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# Germination Ecology of Two Indigenous Range Grasses Lasiurus scindicus and Panicum turgidum

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United Arab Emirates University
Deanship of Graduate Studies
M.Sc. Program in Environmental Sciences

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By

Naeema Sultan Abdullah Al-Shamisi

A thesis submitted to

United Arab Emirates University
In Partial Fulfillment of the Requirements
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2009

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2008/2009

**This work is dedicated to**

**my father & my mother**

**my husband & my children**

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# ABSTRACT

The utilization of indigenous forage species to replace the exotic ones could help in saving large amounts of water. The indigenous forage grasses *Lasiurus scindicus* and *Panicum turgidum* have been ranked among the plants that could tolerate drought during vegetative and reproductive stages and are currently being successfully used as fodders under experimental conditions in the UAE and in some parts of the world. However, there are no enough information about their dormancy and the environmental factors affecting their seed germination. In this study, the innate dormancy, light and temperature requirements, drought and salinity tolerances and the impact of dormancy regulating chemicals on seed germination of the two species were assessed. In addition, the impact of storage and maternal habitats on the dormancy and germination requirements of the two species were assessed.

Fresh seeds of *L. scindicus* were collected during May 2007 from natural populations around Al-Ain and from an experimental field station in Al-Dhaid on April 2004. Seeds of *P. turgidum* were collected from the Zaranik nature protection area in the eastern part of Lake Bardawil, Egypt. Seeds were tested for germination after collection (fresh) and after different periods and conditions of storage. Seeds were also tested in different concentrations of salinity and polyethylene glycol 6000 (PEG-6000) that produced different levels of osmotic pressures. Most of the germination experiments had been done at different temperatures and light conditions.

Seeds of *P. turgidum* showed great innate dormancy. No germination occurred for the fresh harvested seeds of *P. turgidum*. The ability of a considerable fraction of *P. turgidum* seeds to maintain dormancy ensures the buildup and persistence of a soil seed bank which is considered vital for a species in the unpredictable environments of deserts. Germination of seeds stored for five years was significantly greater in dark than in light at 15–25°C, but the

reverse was true at the higher temperatures (35 and 40°C). Salinity significantly reduced germination at 100 mM NaCl and completely inhibited it at 200 mM. Optimum germination was achieved at 30°C. Seed germination of *P. turgidum* was most salinity tolerant at 35°C. Similarly, germination rate decreased with the increase in salinity, but increased with the increase in temperature.

Fresh seeds of *L. scindicus* didn't show great innate dormancy and attained fast germination. Non-saline treated seeds of *L. scindicus* germinated well in a wide range of temperatures and in both light and dark.

Even though there was no germination occurred for *P. turgidum* seeds treated in higher salinities (200 mM NaCl and more), significant proportions of the seeds recovered their germination (about 30%) when transferred to distilled water. Overall optimal recovery germination was at moderate temperatures, compared to both lower and higher temperatures. The recovery germination from different saline solutions depended on temperature of incubation.

Seed germination of *L. scindicus* decreased with the increase in NaCl concentrations. Tolerance to salinity during germination is dependent on temperature; salinity tolerance was greater at the moderate temperatures (20-30°C), compared to both lower and higher temperatures. Germination rate decreased with the increase in salinity, but increased with the increase in temperatures. Recovery germination decreased with the increase in temperature, but decreased with the increase in salinity. Germination rate of the recovered seeds was much faster compared to saline or non-saline treated seeds.

All of the studied chemicals, except thiourea, did not succeed to improve germination of non-saline treated seeds of both *L. scindicus* and *P. turgidum*, compared to the control. The salinity-induced germination reduction in *P. turgidum* was completely alleviated by the

application of Gibberellic Acid ($GA_3$), partially alleviated by the application of fusicoccin, kinetin and thiourea, but not affected by nitrate. In *L. scindicus*, the germination inhibition was completely alleviated by fusicoccin, $GA_3$, nitrate and thiourea, but partially alleviated by kinetin. Germination was completely inhibited by the application of ethephon in the two species.

Seeds of *L. scindicus* were more drought tolerant than those of *P. turgidum*. Seeds of *L. scindicus* germinated to 30% in -0.7 MPa, while those of *P. turgidum* completely inhibited in -0.5 MPa. This indicates that the toxicity effect would be the main cause of salinity intolerance in *L. scindicus*. The lower recovery germination in the seeds of this species, compared to that of *P. turgidum*, further supports this hypothesis.

Seeds of *L. scindicus* from natural habitats germinated to higher level and rate, compared to those collected from plants grown in experimental conditions and received more watering. Seeds of the natural habitats have light brown or dark brown colors. Dormancy and germination requirements differ between the two colors.

The temperature requirements during germination differed among *P. turgidum* seeds stored for different periods.

Seeds of *L. scindicus* stored for three months germinated significantly greater at higher (20–35°C), than at lower temperature (15°C). However, after 2 years of storage, there was no difference in final germination between all temperatures.

# CHAPTER 1

# INTRODUCTION

# 1. INTRODUCTION

Environmental abiotic stress condition, especially drought and salinity, are the major factors that reduce crop yields worldwide. Salinity is an increasing problem affecting 20% of the world's cultivated land and nearly half of the area under irrigation (Sosa *et al.*, 2005). This problem is more acute in arid and semi-arid regions (Sandro *et al.*, 2006). About 9.5 billion hectares of the world's soil are saline, not including large areas of secondarily salinized soil in cultivated land. In addition, freshwater resources are becoming increasingly limited (Li *et al.*, 2005). It has become imperative under these conditions to look for plants with economic value that can grow under saline conditions (Zhao *et al.*, 2002), such as much of the Arabian peninsula ecosystems.

The Arabian Peninsula, including the United Arab Emirates (UAE), experiences some of the most extreme climatic conditions found on the Earth. It is characterized by low, erratic rainfall, high evaporation rates and amongst the highest temperatures on Earth (Boer, 1997; Zahran, 1997; Ghazanfar & Fisher, 1998). In addition, high rate of evaporation is increasing soil salinity. Over the centuries these extreme conditions have applied stringent evolutionary selection pressures resulting in a uniquely plants adapted to extreme environmental (Peacock *et al.*, 2003).

## 1.1. Importance of Indigenous Plants

A sustainable use of the natural resource of the UAE deserts requires a sustainable system for the production of cheap fodder. In the Arabian Peninsula, exotic species are now being grown for fodder, however these use large volumes of irrigation water, and the practice is not sustainable. The main fodder crops are alfalfa (*Medicago sativa*) and Rhodes grass (*Chloris gayana*). These species are not adapted to the prevailing conditions

of drought, temperature and salinity. They require vast quantities of water, which is often derived from nonrenewable ground-water sources (Peacock *et al.*, 2003). Apart from being unsustainable, production of these forages has resulted in many areas having to be abandoned due to problems of salinity. One approach to the conservation of biological diversity and the promotion of sustainable animal production is the conservation and utilization of the indigenous plant species. Indigenous plants are well adapted to harsh weather conditions and can grow with little use of water. By replacing the 'thirsty', exotic fodder species with indigenous, adapted species, it may be possible to produce fodder in a more sustainable manner. This would also reduce the grazing pressure on the rangelands and thereby protecting the delicate environment of the deserts and its valuable biodiversity. In addition to fodder production, indigenous forages may be used to enhance the productivity of rangelands through either restoration (planting or reseeding with indigenous grasses, shrubs and trees) or rehabilitation (planting or reseeding with both exotic and indigenous grasses, shrubs and trees) (Peacock *et al.*, 2003).

Peacock *et al.* (2003) have prioritized Arabian Peninsula desert species, which have potential to be used either for fodder production or for rehabilitation and restoration through the collection of indigenous knowledge, discussions with Bedouin farmers, local botanists, and published floras of the Arabian Peninsula and international consultants on rangeland development. They have selected both *Lasiurus scindicus* and *Panicum turgidum* to be among a list of high-priority species both in the UAE and in the northern part of the Sultanate of Oman.

*Panicum turgidum* Forssk (Poaceae) is a perennial grass with a widely distributed in most deserts of the Middle East and it's common and widespread in sand and gravel

habitats of the Arabian deserts, including the UAE. This species has been considered economically important because of its use: a) as a sand binder, b) as a forage plant in arid areas, and c) as a source of grains. The grains were used to be roasted for human consumption in time of drought and it also used as wound dressing (Batanouny, 2002). Williams and Farias (1972) have indicated that the grains of *P. turgidum* are eaten at the present time by the inhabitants of the Western Sahara. In addition, chemical analysis of the indigenous forages showed that *P. turgidum* has almost the same nutritive value as those for irrigated Rhodes grass. This was true for crude protein, neutral detergent fiber (which provide an indication of dry matter intake), acid detergent fiber, acid detergent insoluble nitrogen and ash (Al Hadramy *et al.*, 2000). *P. turgidum* is a remarkable drought-resistant C4 species. Established plants may survive for several years without rain. In addition, it exhibits high growth rates in late spring and summer months (Batanouny, 2002).

*Lasiurus scindicus* is a highly nutritive, drought tolerant grass (Chowdhury, *et al.*, 2009). This warm-season grass can tolerate prolonged droughts, growing in areas with annual rainfall below 150 mm (Khan and frost, 2001). *L. scindicus* has a high nutritive value and is preferentially consumed by cattle in the desert. It plays an important role in the development of good rangeland and in stabilizing the blowing sand dunes and expanding desert (Khan, 2001; Chauhan, 2003). Furthermore, *Lasiurus scindicus* has already been successfully used in major reseeding programs in desert harsh ecosystems in northern India and Pakistan (Mohammad, 1984; Yadav, 1997; Yadav & Rajora, 1999). In most of the desert rangelands, *P. turgidum* is usually found in association with *L. Scindicus* (Bokhari *et al.*, 1990).

## 1.2. Effects of Light and Temperature on Germination

It has been hypothesized that temperature is one of the most important environmental cues that stimulate seeds to germinate at the appropriate time, which enhance seedling establishment and survival (Probert, 2000). The germination is more likely to occur at a time that will favor seedling survival (Grappin *et al.*, 2000). Summer annuals usually require high temperature for germination, which is usually similar to that prevailing during the favorable period for seedling establishment and survival (spring and early summer). However, at regions that have summer rainfall, most winter annuals protect their seeds from germination during summer by requiring lower temperatures which are more likely not provided during summer. For example, the protection from late summer rains in the Australian winter annual capweed (*Arctotheca calendula*) is insured by the inability of seeds to germinate at temperature more than 30°C and through a relatively slow rate of germination (Dunbabin and Cocks, 1999).

Light is another important environmental regulatory signals that interact with temperature to regulate seed germination in many plant species (El-Keblawy and Al Rawai, 2005, El-Keblawy *et al.*, 2007, El-Keblawy and Al Shamsi, 2008). It is generally regarded that a light requirement prevents germination of seeds buried too deep for seedling to emerge because physiologically active light flux densities rarely penetrate more than a few millimeters into soil (Pons, 1992). Seeds could use the absence of light to indicate burial at some depth while light would indicate location on or near the soil surface (Milberg *et al.*, 2000). Hence, seeds requiring light will not germinate when they are buried under soil or leaf litter, but will germinate when exposed on the soil surface. Milberg *et al.* (2000) have concluded that a light requirement for germination is more likely in small than in large-seeded species and that its likely ecological role is to sense

depth of burial. On the other hand, seedlings from large seeds can emerge successfully from much greater depth than light can penetrate (e.g. Del Arco *et al.*, 1995). Therefore, light would not be an appropriate germination cue for such species.

## 1.3. Effects of Salinity and drought on Germination

Seed germination and early seedling growth are critical stages for the establishment of plant populations under saline conditions of arid regions (Khan and Gulzar, 2003). Increasing salinity leads to reduction and or delay in germination of both halophyte and glycophyte seeds (Tlig *et al.*, 2008). In addition, exposure to high salinity may lead to the priming or even the death of seeds before germination (Gorai and Neffati, 2007). Halophyte seeds can remain viable for long periods under extremely high salinity and germinate at a later time when the osmotic potential of the medium is raised (Boorman, 1968; Macke and Ungar, 1971; Ungar, 1978, 1995; Naidoo and Naicker, 1992). Glycophytic species, however, show great reduction in germination under higher levels of salinity. For example, no germination was recorded at NaCl concentrations higher than 125 mM in the annual *Zygophyllum simplex* (Khan and Ungar, 1996). Similarly, the annual glycophyte *Diplotaxis harra* germination was greatly reduced in 150 mM NaCl and completely inhibited at 200 mM NaCl (Tlig *et al.*, 2008).

