (*Avena sativa* L.) is one of the rainfed annual cereal belonging to family Poaceae. It is grown throughout the temperate zone. Oat is sown in the spring or early summer as it requires low summer heat. Water stress is known to suppress various metabolic processes in plants (Kim *et al.* 2000). Water stress reduces the amount of auxins, gibberellins, cytokinin, and raises the amount of ABA in the plant (Abdalla and El-Khoshiban 2007). Stomata remain closed in response to water stress, thereby reducing carboxylation efficiency of the chloroplasts. Water stress imposed at reproductive stage severely affects grain yield of mungbean more than its occurrence at other stages (Thomas *et al.* 2004).

Water stress decreases plant growth and productivity by slowing the rate of cell division and expansion mainly due to loss of turgor resulting in decline of the water status components of the plant cells (Kiani *et al.* 2007).Water stress results in stomatal closure which limits CO_2 entry required for photosynthesis (Zhu 2001 and Tonon *et al.* 2004). During the onset and development of salt stress within a plant, all the major processes such as photosynthesis, protein synthesis, energy and lipid metabolism are affected (Parida and Das 2005). It has been observed that growing plants in increasing NaCl stress induces increase in Na^+ and Cl^-, and decrease in

Ca^{2+}, K^{+} and Mg^{2+} levels (Heidari-Sharifabada and Mirzaie-Nodoushan 2006). Water stress is also known to cause stomatal closure and reduced transpiration rates, a decrease in the water potential of plant tissues, decrease in photosynthesis and growth inhibition, accumulation of abscissic acid (ABA), proline, mannitol, sorbitol, formation of radical scavenging compounds (ascorbate, glutathione, α-tocopherol etc.) and synthesis of new proteins and mRNA (Lichtenthaler *et al.* 1981). O_2 evolution, O_2 uptake, net CO_2 uptake and CO_2 evolution declined under water stress (Haupt-Herting *et al.* 2002).

Abiotic stresses (drought, high soil salinity, chilling, deforestation, urbanisation, climate change and agricultural malpractice) and other water stresses have been found responsible for the worldwide deterioration of plant cover and the erosion of soils and influence other growth processes in many crop plants (Boyer 1982; Kim *et al.* 2000 Sekeroglu *et al.* 1999; Ashraf and Bashir 2003).

Root has been found less affected than shoot growth under increased salinity (Munns and Termaat 1986). NaCl and PEG is known to inhibit germination and seedling growth in some cultivars of pea (*Pisum sativum*) by Okeu *et al.* (2005). NaCl considerably inhibited nitrogenase activity, nodule number and dry matter accumulation per plant in soybean (Abd- Alla *et al.* 1998). Compatible solutes such as sugars, betaines and proline are known to accumulate in plant tissues that are exposed to abiotic stresses, such as water stress, extreme temperature and salt stress thereby play an important role in plant defensive mechanisms of osmoregulation and energy preservation (Norwood *et al.* 2003; Minorsky 2003; Morsy *et al.* 2007). Application of K^{+} has been shown to improve photosynthetic rate, plant growth and yield and drought resistance in different crops under water stress conditions (Abd-

Alla and Wahab 1995; Sharma *et al.* 1996; Tiwari *et al.* 1998; Yadav *et al.* 1999; Egilla *et al.* 2001).

It is revealed from the above literature that water stress or salt stress have been found to affect the growth processes of plants thereby reduce the productivity and yield of crops. Therefore, a study entitled "An assessment of the stress-induced (using Polyethylene glycol '6000', Mannitol and Sodium Chloride) effects on the seedling growth of *Avena sativa* cultivar JHO-822" was conducted to evaluate the effects of different osmotica such as, salts of sodium and potassium, polyethylene glycol '6000' and mannitol on the variety of oat (cv. JHO-822).

Material and Methods

Avena sativa L. (oat) cultivar JHO-822 was used for the present experiments.Seeds under consideration were obtained from Indian Grassland and Fodder Research Institute, Jhansi UP. Seedlings for laboratory experiments were raised in the laboratory. Different concentrations (0.1M, 0.01M and 0.001M) of NaCl, KCl and K_2O were prepared using appropriate quantity of distilled water (30ml distilled water). 5%, 10% and 15% solution of Polyethylene glycol (PEG) 6000 and mannitol were prepared by adding 5 g, 10g, 15 g of PEG and mannitol in 100 ml of distilled water. Selected seeds of oat cultivar were surface sterilized using 0.01% mercuric chloride and washed thoroughly with running water and finally with distilled water and then allowed to germinate in different concentrations of salts, PEG and mannitol in petriplates lined with filter paper. There were three replicates for each treatment including control. After seven days of seed treatment, plant growth parameters. such as shoot/root length, shoot/root fresh weight and shoot/root dry weight were observed After seven days of stress using salts of sodium and potassium and different concentrations of PEG and mannitol, chlorophyll and

carotenoid content of seedlings were calculated. (Table 2, Fig. 2). Chlorophyll a, Chlorophyll b, total Chlorophylls and carotenoids were calculated by the method of Kirk and Allen (1965) in accordance with the equations given below:

Chlorophyll a (mg/g) = (0.0127 x A_{663}) - (0.00269 x A_{645})
Chlorophyll b (mg /g) = (0.0229 x A_{645}) - (0.00468 x A_{663})
Total Chlorophyll (mg /g) = (0.0202 x A_{645}) + (0.00802 x A_{663})
Carotenoids (mg/g/) = A_{480} + (0.114 x A_{663}) – (0.638 x A_{645}).