Grasses are usually not very highly tolerant to salinity at germination (Khan and Ungar, 2001a), and the germination is usually inhibited at concentrations ranging from 250 to 350 mM NaCl (Lombardi *et al.*, 1998). For example, it was reported that grasses like *Panicum coloratum* (Perez *et al.*, 1998) and *P. hemitimon* (Hester *et al.*, 1998) germinate well in NaCl concentrations up to 200 mM, but halophytic grasses like *Sporobolus virginicus* (Breen *et al.*, 1997) and *Hordeum vulgare* (Badger and Ungar,

1989) germinate under salt concentration up to 350 mM. In the Arabian Sea Coast of Pakistan, halophytic grasses are relatively less tolerant to high NaCl levels during germination. *Halopyrum mucronatum* and *Sporobolus arabicus* were found to germinate in up to 200 mM NaCl (Noor and Khan, 1995; Khan and Ungar, 2001a). In addition, Khan and Gulzar (2003) studied salinity tolerance during germination in four grasses and found that few seeds of *Halopyrum mucronatum* germinated above 300 mM NaCl, while seeds of *Aeluropus lagopoides*, *Sporobolus ioclados*, and *Urochondra setulosa* germinated in up to 500 mM NaCl. In addition, salinity tolerance was low in five species of the UAE desert. Low proportions of the seeds of *Dichanthium annulatum* (5%), *Cenchrus ciliaris* (12%) and *Pennisetum divisum* (20%) were germinated in 100 mM NaCl (El-Keblawy, 2006). In addition, Seeds of *Sporobolus arabicus* and *L. scindicus* germinated to 5 and 10%, respectively, in 200 mM NaCl (El-Keblawy, 2006).

Despite most of the studies have examined salinity tolerance for halophytic grasses of the arid lands, few studies tested the germination behavior of glycophytic desert grasses. Such studies are important as big parts of the deserts are suffering from the salinity increase. In addition, some of the native grasses could be useful in reseeding the degraded arid lands, especially those affected by higher salinity, or to replace exotic plants that are currently used as fodder for animals.

It has been documented that salinity tolerance during germination depends on temperature in many halophytic species. Although higher salinity decreases germination, the detrimental effect of salinity is generally less severe at moderate temperatures in some species, such as *Atriplex triangularis* (Khan and Unger, 1984) *Crambe abyssinica*, (Fowler, 1991), *Zygophyllum simplex* (Khan and Ungar, 1996), *Urochondra setulosa* (Gulzar *et al.*, 2001), *Salsola imbricata* (El-Keblawy *et al.*, 2007), *Haloxylon salicornicum* (El-Keblawy and Al-Shamsi, 2008). However, salinity tolerance was

recorded to be lower (i.e., germination in saline solution is low) at cooler temperatures in many halophytes of Great Basin desert (e.g., *Salicornia pacifica*, Khan and Weber, 1986; *Allenrolfea accidentalis*, Gul and Weber, 1999; *Salicornia rubra,* Khan *et al.*, 2000; *Suaeda moquinii*, Khan *et al.*, 2001a), but the reverse was true in other halophytes of subtropical maritime deserts of Pakistan (*Atriplex griffithii*, Khan and Rizivi, 1994; *Haloxylon recurvum* and *Suaeda fruticosa*, Khan and Ungar, 1996; *Arthrocnemum macrostachyum* Gul and Khan, 1998). Still no studies have assessed the interactive effect of salinity and temperature on germination of glycophytes. Interaction between light and temperature under saline conditions also affects the germination of halophytic grasses (Myers and Morgan, 1989; Khan and Gulzar, 2003).

Drought has been defined as a period of below normal precipitation that limits plant productivity in a natural or agricultural system (Boyer, 1982). It is environmental stresses that adversely affect plant growth and crop. Plant responses to drought stress at the molecular, biochemical and physiological levels that have been studied extensively (Munns 2002; Verdoy *et al.*, 2004; Barnabas *et al.*, 2008). The response depends on the species and genotype, the length and severity of water loss, the age and stage of development, the organ and cell type and sub-cellular compartment (Battaglia *et al.*,2007; Barnabas *et al.*, 2008). In addition, the response of seeds to drought could be an indicator of the tolerance of plants for the later stages of development. Therefore, there have been attempts at germinating seeds under variable stress conditions to identify the populations which adapt to dryness. Polyethylene glycol 6000 solutions are frequently used for producing a range of water potentials, as they are relatively non-toxic to seeds. Seed treated with PEG 6000 inhibit germination due to osmotic effect (Emmerich and Hardegree, 1990).

## 1.4. Recovery Germination from Saline Solution

Generally salinity inhibits germination of both glycophytes and halophytes (Baskin and Baskin, 1998). It is essential for seeds that are unable to germinate at high salinity to survive during exposure and maintain the ability to germinate later, when salinity may decrease due to various environmental events. In many species of saline habitats, germination occurs when salt content of the habitat reaches its lowest level, e.g., toward the end of or after the rainy period (Ismail, 1990; Khan and Ungar, 1996; El-Keblawy, 2004). Under experimental conditions, seeds of several halophytes can recover the capacity to germinate after exposure to salt stress that inhibits their germination (Woodell, 1985; El-Keblawy, 2004; El-Keblawy and Al-Rawai, 2005; El-Keblawy and Al Shamsi, 2008).

It has been reported that seeds of several halophytes treated with higher salinities recovered their germination following their transfer to distilled water and the recovery percentage depended on species and temperature of incubation (Khan and Ungar, 1997a; Pujol *et al.*, 2000; Khan *et al.*, 2001b, El-Keblawy and Al-Rawai, 2005, El-Keblawy *et al.*, 2007, El-Keblawy and Al Shamsi, 2008). For example, seeds of *Limonium stocksii* germinated to only 5% at 500mM NaCl but to nearly 100% after they were transferred to distilled water (Zia and Khan, 2004). In the halophytic *Haloxylon salicornicum* from the UAE deserts, about 47% of the seeds presoaked in 700 mM NaCl recovered their germination at 15°C after transfer to distilled water (El-Keblawy Al-Shamsi, 2008). In addition, *Salsola imbricata*, another halophytic plant of the UAE, about 75% seeds presoaked in 400 mM NaCl recovered their germination at 15°C (El-Keblawy *et al.*, 2007).

## 1.5. Seed Dormancy and Germination Stage

In the life cycle of plants, seeds have the highest resistance to extreme environmental stresses, whereas seedlings are most susceptible, and this is especially true for desert plants (Gutterman, 1992, Kitajima and Fenner, 2000). Seed dormancy and germination are complex developmental processes that are regulated by a variety of endogenous and environmental signals.

Successful establishment of plants largely depends on germination, which greatly varies over space and time, especially in the unpredictable heterogeneous deserts of arid regions (El-Keblawy, 2003a). Germination bed, which is the top soil, shows wide seasonal and daily fluctuations of temperature, high soil moisture tension and sometime high salt content (El-Keblawy, 2004). In the top soil, dormancy reduces the risk of seedling mortality, when moisture is limited and salinity is increased (e.g., during summer). Consequently, time of germination determines the environment in which the plant will develop, and eventually it's fitness.

Seed dormancy is a temporary failure or block of a viable seed to complete germination under favourable physical conditions (Baskin and Baskin, 2004). A dormant seed does not have the ability to germinate in a specified period of time under any combination of normal physical environmental factors that are otherwise favourable for its germination. Dormant seeds can define the environmental conditions in which they are able to germinate. For example, in the desert annual *Zygophyllum simplex,* germination could occur only when temperature and salinity were reduced, but this could happen either during winter or after monsoon rain (Khan and Ungar, 1997b).

The dormancy status is influenced by both the seed maturation environment and the ambient environmental conditions following their shedding in the soil (Baskin and

Baskin, 2004). Through dormancy, germination is timed to avoid unfavourable weather for subsequent plant establishment and reproductive growth (Finch-Savage and Leubner-Metzger, 2006). On the other hand, a completely non-dormant seed has the capacity to germinate over the widest range of normal physical environmental factors possible for the genotype (Baskin and Baskin, 2004).

## 1.6. Impacts of Dormancy Regulating Chemicals

According to the revised hormone-balance hypothesis of seed dormancy (Karssen and Laçka, 1986), abscisic acid (ABA) and gibberellic acid ($GA_3$) act at different times and sites during "seed life". ABA induces dormancy during maturation and $GA_3$ plays a key role in the promotion of germination (Leubner-Metzger, 2003). There is considerable evidence that ABA is an important positive regulator of both the induction of dormancy and the maintenance of the dormant state in imbibed seeds following shedding. While dormancy maintenance also depends on high ABA:$GA_3$ ratios, dormancy release involves a net shift to increased $GA_3$ biosynthesis and ABA degradation resulting in low ABA:GA ratios (Ali-Rachedi *et al.*, 2004; Cadman *et al.*, 2006; Finch-Savage and Leubner-Metzger, 2006).

High salt concentrations are known to induce dormancy in seeds of many species (Ungar, 1978). Such dormancy could be explained by internal factors in the seeds such as the permeability of the integuments to water or oxygen, presence of inhibitors, or physiological maturity of the embryo (Khan, 1977). For example, germination inhibition after exposing seeds to high salinity may be caused by changes in the balance of various growth regulators due to high concentrations of several ions in seeds. Salinity stress usually results in imbalance in growth regulators causing an increased level of

endogenous ABA and other germination inhibitors and a decrease in endogenous growth promoters (Bewley and Black, 1994). A decline in cytokinin and gibberellic acid ($GA_3$) concentrations, which can induce changes in membrane permeability and seed water relations, has been reported to be associated with salinity stress (Kabar and Baltepe, 1989).

Fusicoccin, a diterpene glycoside and major phytotoxic substance in culture filtrates of the plant pathogen *Fusicoccin amygdale,* markedly stimulates germination, growth, and several physiological processes in plant tissues (Marre, 1979; Ballio and Scalorbi, 1981). Fusicoccin reproduces the effect of cytokinins on cell enlargement, on the extrusion of hydrogen ions, and on the trans-membrane potential in isolated cotyledons (Marre *et al.*, 1974). Fusicoccin acts like cytokinins and gibberellins in their effects on seed germination (Ballio and Scalorbi, 1981). In addition, nitrogenous compounds like nitrate and thiourea are also reported to stimulate germination of different species (Bewley and Black, 1994). Physiologically, thiourea offsets the effect of ABA and decreases the level of cytokine in plant tissues exposed to water stress due to drought, salinity, or supra optimal temperature (Kabar & Baltepe, 1989). Nitrate is also known to stimulate the germination of seeds, and it received considerable attention as possible regulator of seed germination in the soil (Egley, 1995). The mixture of nitrate and ethephon stimulated germination of *Chenopodium album* seeds (Karssen, 1976).

Kabar (1987) suggested that endogenous hormone level is affected by many environmental stresses; however, external application of appropriate growth regulator optimizes physical metabolic conditions for germination. The role of various germination regulating chemicals such as proline, betaine, gibberellin, kinetin, nitrate, thiourea and

ethephon in reducing the inhibitory effects of salinity on germination has been reported for several halophytes (Kabar, 1987; Bewley and Black, 1994; Pyler and Proseus, 1996; Gul and Weber, 1998; Khan and Ungar, 1997b, 2000, 2001 a, b, c, 2002). Different regulatory roles are suggested for these chemicals in breaking seed dormancy in halophytes. They are thought to alleviate salinity effects on the germination by: 1) substituting for light and temperature (Khan and Weber, 1986; Bewley and Black, 1994; Sutcliffe and Whitehead, 1995), 2) acting as an osmoregulator or osmoprotectants of proteins in the cytoplasm (Poljakoff-Mayber *et al.*, 1994; Gorham, 1995) and 3) counteracting the effect of reduced promoter (cytokinins and gibberellins) and increased inhibitor substances, such as abscisic acid in seeds under high salinity (Kabar and Baltepe, 1990).