Results

It was revealed from the study that Polyethylene glycol (15% PEG) at higher concentration shows highest reduction of shoot length (4.526 cm) and root length (5.282 cm) followed by lower concentration of PEG 6000 i.e, PEG 10% and PEG 5%. However, shoot fresh weight showed reduction from 0.2011gm in 15% PEG to 0.390 gm in 5% PEG. Shoot dry weight (gm) and root dry weight (gm) shows similar trend as shown in shoot fresh weight (Table 1). Root fresh weight (gm) shows maximum reduction in 15% PEG as compared to control. Shoot/root length as well as their fresh/dry masses shows drastic reduction in 10% and 15% mannitol as compared to 5% mannitol . However, at higher concentration i.e,0.1M NaCl, the shoot/root length as well as their fresh /dry masses shows maximum reduction compared with lower concentrations i.e,0.01M and 0.001M NaCl.

Table 1: Shoot / Root length (cm) and fresh/dry weight (g) of Oat (*Avena sativa* L. cultivar JHO-822) seedlings under different treatments (7 DAS).

Treatments	Shoot length(cm)	Root length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
	Mean ±SE	Mean ±SE	Mean ±SE	Mean ±SE	Mean ±SE	Mean ± SE

Control	8.571 ±1.150	8.485 ±0.551	0.375 ±0.097	0.038 ±0.010	0.0532 ±0.013	0.022 ±0.0013
PEG 5%	8.041 ±0.291	7.771 ±0.407	0.390 ±0.025	0.0494 ±0.0002	0.067 ±0.0022	0.031 ±0.002
PEG 10%	6.49 ±0.218	6.184 ±0.023	0.294 ±0.077	0.035±0.008	0.0865 ±0.032	0.031 ±0.006
PEG 15%	4.526 ±0.766	5.282 ±0.584	0.2011 ±0.0318	0.028 ±0.0072	0.071 ±0.022	0.0230 ±0.0046
Mannitol 5%	3.93 ±0.083	3.66 ±0.407	0.068 ±0.018	0.0147 ±0.0043	0.020 ±0.0074	0.011 ±0.0057
Mannitol 10%	-	-	-	-	-	-
Mannitol 15%	-	-	-	-	-	-
0.1M NaCl	4.58 ±0.677	3.65 ±0.654	0.092 ±0.0150	0.010 ±0.002	0.011 ±0.0020	0.0071 ±0.0011
0.01 M NaCl	9.684 ±1.861	7.099 ±1.343	0.418 ±0.067	0.039 ±0.0067	0.052 ±0.016	0.020 ±0.0045
0.001 M NaCl	8.89 ±1.325	7.742 ±1.571	0.359 ±0.069	0.029 ±0.0021	0.094 ±0.0411	0.0184 ±0.0048

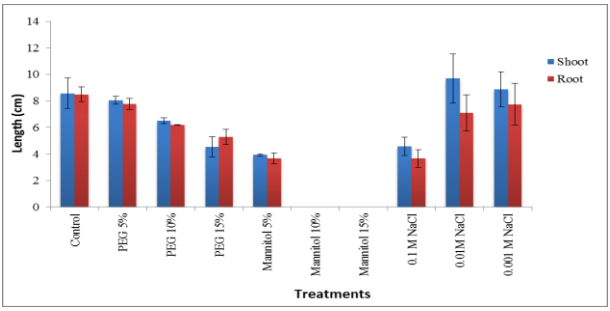

Figure 1a: Shoot/ Root length (cm) of Oat (*Avena sativa* L. cultivar JHO- 822) seedlings under different treatments (7 DAS).

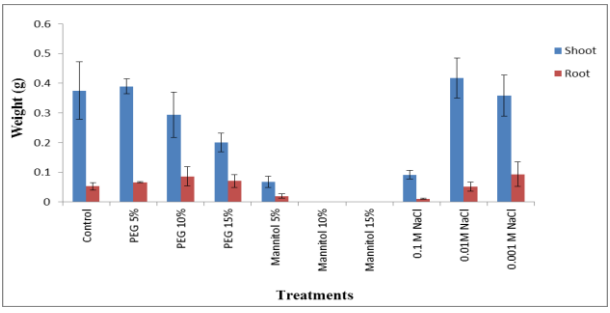

Figure 1b: Shoot/ Root fresh weight (g) of Oat (*Avena sativa* L cultivar JHO- 822) seedlings under different treatments (7 DAS).