It has been reported that the salinity effect on the seed germination of subtropical halophytes is not alleviated by many chemicals. For example, little or no effect of the germination regulating chemicals in alleviating germination inhibition, caused by high salinity, have been observed in *Halopyrum mucronatum, Haloxylon stocksii, Salsola imbricata, Sporobolous ioclados, Suaeda fruticosa* and *Urochondra setulosa* (see references reviewed in Khan and Gul, 2006). However, most chemicals had some effects on alleviating salinity induced dormancy on the germination of *Atriplex stocksii* and *Zygophyllum simplex*. Generally, thiourea, ethephon and fusicoccin were most effective in alleviating the salinity effects on germination, followed by $GA_3$, kinetin and nitrate (Khan and Gul, 2006).

Despite most of the studies have examined salinity tolerance and impact of dormancy regulating chemicals on halophytic grasses of the aridlands, few studies did

that with glycophytic desert grasses (El-Keblawy, 2008). El-Keblawy (2008) studied the effect of dormancy regulating chemicals on the alleviation of salinity induced dormancy in five grasses of the UAE deserts and found significant difference in the effect of the different chemicals and the response of the different species.

Generally, the different chemicals had little or no effect on alleviating germination inhibition in *Centropodia forsskalii* and *Pennisetum divisum*, but significantly alleviated it in *Tragus racemosus*, *Sporobolus spicatus* and *Eragrostis barrelieri*. The response of the different species differed for the different substances. Partial alleviation was observed in 100 mM NaCl by fusicoccin in *C. brevifolium*, by $GA_3$ and Kinetin in *P. divisum* and by $GA_3$, kinetin and thiourea in *C. forsskalii*. $GA_3$ was the most effective in alleviating the germination inhibition *E. barrelieri*. Nitrate was the most effective in *S. spicatus*, followed by fusicoccin and $GA_3$ (El-Keblawy, 2008).

## 1.7. Maternal effects on Germination

The conditions under which seeds mature on the mother plant can determine subsequent dormancy and responses of germination to environmental conditions, and consequently the fate of the next generation (Roach and Wulff, 1987; Baskin and Baskin, 1998). It has been documented that seed dormancy and germination responses vary greatly depending on maternal habitat and time of seed development and maturation on mother plants. Several studies have demonstrated that seed germination varies between populations of different species (El-Keblawy and Al-Ansari, 2000; El-Keblawy and Al-Rawai 2006; El-Keblawy *et al.*, 2009). In addition, several other studies have documented that

environmental conditions experienced by maternal plants during the growing season play a significant role in determining subsequent germination rate and responses in seeds of many species, such as *Artemisia tridentata* (Meyer and Monsen, 1991), *Spergularia marina* (Ungar, 1988), *Portulaca oleracea* (El-Keblawy and Al-Ansari, 2000), *Eruca vesicaria* (Pita Villamil *et al.*, 2002) and *Campanula americana* (Galloway, 2002).

## 1.8. Impact of Seed Storage on Germination

Primary (innate) dormancy is imposed genetically during seed maturation on the mother plant. As a general rule, at the time of natural dispersal from mother plants, innate dormancy will be expressed and germination requirements will be highly specific. In this case, environmental factors during storage will program the seeds to germinate under certain environmental cues so that germination occurs at the appropriate time (Probert, 2000). In many grass species, the dormancy level is reduced after-ripening (dry and warm storage) and stratification (cold treatment) (Schutz *et al.*, 2002, Li *et al.*, 2005). Non-dormant seeds germinate upon water uptake if they are exposed to favorable environmental conditions. Seed after-ripening is a common method used to release dormancy (Kucera *et al.*, 2007; Bair *et al.*, 2006). Generally, after-ripening decreases the ABA concentration and sensitivity and increases in $GA_3$ sensitivity or loss of $GA_3$ requirement (Li *et al.*, 2005, Kucera *et al.*, 2007). In addition, after-ripened seeds lose species-specific germination requirements, which are required for fresh harvested seeds, such as nitrate and light (Orozco-Segovia *et al.*, 2000, El-Keblawy and Al Rawai, 2006).

Temperature during after-ripening has great effect on dormancy releasing and this depend on the time of seed shedding. In summer annuals in general, low winter temperature release dormancy whereas high summer temperature induce it, while in winter annuals the reverse is true (Probert, 2000). In many species of arid and semi-arid regions, after-ripening at high temperatures during dry storage increased seed germination in several winter species that shed their seed at spring. For example, high temperature during dry storage had increased the germination percentages in eight of nine annual winter species from the Mojave and Sonoran Deserts of North America (Capon and Van Asdall, 1967). Similarly, in the Negev desert highlands, no germination occurred shortly after seed maturation of several desert annuals. Dry storage of the seeds at high temperature, similar to that prevailing in the Negev desert during summer, significantly increased the germination percentages of *Hordeum spontaneum* (Gutterman *et al., 1*996), *Shismus arabicus* (Gutterman, 1996), and *Plantago coronopus* (Gutterman *et al.*, 1998).

## 1.9. Objectives of the Study

The economic importance of *Lasiurus scindicus* and *Panicum turgidum* as fodders and as potential plants for reseeding the degraded deserts necessitate more data collection, especially on factors affecting germination and reducing its requirements. Such studies are particularly important because of the lack or scarcity of the important factors affecting dormancy and germination of the two species, such as light, salinity and temperature and the interaction between these factors. The aims of present study for *L. scindicus* and *P. turgidum* were to:

(1) Define the kind and level of innate dormancy and determine the most appropriate methods for breaking this dormancy.

(2) Define the most appropriate temperature and light conditions for the germination stage.

(3) Evaluate the salinity and drought tolerances for seeds during germination stage.

(4) Determine the effects of some successful dormancy regulating compounds (gibberellic acid, kinetin, thiourea, nitrate, ethophon and fusicoccin) in alleviating germination inhibition induced by higher salinity levels.

(5) Assess the effects of storage conditions and periods on germination behavior and dormancy loss.

# CHAPTER 2

# MATERIALS & METHODS

# 2. MATERIALS AND METHODS

## 2.1. The Study Area

The UAE cover an area of about 83, 000 $km^2$ lying at the Southwestern tip of the Arabian Peninsula between 22°50' and 26°N and 51° and 56°E to the west lies the Arabian Gulf and Qatar; to the north an enclave of Oman facing the Strait of Hormuz; to the east the Gulf of Oman and the Sultanate of Oman; and to the south the Rub al Khali, or Empty Quarter of Arabia (Western, 1989). Seeds of the present study were collected from both Al-Ain (24°44′N, 55°46′E and 306 m a.s.l.) and Al-Dhaid (25° 16′ N, 55°53′ E).

## 2.2. Climate of the UAE

The Arabian Peninsula, including the UAE, is predominated by a dry hot climate. Generally the climate of the UAE is classified as hyperarid. Within the country, there are different bioclimatic zones. In the north-eastern areas (where Al-Dhaid is located), there are higher mean precipitation, and lower temperatures, in comparison with the central (where Al-Ain is located), southern and the western region, which are characterized by low mean precipitation (Böer, 1997).

Along a narrow coastal strip, climatic conditions are slightly less extreme, especially towards the north-east. Arid to semi-arid conditions occur in the Hajar Mountains in the far east of the country. Generally, the temperature in the UAE is very high during the summer (May to October), it varies between 41 and 50°C. Winter are cooler (around 13°C), but even at night, temperature below 5°C are uncommon (Brown & Sakkir, 2004). Mean annual temperature is about 27°C (Böer, 1997).

Humidity is significantly variable from place to place, but it is generally higher in coastal areas. Average maximum humidity is 97% and the average minimum is 20.6% (Climatological Data, 1993).

Rainfall varies considerably throughout the Emirates, but the long-term annual mean is about 90 mm for most of the area. Slightly higher precipitation amounts are received towards the mountains in the east, with a mean of about 100 mm in Al-Ain (Böer, 1997; Jorgensena and Al-Tikiriti, 2003). Rainfall occurs mainly in the winter months, but is possible at any time of the year.

## 2.3. Climate of the Egypt

Seeds of *P. turgidum* were collected from the Zaranik nature protection area in the eastern part of Lake Bardawil (31°03' N, 33°30' E), on the Mediterranean coast of the Sinai Peninsula, Egypt. The landscape is broken by huge sand dunes and salt marshes. The Lake Bardawil climate is arid, according to Emberger's degree of aridity (Shaheen, 1998). The rainy season extends from October to May and the average amount of precipitation is 82 mm/yr, but it is highly variable (Zahran & Willis, 1992). The mean temperature is 14°C in winter and 32°C in summer. Monthly mean relative humidity varies between 68% and 74% with an annual mean of 72%.

## 2.4. Studied Species

### 2.4.1 *Lasiurus scindicus*

*Lasiurus Scindicus* Henrard is perennial grass of the family of *Poaceae*; locally know as "dúayy". It is native to many regions all over the world, such as Africa, India, Pakistan and the Arabian Peninsula. In the UAE, *L. scindicus* is widely distributed in low dunes of northern emirates as well as around the road-sides in the inland deserts of Al Ain (Jongbloed, 2003). *L. scindicus* has woody base with single or branched stems, grows up to 100cm tall. Leaves are few, rolled or flat, linear or hair-like, with rim of hairs at insertion. Inflorescence is solitary, terminal spike reach to 1cm, 2 flowered in pairs or trios, hairy (Batanouny, 2002). *L. scindicus* is flowering in February to June. The young leaves and shoots are very palatable; even in the dry state it; is still eaten by camels and goats (Batanouny, 2002).

### 2.4.2 *Panicum Turgidum*

*P. turgidum* Forssk, is another member of the family *Poaceae.* It is a perennial grass with woody deep fibrous root system and reaches a height of 100-150cm. "Thamam" is the local name for *P. turgidum* in the UAE (Jongbloed, 2003). Leaves of *P. turgidum* are linear to lance-shaped, flat, with pointed tip, rim of fine hairs at insertion. The vegetation growth is very rapid. Within a few weeks following precipitation, it produces abundant, palatable biomass. During the reproductive period, the spikelets on older branches mature and seed is scattered by the desert wind, while younger branches continue producing spikelets. Flowering is variable, usually from February to June (Batanouny, 2002).

Due to its palatability and the high nutrient and protein contents, the grains of *P. turgidum* were roasted for human consumption in time of drought and are used as wound dressing (Al- Hadramy *et al.*, 2000, Batanouny, 2002). In addition, this species is one of the most important range plants in the UAE because of its palatability and the high nutrient and protein contents (Al-Hadramy, 2000).

*P. turgidum* is a drought-resistant C4 plant, which exhibits high growth rates in late spring and summer months (Batanouny, 2002). In addition, El-Keblawy (2003b) indicated that *P. turgidum* is grazing tolerant as buds on the rhizomes under the soil surface are protected from grazers.

## 2.5. Seed Collections

Fresh seeds of *L. scindicus* were collected during May 2007 from natural populations growing around the sides of Al-Ain–Dubai highway of the UAE. In addition, seeds of *L. scindicus* were collected from an experimental field station in Al-Dhaid on April 2004. Seeds of *P. turgidum*, however, were hard to collect from natural habitats of the UAE because of overgrazing. Consequently, seeds of this species were collected from the Zaranik nature protection area in the eastern part of Lake Bardawil (31°03' N, 33°30' E), on the Mediterranean coast of the Sinai Peninsula, Egypt during July 2002 and 2006.

Spikes were threshed to separate caryopses (hereafter termed seeds) by using a hand-made rubber thresher. Seeds were randomly collected from the whole population to represent the genetic diversity of the population. Seeds of the two species were dry stored in brown paper bags at room temperature until their use in the germination.