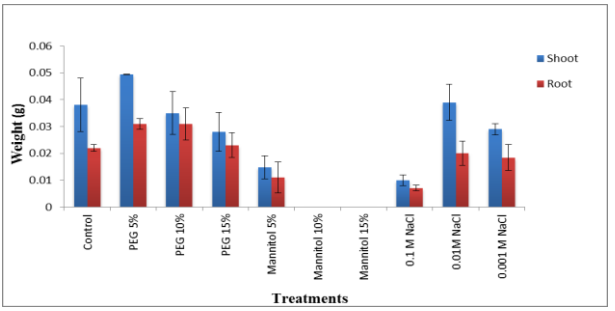

Figure 1c: Shoot/ Root dry weight (g) of Oat (*Avena sativa* L. cultivar JHO- 822) seedlings under different treatments (7 DAS).

It was revealed from the present study that Chlorophyll a, chlorophyll b, total chlorophylls and carotenoids registered an increase in 0.001M NaCl treatment (Table 2 and Figure 2). Seedlings in higher concentrations i.e. 0.1M NaCl and 0.1M K_2O treatments show reduced contents of Chlorophylls and carotenoids. However, even at low concentration of NaCl and even KCl and K_2O (0.01M and 0.001M) differences in growth are not obvious in this cultivar (JHO-822) as in the cultivars (O-9-2 and KENT) .Hence further experimentation is needed to ascertain these cultivar differences (Table 2 and Figure 2).

Table 2: Chlorophyll and Carotenoid contents in Oat (*Avena sativa* L. cultivar JHO-822) seedlings in mg/g fresh weight under different treatments (7 DAS).

Treatments	Chlorophyll a	Chlorophyll b	Total Chlorophylls	Carotenoids
	Mean ±SE	Mean ±SE	Mean ±SE	Mean ±SE
Control	0.197 ±0.0068	0.09 ±0.005	0.292 ±0.015	0.238 ±0.0043
0.1 M NaCl	0.128 ±0.0082	0.0725 ±0.0025	0.202 ±0.0077	0.156 ±0.0022
0.01 M NaCl	0.205 ±0.03	0.0715 ±0.0285	0.2955 ±0.0395	0.2385 ±0.010
0.001 M NaCl	0.254 ±0.0124	0.1018 ±0.0043	0.355 ±0.0170	0.274 ±0.025
0.1 M KCl	0.176 ±0.034	0.083 ±0.0091	0.2575 ±0.044	0.196 ±0.028
0.01 M KCl	0.15 ±0.015	0.082 ±0.0014	0.232 ±0.0139	0.174 ±0.011
0.001 M KCl	0.159 ±0.0078	0.085 ±0.0050	0.245 ±0.0127	0.2022 ±0.012
0.1 M K_20	0.129 ±0.0092	0.077 ±0.0039	0.208 ±0.013	0.182 ±0.024
0.01 M K_20	0.1886 ±0.0128	0.0914 ±0.0111	0.280 ±0.0236	0.244 ±0.0162
0.001 M K_20	0.175 ±0.010	0.1075 ±0.0255	0.2822 ±0.0367	0.165 ±0.012

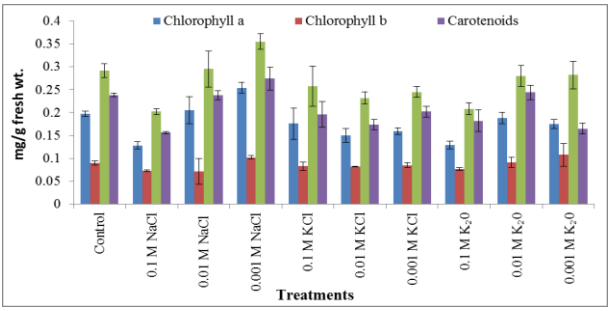

Figure 2: Chlorophyll and Carotenoid contents in Oat (*Avena sativa* L. cultivar JHO- 822) seedlings under different treatments (7DAS).

Discussion

The present study revealed that seedlings raised even under 5% mannitol treatment showed drastic reduction in growth of roots and shoots. Hence, for laboratory conditions it is better to use PEG '6000' rather than mannitol to induce water stress. Salt treatment led to decrease in root and shoot biomass, photosynthetic rate and stomata conductance, and K^+ content, and a concurrent increase in Na^+ content (Wang *et al* 2011). Salt stress might result in limited transport of essential nutrients to the shoot and net transport of K^+, Ca^{2+} ,Mg^{2+} to the shoot was lower in NaCl grown plants (Munus and Termaat 1986).. NaCl and PEG inhibited germination and seedling growth in all cultivars of Pisum sativum (Okeu *et al.* 2005). Shoot growth is more inhibited than root growth in *Phaseolus* species (Jimenez et al 2003). Significant reduction in root and shoot length, fresh and dry weight of *Lentil* plant by NaCl salinity stress (Bandeoglu *et al*. 2004). Significant reduction in fresh and dry weights of shoots and roots, root and shoot lengths of *Phaseolus vulgaris* and *Sesbania aculeate* plant under salt stress (Ashraf and Bashir 2003). It has been reported earlier drought stress decreases the content of chlorophyll a, carotenoids and total pigments (Agastian *et al*. 2000). Earlier potassium has been reported to have substantial effect on cell

elongation, osmotic potential driven water uptake and turgor driven cell expansion (Lindhauer 1989).

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