## 2.6. Germination Experiment

Germination was conducted using 90 mm plastic Petri dishes containing one disk of Whatman No.1 filter paper moistened with 10 ml distilled water or tested salinity levels. For each treatment, four replicates, each with 20-25 seeds, were used. In the salinity, dormancy relieving substances and drought experiments, each dish was placed in a larger plastic Petri dish and then wrapped by Para film stripes as an added precaution against loss of water by evaporation. Radical emergence was the criterion for germination. Germinated seedlings were counted and removed every second day for 20 days following seeds sowing. Dishes wrapped in aluminum foil (during dark treatment) were opened after 20 days (at the end of the experiment).

## 2.7. Effects of Light, Temperature and Salinity

To evaluate the effects of light and temperature requirement on germination of *Panicum turgidum* and *Lasiurus scindicus*, their seeds were germinated in six incubators set at 15, 20, 25, 30, 35 and 40°C in both continuous light and darkness. The dishes were wrapped in aluminum foil to prevent any exposure to light (during dark treatment).

In order to evaluate salinity tolerance and the interaction between salinity tolerance and both light and temperature of incubation, seeds of the two species germinated in different NaCl concentrations solutions in the above-mentioned temperatures in both continuous light and in darkness. The saline solutions were 0 (distilled water), 100, 200, 300 and 400 mM NaCl for *P. turgidum* and 0, 50, 100, 150 and 200 mM NaCl for *L. scindicus*. The salinity levels were selected based on a preliminary experiment tested the salinity tolerance of the two

studied species. Seeds of *L. scindicus* used in this experiment were stored for one month, but seeds of *P. turgidum* were stored for five years.

After 14 days, ungerminated seeds were transferred to distilled water in order to test their ability to retain viability under saline conditions. Germinated seedlings were counted and removed every alternative day for 10 days. The germination recovery index was calculated as reported by Khan *et al.*, (2000):

$$\text{Recovery percentage} = (a-b)/(c-b)*100$$

where "a" is the total number of seeds germinated after being transferred to distilled water, "b" is the total number of seeds germinated in saline solution, and "c" is the total number of seeds.

## 2.8. Effects of Dormancy Regulating Chemicals

The effects of six different dormancy regulating chemicals (DRC) on the innate dormancy as well as salinity induced dormancy of the two studied species were assessed by using six DRS and the abovementioned concentrations of NaCl. The studied DRC were fusicoccin (5 μM), gibberellic acid (3 mM), kinetin (0.5 mM), nitrate (20 mM), thiourea (10 mM) and ethephon (10 mM). Seeds were germinated in a growth chambers set at the most appropriate temperature for each species (25 and 30°C, for *L. scindicus* and *P. turgidum*, respectively) under continuous light condition.

## 2.9. Effect of Fruit Color and Maternal Habitat on Germination of *Lasiurus scindicus*

Seeds of *L. scindicus*, which were collected from natural habitat of Al-Ain, were separated according to their color into light brown and dark brown seeds. However, seeds of the same species collected from Al Dhaid had only the light brown color. In order to assess the impact of seed color on both light and temperature requirements, seeds of the two colors from the Al-Ain natural population were germinated in six incubators set at 15, 20, 25, 30, 35 and 40°C in both continuous light and darkness. Similarly, the impacts of maternal habitat on light and temperature requirements were assessed by germinating seeds from the Al-Ain natural population and Al Dhaid experimental field station under the above mentioned conditions.

## 2.10. Effect of Seed Storage

Seeds of *L. scindicus* collected from Al Ain natural population were divided into five groups. Seeds of one group were germinated immediately after collection (within 2–10 days, will be referred to as fresh seeds). Seeds of the other four groups were put into 4cm x 6 cm mesh bags. The bags were stored (1) in room temperature, (2) at freezer (-4°C, hereafter will be called cold storage), (3) in oven adjusted at 40°C (±2°C), hereafter will be called warm storage and (4) on soil surface of a field site, which is similar to the place of seed storage in the field, as seeds are retained inside their spikes.

Seeds of the different storage conditions were tested for germination after 4, 7 and 12 months of storage, except seeds of the field storage tested only after 4 and 7 months. Seeds were germinated in an incubators adjusted at 30°C and continuous light. In order to assess the

impact of storage on temperature requirement, seeds stored for two years at room temperatures were germinated in 5 incubators adjusted at 15, 20, 25, 30 and 35°C in continuous light. There were no enough seeds to test the impact of light requirement. In addition, there were no seeds available to do the same test on seeds stored at the other conditions.

Seed of *P. turgidum* collected from the Egyptian population in July 2006 were tested for germination immediately after collection and after one and two years. In order to assess the impacts of storage on light and temperature of incubation, germination was tested in 6 incubators adjusted at 15, 20, 25, 30, 35 and 40°C in continuous light and in darkness.

## 2.11. Drought experiment

The impact of drought on seed germination was assessed by using different concentrations of polyethylene glycol 6000 (PEG-6000) that produced different levels of osmotic pressures. The osmotic pressures that used for *P. turgidum* were 0, -0.2 and -0.5 MPa and those that used for *L. scindicus* were 0, -0.2, -0.5, -0.7 and -1.0 MPa (Michel and Kaufman, 1973). Seeds were germinated at 25°C in continuous light.

## 2.12. Calculations and Statistical Analysis

### 2.12.1. Calculation of germination rate

The rate of germination was estimated using a modified Timson index of germination velocity = $\Sigma G/t$, where "G" is the percentage of seed germination at 2d intervals and "t" is the total germination period (Khan and Ungar, 1984). The maximum value possible using this index

with my data was 1000/20=50. The higher the index value, the more rapid was the germination.

### 2.12.2. Statistical analysis

A three-way analysis of variance (ANOVA) was carried out to demonstrate the effects of the main factors (salinity, light, temperature) and their interactions on the final germination percentage of the two species. The same test was carried out to examine the effects of fruit color on light and temperature and their interactions on the final germination percentage of *L. scindicus*. Three-way ANOVA was also carried out to demonstrate the effects of maternal habitat, temperature and light and their interactions on final germination percentage of *Lasiurus scindicus*. In addition, three-way ANOVA was performed to assess the impact of storage period, and temperature and light of incubation and their interactions on final germination of *P. turgidum* seeds.

Two-way ANOVAs were performed to evaluate the effect of salinity and temperature on germination rate and the effect of light and temperature on germination percentage of non-saline treated seeds of the two species. The same test was performed to evaluate the effect of fruit color and temperature of incubation and their interactions on germination rate of *L. scindicus* seeds. Two-way ANOVA was used also to evaluate the effects of maternal habitat and temperature of incubation on germination rate of *L. scindicus* seeds. In addition, Two-way ANOVAs were performed to evaluate the effect of salinity and dormancy regulating chemicals on final germination and germination rate of the two species. Furthermore, two-way ANOVA was performed to assess the impact of storage period and temperature of incubation and their interactions on final germination of *P. turgidum* seeds. The same test was

used to evaluate the impact of storage period and storage condition on final germination and germination rate of *L. scindicus* seeds.

One-way ANOVAs were performed at each salinity treatment to assess both the effect of the concentrations of the different DRCs and the difference between the four DRCs. The same test was done when significant interaction between factors were found. Tukey least significant range (LSR) tests were used to determine the significance between the means at probability level equal 0.05. The germination percentages were arcsine transformed to meet the assumptions of ANOVA. This transformation improved normality of the distribution of the data. All the statistical methods were performed using SYSTAT, version 11.

# CHAPTER 3

# RESULTS

# 3. RESULTS

## 3.1. Effect of Salinity, Temperature and Light on Final Germination Percentage of *P. turgidum*

### 3.1.1 Effects on final germination

Non saline treated seeds of *P. turgidum* germinated well in a wide range of temperatures and in both light and dark. The germination of these seeds was significantly lower at extreme temperatures (15, 35 and 40°C), compared to moderate temperatures (20–30°C). Germination in dark was significantly greater than in light at 15–25°C, but the reverse was true at the higher temperatures (35 and 40°C) (Figure 1).

Results of three-way ANOVA indicated that the effects of the three main factors (salinity, temperature and light of incubation) significantly affected final germination percentage of *P. turgidum* seeds ($P<0.001$, Table 1). Generally, salinity significantly reduced germination in 100 mM NaCl and completely inhibited it in 200 mM. The germination decreased from 52.3% in non-saline treated seeds to only 17% in 100 mM NaCl. Optimum germination was achieved at 30°C (21.9%) and germination decreased with the increase or decrease from that temperature. The lowest germination was at both 15 and 40°C (5.8 and 5.5%, respectively). Overall germination in dark (15.7%) was significantly greater than it in light (12.3%, Table 2).

The interaction between salinity and temperature was significant, indicating that salinity tolerance depended on temperature ($P<0.001$, Table 1). Seed germination of *P. turgidum* was most salinity tolerant at 35°C. This was evident by comparing the final germinations in non-saline treated seeds (control) and in 100 mM NaCl at the various

temperatures. For example, at 15°C, germination was 28.8% in control, but completely inhibited in 100 mM NaCl. Similarly, the germination in the control was greater than in 100 mM NaCl by 270%, 210%, 180% and 690% at 20, 25, 30, and 40°C, respectively, but only by 30% at 35°C (Table 2, Figure 1).

Three-way ANOVA indicated that the interaction between salinity, light and temperature of the incubation was significant ($P<0.001$, Table 1). In control, despite germination in dark was significantly greater than in light at the lower temperatures (15–25°C), the reverse was true at higher temperatures (35 and 40°C). For example, the germination in dark was greater than in light by 42%, 47.6%, 45.7% at 15, 20 and 25°C, respectively, but germination in light was greater than in dark by 22.2% and 100% at 35 and 40°C. In 100 mM NaCl, however, germination in dark was greater than in light at all the temperatures, so the differences were lower at higher temperatures (Table 2 and Figure 1).

### 3.1.2. Effects on germination rate

Salinity and temperature has significant effects on germination rate of *Panicum turgidum* seeds ($P<0.001$, Table 3). Generally, germination rate decreased with the increase in salinity. Germination rate index decreased from 35.9 for non-saline treated seeds to 30.7 in 100 mM NaCl. Germination rate increased with the increase in temperature for non-saline treated seeds. In 100 mM NaCl, however, germination rate index decreased at 40°C, compared to that at lower temperatures (20–35°C) (Table 4, Figure 2).

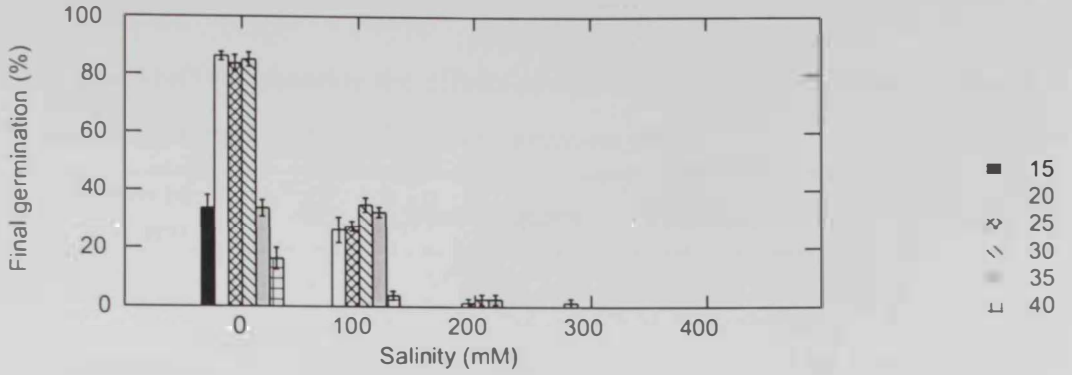
Table 1: Results of three-way ANOVA showing the effects of salinity, temperature, light and their interactions on final germination percentages in of *Panicum turgidum* seeds.

| Source of variation | df | MS | F-ratio | P |
|---|---|---|---|---|
| Salinity (S) | 4 | 3.049 | 2501.94 | <0.001 |
| Temperature (T) | 5 | 0.267 | 218.89 | <0.001 |
| Light (L) | 1 | 0.126 | 103.52 | <0.001 |
| S*T | 20 | 0.155 | 126.81 | <0.001 |
| S*L | 4 | 0.044 | 36.295 | <0.001 |
| T*L | 5 | 0.033 | 26.68 | <0.001 |
| S*T*L | 20 | 0.022 | 18.08 | <0.001 |
| Error | 180 | 0.001 | | |

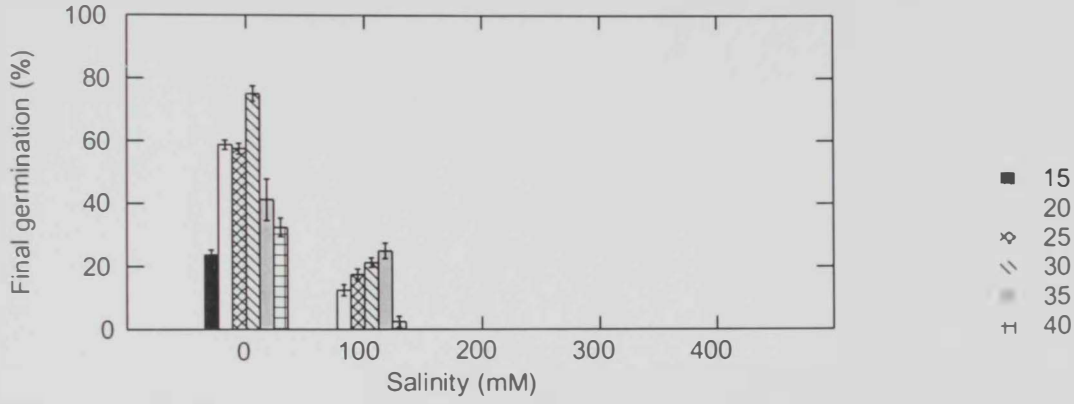
Table 2: Effects of salinity, temperature and light of incubation on final germination percentage (mean ± standard error) of *Panicum turgidum* seeds

| Salinity | Light | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| Control | Light | 23.8 ± 1.3 | 58.8 ± 1.3 | 57.5 ± 1.4 | 75.0 ± 2.0 | 41.3 ± 5.5 | 32.5 ± 2.5 | 48.1 ± 3.8 |
| | Dark | 33.8 ± 3.8 | 86.3 ± 1.3 | 83.8 ± 2.4 | 85.0 ± 2.0 | 33.8 ± 2.4 | 16.3 ± 3.1 | 65.5 ± 6.1 |
| | Overall | 28.8 ± 2.6 | 72.5 ± 5.3 | 70.6 ± 5.1 | 80.0 ± 2.3 | 37.5 ± 3.1 | 24.4 ± 3.6 | 52.3 ± 3.6 |
| 100 | Light | 0.0 ± 0.0 | 12.5 ± 1.4 | 17.5 ± 1.4 | 21.3 ± 1.3 | 25.0 ± 2.0 | 2.5 ± 1.4 | 13.1 ± 2.0 |
| | Dark | 0.0 ± 0.0 | 26.3 ± 3.8 | 27.5 ± 1.4 | 35.0 ± 2.0 | 32.5 ± 1.4 | 3.8 ± 1.3 | 20.8 ± 3.5 |
| | Overall | 0.0 ± 0.0 | 19.4 ± 3.2 | 22.5 ± 2.1 | 28.1 ± 2.8 | 28.8 ± 1.8 | 3.1 ± 0.9 | 17.0 ± 1.9 |
| 200 | Light | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| | Dark | 0.0 ± 0.0 | 0.0 ± 0.0 | 1.3 ± 1.3 | 2.5 ± 1.4 | 2.5 ± 1.4 | 0.0 ± 0.0 | 1.0 ± 0.4 |
| | Overall | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.6 ± 0.6 | 1.3 ± 0.8 | 1.3 ± 0.8 | 0.0 ± 0.0 | 0.5 ± 0.2 |
| 300 | Light | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| | Dark | 0.0 ± 0.0 | 1.3 ± 1.3 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.2 ± 0.2 |
| | Overall | 0.0 ± 0.0 | 0.6 ± 0.6 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.1 ± 0.1 |
| 400 | Light | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| | Dark | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| | Overall | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Overall | Light | 4.8 ± 2.2 | 14.3 ± 5.2 | 15.0 ± 5.1 | 19.3 ± 6.7 | 13.3 ± 4.0 | 7.0 ± 3.0 | 12.3 ± 1.9 |
| | Dark | 6.8 ± 3.2 | 22.8 ± 7.7 | 22.5 ± 7.4 | 24.5 ± 7.6 | 13.8 ± 3.7 | 4.0 ± 1.6 | 15.7 ± 2.4 |
| | Overall | 5.8 ± 1.9 | 18.5 ± 4.6 | 18.8 ± 4.5 | 21.9 ± 5.0 | 13.5 ± 2.7 | 5.5 ± 1.7 | |

(a) Dark germination




(b) Light germination




(c) Overall light and dark germination

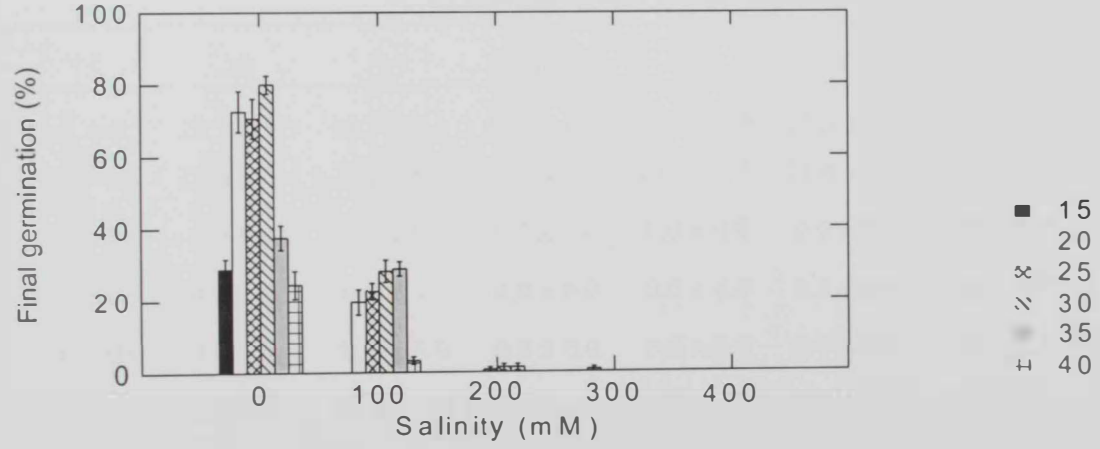



Figure 1: Effects of salinity, temperature (°C) and light of incubation on final germination percentage (mean ± standard error) of *Panicum turgidum* seeds

Table 3: Two-way ANOVA showing the effects of salinity and temperature of incubation on germination rate index of *Panicum turgidum* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity | 1 | 0.621 | 17.955 | <0.001 |
| Temperature | 5 | 0.426 | 12.313 | <0.001 |
| Error | 32 | 0.035 | | |

Table 4: Effects of salinity and temperature of incubation on germination rate index (mean ± standard error) of *Panicum turgidum* seeds

| Salinity | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 35 | 40 | |
| Control | 21.1 ± 0.7 | 29.7 ± 1.5 | 38.9 ± 1.1 | 41.2 ± 0.6 | 41.8 ± 0.9 | 42.6 ± 3.1 | 35.9 ± 1.7 |
| 100 | 0.0 ± 0.0 | 23.5 ± 3.4 | 28.6 ± 0.0 | 34.1 ± 3.1 | 39.8 ± 1.3 | 21.4 ± 7.1 | 30.7 ± 2.3 |
| 200 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| 300 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| 400 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Overall | 21.1 ± 0.7 | 26.6 ± 2.1 | 36.8 ± 2.2 | 37.6 ± 2.0 | 40.8 ± 0.8 | 35.5 ± 5.2 | 33.9 ± 1.4 |

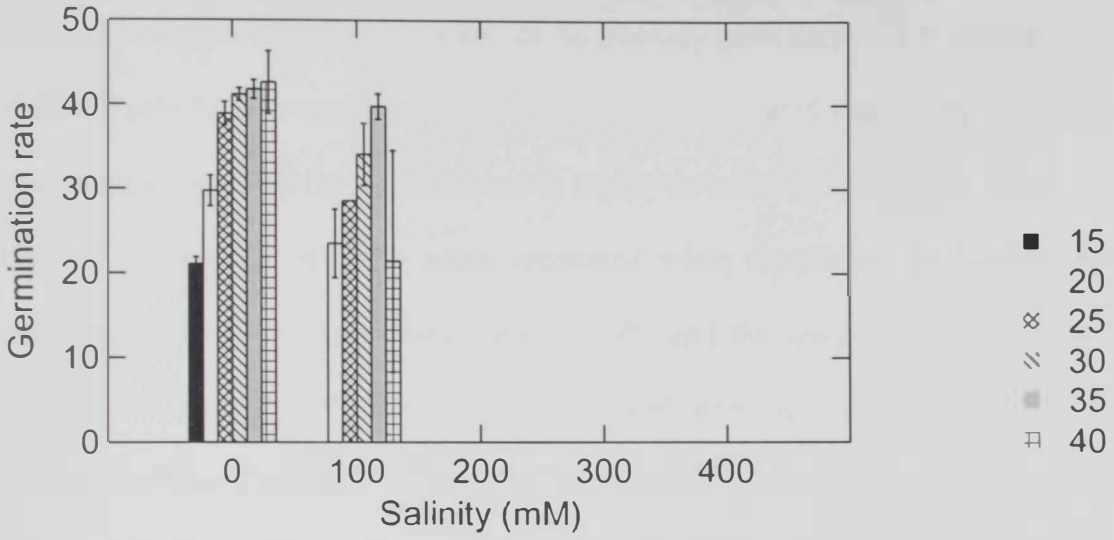



Figure 2: Effects of salinity and temperature (°C) of incubation on germination rate index (mean ± standard error) of *Panicum turgidum* seeds

## 3.2. Effects of Salinity, Temperature and Light on Recovery Germination of *P. turgidum*

### 3.2.1. Effects on final germination

After transferring non-germinated seeds to distilled water, salinity, temperature and light and their interactions had significant effects on recovery germination of *P. turgidum* seeds ($P<0.001$, Table 5). No recovery occurred for non-saline treated seeds. Despite there was no germination occurred for seeds treated in higher salinities (200 mM NaCl and more), significant proportions of these seeds recovered when transferred to distilled water. Overall optimal recovery germination was at 20°C and the lowest recovery was at low (15°C) as well as high (40°C) temperatures. Recovery germination decreased from 38.3% at 20°C to 21.1% and 12.4% at 15 and 40°C, respectively. Overall recovery germination in dark (33.4%) was significantly greater than it in Light (24.6%, Table 6).

The interaction between salinity and temperature was significant ($P<0.001$, Table 5), indicating that the recovery of *P. turgidum* seeds from different saline solution depended on temperature of incubation. Recovery germination was about two folds greater in 100 mM NaCl at 15°C compared to higher salinities (200, 300 and 400 mM NaCl). However, at all other temperatures (20--40°C), there were no significant differences in germination recovery between the different salinities (Table 6 and Figure 3).

The interaction between light and temperature on recovery germination was significant ($P<0.001$, Table 5), indicating that the response of recovery germination at the different temperatures of incubation depended on light of incubation. Recovery germination in dark was greater than in light at all temperatures, except at 40°C, where the reverse was true. The recovery germination in dark was greater than in light by 65 %, 50

%, 43 %, 34 % and 23% at 15, 20, 25, 30 and 35°C, respectively, but recovery germination in light was greater than in dark by, 19 % at 40°C (Table 6).

The interaction between salinity, temperature and light was significant ($P<0.001$, Table 5). In 100- 300 mM NaCl, germination in dark was greater than it in light at all temperatures, except at 40°C, as the reverse was true. In 400 mM NaCl, however, germination in dark was greater than in light at all temperatures (Table 6, Figure 3).

### 3.2.2. Effects on germination rate

There was no effect of salinity on recovery germination rate ($P>0.05$).The effect of temperature, however, was highly significant ($P<0.001$, Table 7). At all salinity levels, recovery germination was significantly lower at 15°C, compared to the other higher temperatures (20– 40°C, Table 8, Figure 4).

Table 5: Results of three-way ANOVA showing the effects of salinity, temperature, light and their interactions on germination recovery of *Panicum turgidum* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity (S) | 4 | 0.851 | 415.263 | <0.001 |
| Temperature (T) | 5 | 0.281 | 136.913 | <0.001 |
| Light (L) | 1 | 0.339 | 165.329 | <0.001 |
| S*T | 20 | 0.030 | 14.572 | <0.001 |
| S*L | 4 | 0.022 | 10.678 | <0.001 |
| T*L | 5 | 0.027 | 13.224 | <0.001 |
| S*T*L | 20 | 0.006 | 2.783 | <0.05 |
| Error | 180 | 0.002 | | |

Table 6: Effects of salinity, temperature and light of incubation on recovery germination percentage (mean ± standard error) of *Panicum turgidum* seeds previously imbibed in various concentrations of NaCl and then transferred to distilled water

| Salinity | Light | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| 100 | Light | 27.5 ± 3.2 | 28.7 ± 2.7 | 25.7 ± 2.9 | 30.1 ± 2.8 | 30.3 ± 4.2 | 12.8 ± 1.5 | 25.9 ± 1.7 |
| | Dark | 42.5 ± 1.4 | 49.3 ± 3.0 | 43.1 ± 3.2 | 38.7 ± 3.7 | 27.6 ± 3.0 | 9.1 ± 1.3 | 35.0 ± 3.0 |
| | Overall | 35.0 ± 3.3 | 39.0 ± 4.3 | 34.4 ± 3.8 | 34.4 ± 2.7 | 29.0 ± 2.4 | 11.0 ± 1.2 | 30.5 ± 1.8 |
| 200 | Light | 13.8 ± 2.4 | 32.5 ± 2.5 | 28.8 ± 2.4 | 27.5 ± 1.4 | 27.5 ± 2.5 | 16.3 ± 1.3 | 24.4 ± 1.6 |
| | Dark | 22.5 ± 1.4 | 41.3 ± 3.1 | 40.5 ± 2.1 | 39.8 ± 2.7 | 40.9 ± 2.4 | 10.0 ± 2.0 | 32.5 ± 2.7 |
| | Overall | 18.1 ± 2.1 | 36.9 ± 2.5 | 34.6 ± 2.7 | 33.7 ± 2.7 | 34.2 ± 3.0 | 13.1 ± 1.6 | 28.4 ± 1.7 |
| 300 | Light | 13.8 ± 2.4 | 30.0 ± 2.0 | 31.3 ± 2.4 | 30.0 ± 2.0 | 31.3 ± 2.4 | 15.0 ± 2.0 | 25.2 ± 1.8 |
| | Dark | 20.0 ± 2.0 | 45.6 ± 2.1 | 42.5 ± 1.4 | 40.0 ± 2.0 | 40.0 ± 2.0 | 11.3 ± 1.3 | 33.2 ± 2.8 |
| | Overall | 16.9 ± 1.9 | 37.8 ± 3.2 | 36.9 ± 2.5 | 35.0 ± 2.3 | 35.6 ± 2.2 | 13.1 ± 1.3 | 29.2 ± 1.7 |
| 400 | Light | 8.8 ± 1.3 | 31.3 ± 3.8 | 31.3 ± 1.3 | 28.8 ± 2.4 | 28.8 ± 2.4 | 10.0 ± 2.0 | 23.1 ± 2.2 |
| | Dark | 20.0 ± 2.0 | 47.5 ± 1.4 | 41.3 ± 3.1 | 37.5 ± 1.4 | 36.3 ± 2.4 | 15.0 ± 2.0 | 32.9 ± 2.5 |
| | Overall | 14.4 ± 2.4 | 39.4 ± 3.6 | 36.3 ± 2.5 | 33.1 ± 2.1 | 32.5 ± 2.1 | 12.5 ± 1.6 | 28.0 ± 1.8 |
| Overall | Light | 15.9 ± 2.1 | 30.6 ± 1.3 | 29.2 ± 1.2 | 29.1 ± 1.0 | 29.4 ± 1.4 | 13.5 ± 1.0 | 24.6 ± 0.9 |
| | Dark | 26.3 ± 2.6 | 45.9 ± 1.4 | 41.8 ± 1.2 | 39.0 ± 1.2 | 36.2 ± 1.8 | 11.3 ± 1.0 | 33.4 ± 1.3 |
| | Overall | 21.1 ± 1.9 | 38.3 ± 1.7 | 35.5 ± 1.4 | 34.0 ± 1.2 | 32.8 ± 1.3 | 12.4 ± 0.7 | |

Table 7: Three-way ANOVA showing the effects of salinity and temperature of incubation on recovery germination rate index of *Panicum turgidum* seeds.

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity | 3 | 0.011 | 1.99 | ns |
| Temperature | 5 | 0.260 | 49.2 | <0.001 |
| Error | 85 | 0.005 | | |

ns = insignificantly difference at P≤ 0.05

Table 8: Effects of salinity and temperature on recovery germination rate index (mean ± standard error) of *Panicum turgidum* seeds

| Salinity | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 35 | 40 | |
| 100 | 33.1 ± 2.3 | 48.6 ± 0.7 | 47.7 ± 1.6 | 49.4 ± 0.6 | 46.4 ± 1.6 | 40.8 ± 6.1 | 44.5 ± 1.5 |
| 200 | 31.2 ± 2.1 | 48.1 ± 0.3 | 27.1 ± 2.1 | 49.6 ± 0.4 | 44.4 ± 1.1 | 42.4 ± 5.9 | 41.7 ± 2.0 |
| 300 | 25.9 ± 0.9 | 49.0 ± 0.6 | 43.8 ± 3.2 | 49.7 ± 0.3 | 47.9 ± 0.6 | 48.8 ± 1.3 | 45.0 ± 1.8 |
| 400 | 25.0 ± 0.0 | 48.2 ± 0.5 | 32.5 ± 15.8 | 49.0 ± 0.4 | 48.1 ± 0.8 | 50.0 ± 0.0 | 44.8 ± 2.2 |
| Overall | 29.6 ± 1.3 | 48.5 ± 0.3 | 40.1 ± 3.5 | 49.4 ± 0.2 | 46.7 ± 0.6 | 45.8 ± 2.1 | 43.4 ± 0.9 |

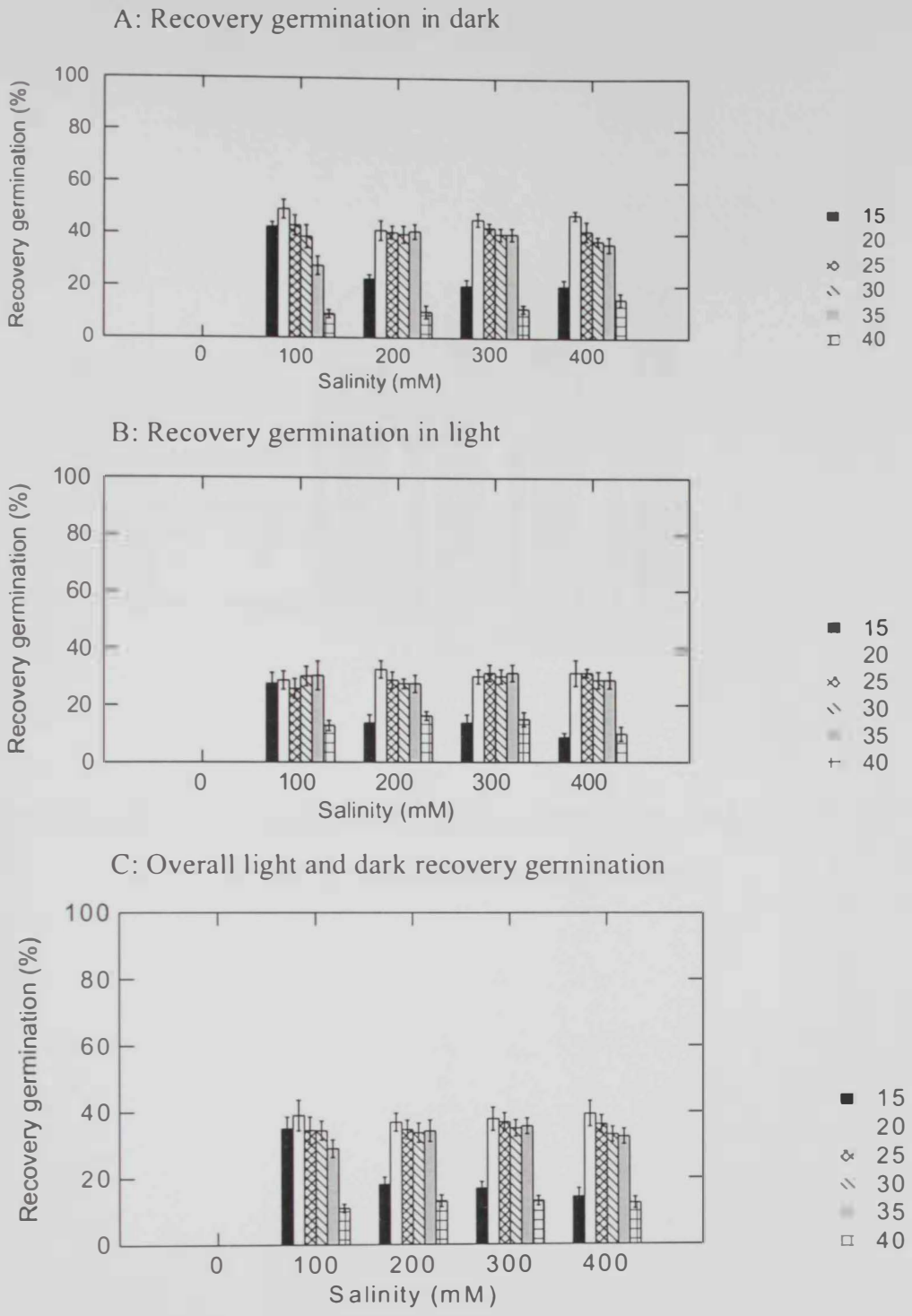



Figure 3: Effects of salinity, temperature (°C), and light of incubation on recovery germination percentage mean ± standard error) of *Panicum turgidum* seeds previously imbibed in various concentrations of NaCl and then transferred to distilled water

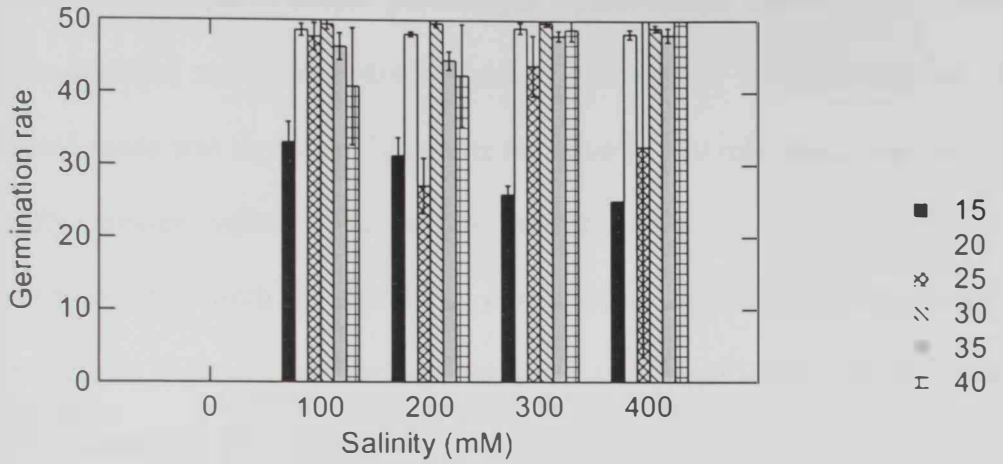



Figure 4: Effects of salinity and temperature (°C) on recovery germination rate index (mean ± standard error) of *Panicum turgidum* seeds

## 3.3. Effects of Salinity, Temperature and Light on Total Germination Percentage of *P. turgidum*

The effects of the main factors (salinity, temperature and light) and their interactions were significant for total germination percentages (germination during salt treatment + recovery in distilled water) at $P<0.05$ (Table 9). Generally, total germination of non-saline treated seeds was significantly greater than that in 100 mM NaCl and both attained significantly greater values than in the higher salinities. Total germination was significantly lower at both 15 and 40°C, compared to the medium temperatures (20–35°C). Regarding light effect, dark germination was significantly greater than light germination (Table 10, Figure 5).

Total germination was significantly greater at moderate temperatures (20–30°C), especially for non-saline treated seeds in dark. The variation in total germination at the different temperatures was noteworthy in the different salinities in the light when compared to the dark (Table 10, Figure 5).

Table 9: Results of three-way ANOVA showing the effects of salinity, temperature, light and their interactions on total germination percentage (i.e., in saline solution plus recovery, mean (standard error) of *Panicum turgidum* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity (S) | 4 | 0.807 | 268.912 | <0.001 |
| Temperature (T) | 5 | 0.941 | 313.645 | <0.001 |
| Light (L) | 1 | 0.774 | 257.861 | <0.001 |
| S*T | 20 | 0.085 | 28.457 | <0.001 |
| S*L | 4 | 0.008 | 2.805 | <0.05 |
| T*L | 5 | 0.101 | 33.707 | <0.001 |
| S*T*L | 20 | 0.017 | 5.566 | <0.001 |
| Error | 180 | 0.003 | | |

Table 10: Effects of salinity, light and temperature of incubation on total germination percentage (i.e., in saline solution plus recovery, mean ± standard error) of *Panicum turgidum* seeds

| Salinity | Light | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| Control | Light | 23.8 ± 1.3 | 58.8 ± 1.3 | 57.5 ± 1.4 | 75.0 ± 2.0 | 41.3 ± 5.5 | 32.5 ± 2.5 | 48.2 ± 3.8 |
| | Dark | 33.8 ± 3.8 | 86.3 ± 1.3 | 83.8 ± 2.4 | 85.0 ± 2.0 | 33.8 ± 2.4 | 16.3 ± 3.1 | 56.5 ± 6.1 |
| | Overall | 28.8 ± 2.6 | 72.5 ± 5.3 | 70.6 ± 5.1 | 80.0 ± 2.3 | 37.5 ± 3.1 | 24.4 ± 3.6 | 52.3 ± 3.6 |
| 100 | Light | 27.5 ± 3.2 | 37.5 ± 3.2 | 38.8 ± 2.4 | 45.0 ± 2.0 | 47.5 ± 4.3 | 15.0 ± 2.0 | 35.2 ± 2.5 |
| | Dark | 42.5 ± 1.4 | 62.5 ± 3.2 | 58.8 ± 2.4 | 60.0 ± 3.5 | 51.3 ± 1.3 | 12.5 ± 1.4 | 47.9 ± 3.7 |
| | Overall | 35.0 ± 3.3 | 50.0 ± 5.2 | 48.8 ± 4.1 | 52.5 ± 3.4 | 49.4 ± 2.2 | 13.8 ± 1.3 | 41.6 ± 2.4 |
| 200 | Light | 13.8 ± 2.4 | 32.5 ± 2.5 | 28.8 ± 2.4 | 27.5 ± 1.4 | 27.5 ± 2.5 | 16.3 ± 1.3 | 24.4 ± 1.6 |
| | Dark | 22.5 ± 1.4 | 41.3 ± 3.1 | 41.3 ± 2.4 | 41.3 ± 3.1 | 42.5 ± 1.4 | 10.0 ± 2.0 | 33.1 ± 2.7 |
| | Overall | 18.1 ± 2.1 | 36.6 ± 2.5 | 35.0 ± 2.8 | 34.4 ± 3.1 | 35.0 ± 3.1 | 13.1 ± 1.6 | 28.8 ± 1.7 |
| 300 | Light | 13.8 ± 2.4 | 30.0 ± 2.0 | 31.3 ± 2.4 | 30.0 ± 2.0 | 31.3 ± 2.4 | 15.0 ± 2.0 | 25.2 ± 1.8 |
| | Dark | 20.0 ± 2.0 | 46.3 ± 2.4 | 42.5 ± 1.4 | 40.0 ± 2.0 | 40.0 ± 2.0 | 11.3 ± 1.3 | 33.3 ± 2.8 |
| | Overall | 16.9 ± 1.9 | 38.1 ± 3.4 | 36.9 ± 2.5 | 35.0 ± 2.3 | 35.6 ± 2.2 | 13.1 ± 1.3 | 29.3 ± 1.7 |
| 400 | Light | 8.8 ± 1.3 | 31.3 ± 3.8 | 31.3 ± 1.3 | 28.8 ± 2.4 | 28.8 ± 2.4 | 10.0 ± 2.0 | 23.1 ± 2.2 |
| | Dark | 20.0 ± 2.0 | 47.5 ± 1.4 | 41.3 ± 3.1 | 37.5 ± 1.4 | 36.3 ± 2.4 | 15.0 ± 2.0 | 32.9 ± 2.5 |
| | Overall | 14.4 ± 2.4 | 39.4 ± 3.6 | 36.3 ± 2.5 | 33.1 ± 2.1 | 32.5 ± 2.1 | 12.5 ± 1.6 | 28.0 ± 1.8 |
| Overall | Light | 17.5 ± 1.8 | 38.0 ± 2.7 | 37.5 ± 2.6 | 41.3 ± 4.2 | 35.3 ± 2.3 | 17.8 ± 1.9 | 31.2 ± 1.4 |
| | Dark | 27.8 ± 2.3 | 56.8 ± 3.9 | 53.5 ± 3.9 | 52.8 ± 4.3 | 40.8 ± 1.6 | 13.0 ± 1.0 | 40.8 ± 1.9 |
| | Overall | 22.6 ± 1.7 | 47.4 ± 2.8 | 45.5 ± 2.6 | 47.0 ± 3.1 | 38.0 ± 1.5 | 15.4 ± 1.1 | |

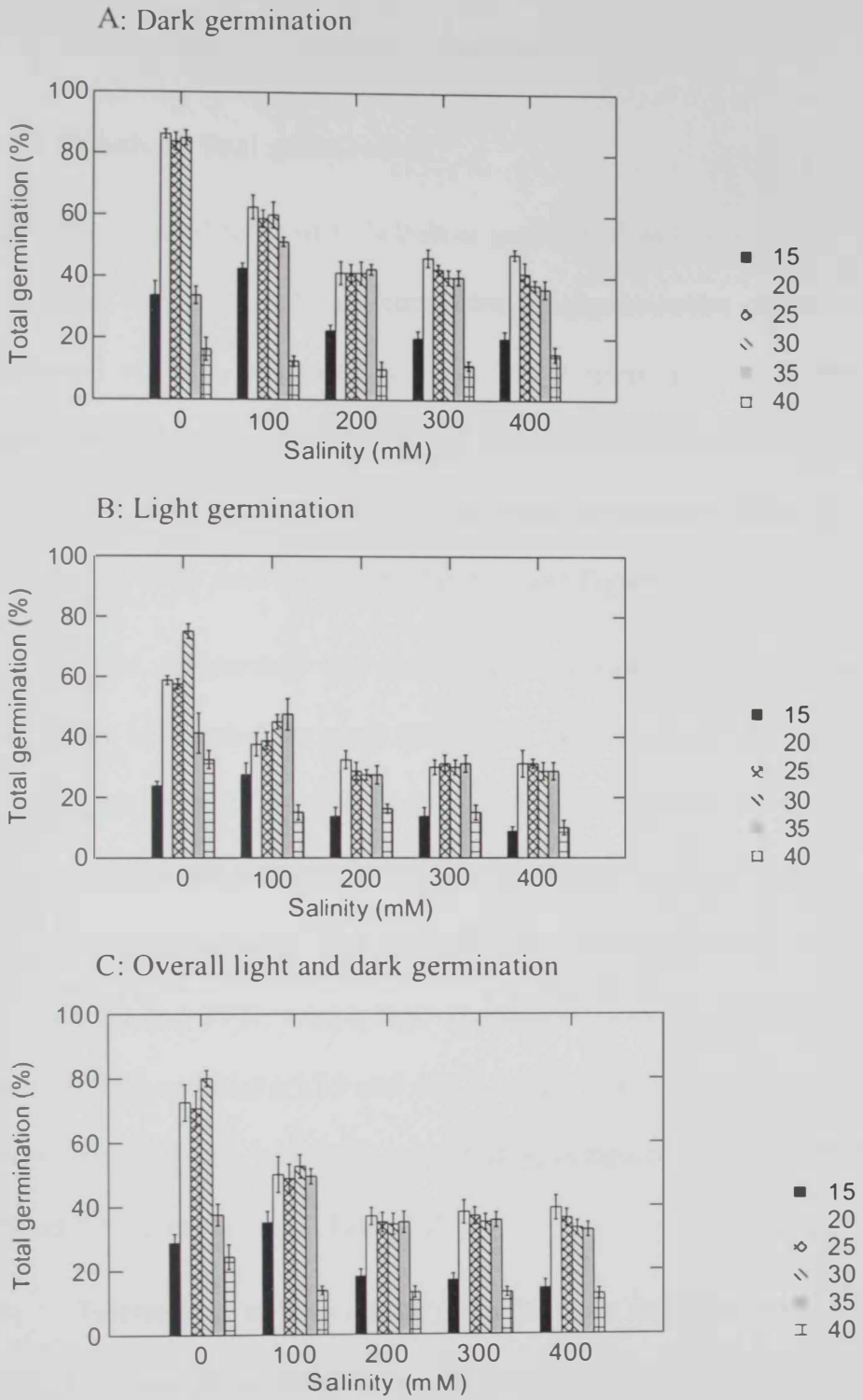



Figure 5: Effects of salinity, light and temperature (°C) of incubation on total germination percentage (i.e., in saline solution plus recovery, mean ± standard error) of *Panicum turgidum* seeds

## 3.4. Effects of Salinity, Temperature and Light on Final Germination Percentage of *Lasiurus scindicus*

### 3.4.1. Effects on final germination

Non-saline treated seeds of *L. Scindicus* germinated well in a wide range of temperatures and under both light and dark conditions. The germination of these seeds significantly decreased at 40°C, compared to other lower temperatures (15–35°C). There was no significant difference between dark and light temperature of non-saline treated seeds at all temperatures, except at 35 and 40°C, at which germination under light was significantly greater than under dark condition (Table 12 and Figure 6).

Light, temperature and salinity all had significant effects on final germination percentage of *L. scindicus* seeds (Table 11). Generally, seed germination decreased with the increase in NaCl concentrations. Final germination decreased from 64.5% in non-saline treated seeds (control) to 45.2%, 29.5%, 23.1% and 9.3% in 50, 100, 150 and 200 mM NaCl, respectively. The optimal germination occurred at temperatures ranged between 20 and 30°C, where final germination was significantly greater than at both lower (15°C) and higher (35 and 40°C) temperatures. Final germination was 49.5, 47.3 and 41.8% at 20, 25, and 30°C, respectively, compared to 27.5%, 29.9% and 10% at 15, 35 and 40 °C, respectively (Table 12).

Tolerance to salinity during germination is dependent on temperature ($P< 0.001$, Table 11). Final germination in non-saline treated seeds was greater than for treated seeds at all temperatures. There was no significant difference between the germination of non-saline treated seeds at temperatures between 15 and 35°C. Germination in 200 mM NaCl was completely inhibited at 15 and 35°C, but attained considerable proportions at 20, 25 and 30°C (Table 12).

The interaction between temperature and light was significant indicating that the response of final germination on temperature depended on whether seeds germinated in light or in dark. Whereas overall dark germination was greater than light germination at lower temperatures (15–25°C), the reverse was true at higher temperature (35-40°C). Overall final germination was greater in dark than in light by 114%, 16.3% and 18.5% at 15, 20 and 25°C, respectively, but light germination was greater than dark germination by 133% and 32 % at 40 and 35°C, respectively (Table 12).

The interaction between salinity, light and temperature was significant on final germination of *L. scindicus* ($P < 0.001$, Table 11). Germination response to 15 and 40°C temperatures depended on both salinity level and light condition. In light, germination at 15°C was significantly reduced in 50 mM NaCl, compared to non-saline treated seeds, and completely inhibited in higher salinities (100–200 mM NaCl). In dark, however, there were significant differences between germination at 15°C and most of the other temperatures in both 50 and 100 mM NaCl. Significant proportion of the seeds (22.5 %) germinated at 15°C in 150 mM NaCl. At 15°C in light, germination was reduced by 68%, compared to control, in 50 mM NaCl and completely inhibited in the higher salinities, but germination under dark conditions reduced by 27%, 37% and 68% in 50, 100 and 150 mM NaCl, respectively. Germination at 40°C, however, attained an opposite trends to that observed at 15°C. In 50 mM NaCl, whereas dark, germination almost inhibited (1.3% germination) at 40°C, light germination attained 18.8% (Table 12 and Figure 6).

### 3.4.2. Effects on germination rate

Both temperature and salinity affected the germination rate index of *L. scindicus* ($P<0.001$, Table 13). Generally, germination rate index was significantly greater in non-saline treated seeds, compared to other salinities. Germination rate index was significantly slower at 15°C in both non-saline treated seeds and 50 mM NaCl, but the difference was significant in 50 mM NaCl. In non-saline treated seeds, germination rate at 15°C was slower, compared to the higher temperatures (20– 40°C), by 12.2% and 20.8%. In 50 mM NaCl, however, the rate at 15°C was slower by 59.4% and 65.5% (Table 14 and Figure 7).

Table 11: Three-way ANOVA showing the effects of salinity, temperature, light and their interactions on final germination percentages of *Lasiurus scindicus* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity (S) | 4 | 2.807 | 460.93 | <0.001 |
| Temperature (T) | 5 | 1.073 | 176.17 | <0.001 |
| Light (L) | 1 | 0.052 | 8.61 | <0.01 |
| S*T | 20 | 0.057 | 9.36 | <0.001 |
| S*L | 4 | 0.063 | 10.38 | <0.001 |
| T*L | 5 | 0.143 | 23.45 | <0.001 |
| S*T*L | 20 | 0.057 | 9.38 | <0.001 |
| Error | 180 | 0.006 | | |

Table 12: Effects of salinity, temperature, and light on final germination percentage (mean ± standard error) of *Lasiurus scindicus* seeds

| Salinity | Light | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| Control | Light | 66.3 ± 3.1 | 75.0 ± 4.1 | 76.3 ± 4.3 | 67.5 ± 4.3 | 70.0 ± 3.5 | 50.0 ± 2.0 | 67.5 ± 2.2 |
| | Dark | 70.0 ± 3.5 | 56.3 ± 4.7 | 83.8 ± 4.3 | 78.8 ± 3.8 | 53.8 ± 10.3 | 26.3 ± 1.3 | 61.5 ± 4.4 |
| | Overall | 68.1 ± 2.3 | 65.6 ± 4.6 | 80.0 ± 3.1 | 73.1 ± 3.4 | 61.9 ± 5.9 | 38.1 ± 4.6 | 64.5 ± 2.5 |
| 50 | Light | 21.3 ± 3.1 | 53.8 ± 3.1 | 58.8 ± 5.2 | 61.3 ± 3.8 | 40.0 ± 2.9 | 18.8 ± 1.3 | 42.3 ± 3.8 |
| | Dark | 51.3 ± 3.8 | 70.0 ± 2.0 | 62.5 ± 4.3 | 58.8 ± 1.3 | 45.0 ± 2.9 | 1.3 ± 1.3 | 48.1 ± 4.8 |
| | Overall | 36.3 ± 6.1 | 61.9 ± 3.5 | 60.6 ± 3.2 | 60.0 ± 1.9 | 42.5 ± 2.1 | 10.0 ± 3.4 | 45.2 ± 3.0 |
| 100 | light | 0.0 ± 0.0 | 55.0 ± 2.9 | 47.5 ± 3.2 | 43.8 ± 2.4 | 40.0 ± 2.0 | 1.3 ± 1.3 | 31.3 ± 4.7 |
| | dark | 43.8 ± 3.8 | 56.3 ± 4.3 | 27.5 ± 1.4 | 17.5 ± 3.2 | 18.8 ± 1.3 | 2.5 ± 1.4 | 27.7 ± 3.8 |
| | overall | 21.9 ± 8.4 | 55.6 ± 2.4 | 37.5 ± 4.1 | 30.6 ± 5.3 | 29.4 ± 4.2 | 1.9 ± 0.9 | 29.5 ± 3.0 |
| 150 | Light | 0.0 ± 0.0 | 32.5 ± 1.4 | 25.0 ± 2.0 | 35.0 ± 3.5 | 18.8 ± 2.4 | 0.0 ± 0.0 | 18.5 ± 3.0 |
| | Dark | 22.5 ± 2.5 | 57.5 ± 2.5 | 46.3 ± 2.4 | 28.8 ± 4.3 | 11.3 ± 1.3 | 0.0 ± 0.0 | 27.7 ± 4.2 |
| | Overall | 11.3 ± 4.4 | 45.0 ± 4.9 | 35.6 ± 4.3 | 31.9 ± 2.8 | 15.0 ± 1.9 | 0.0 ± 0.0 | 23.1 ± 2.6 |
| 200 | Light | 0.0 ± 0.0 | 12.5 ± 2.5 | 8.8 ± 2.4 | 11.3 ± 1.3 | 1.3 ± 1.3 | 0.0 ± 0.0 | 5.6 ± 1.3 |
| | Dark | 0.0 ± 0.0 | 26.3 ± 3.8 | 36.3 ± 2.4 | 15.0 ± 3.5 | 0.0 ± 0.0 | 0.0 ± 0.0 | 12.9 ± 3.1 |
| | Overall | 0.0 ± 0.0 | 19.4 ± 3.3 | 22.5 ± 5.4 | 13.1 ± 1.9 | 0.6 ± 0.6 | 0.0 ± 0.0 | 9.3 ± 1.7 |
| Overall | Light | 17.5 ± 6.0 | 45.8 ± 5.0 | 43.3 ± 5.7 | 43.8 ± 4.8 | 34.0 ± 5.4 | 14.0 ± 4.5 | 33.1 ± 2.4 |
| | Dark | 37.5 ± 5.7 | 53.3 ± 3.6 | 51.3 ± 4.8 | 39.8 ± 5.9 | 25.8 ± 5.1 | 6.0 ± 2.4 | 35.6 ± 2.4 |
| | Overall | 27.5 ± 4.4 | 49.5 ± 3.1 | 47.3 ± 3.7 | 41.8 ± 3.7 | 29.9 ± 3.7 | 10.0 ± 2.6 | |

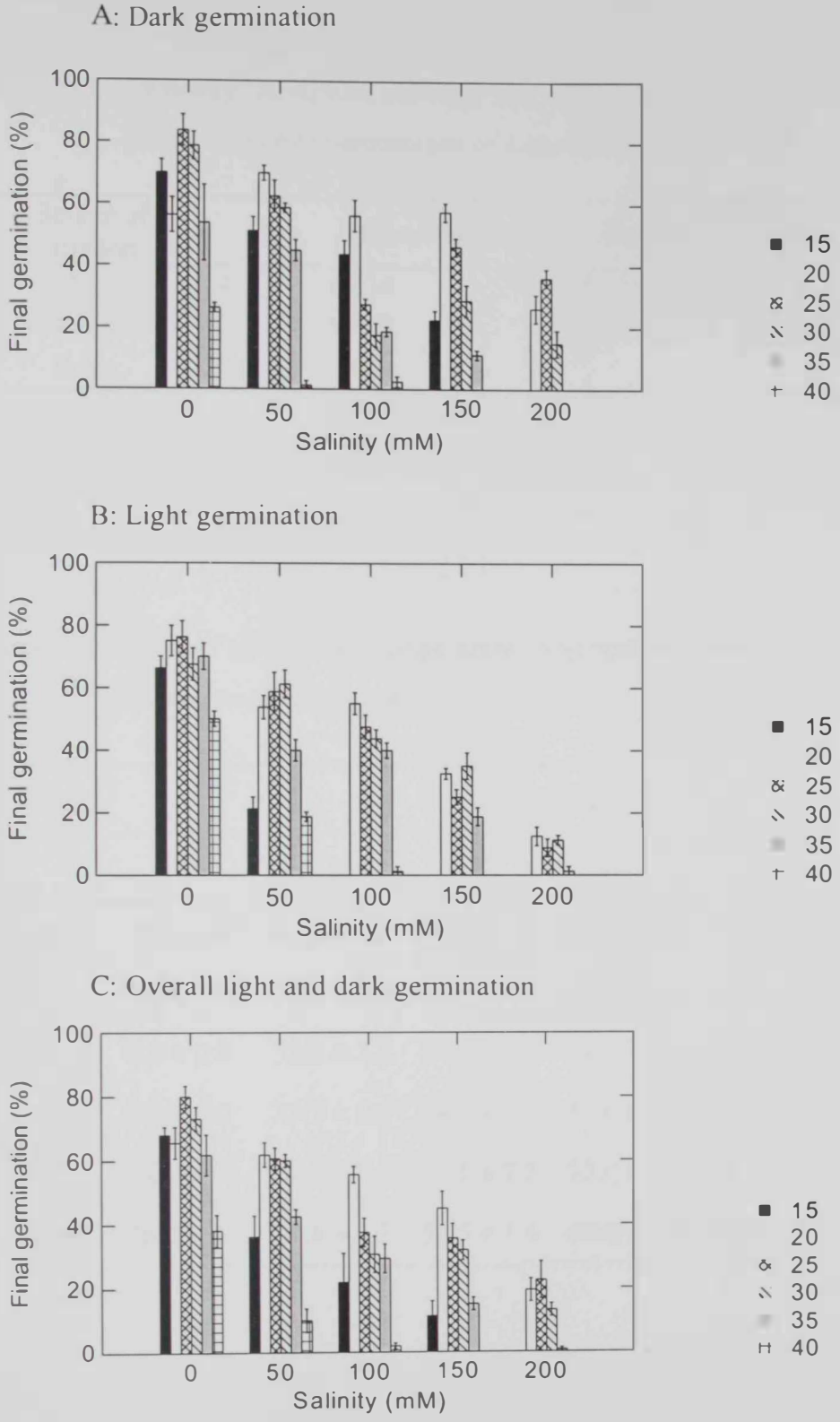



Figure 6: Effects of salinity, temperature (°C) and light of incubation on final germination percentages (mean ± standard error) of *Lasiurus scindicus* seeds

Table 13: Two-way ANOVA showing the effects of salinity and temperature on germination rate percentages of *Lasiurus scindicus* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity | 4 | 0.534 | 17.127 | <0.001 |
| Temperature | 5 | 0.668 | 21.413 | <0.001 |
| Error | 84 | 0.031 | | |

Table 14: Effects of salinity and temperature on germination rate (mean ± standard error) of *Lasiurus scindicus* seeds

| Salinity | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 35 | 40 | |
| Control | 37.4 ± 0.7 | 42.6 ± 1.5 | 44.5 ± 1.0 | 47.2 ± 0.8 | 45.2 ± 0.7 | 44.9 ± 0.7 | 43.7 ± 0.7 |
| 50 | 14.9 ± 0.6 | 36.7 ± 1.5 | 42.6 ± 0.9 | 43.2 ± 0.6 | 42.0 ± 1.6 | 42.9 ± 2.7 | 37.0 ± 2.2 |
| 100 | 0.0 ± 0.0 | 32.2 ± 2.8 | 34.4 ± 1.8 | 39.5 ± 1.3 | 36.3 ± 1.4 | 28.6 ± 0.0 | 35.2 ± 1.1 |
| 150 | 0.0 ± 0.0 | 23.7 ± 0.9 | 34.4 ± 2.2 | 37.6 ± 1.3 | 41.4 ± 2.8 | 0.0 ± 0.0 | 34.3 ± 1.9 |
| 200 | 0.0 ± 0.0 | 23.7 ± 3.8 | 31.5 ± 2.5 | 35.4 ± 2.9 | 35.7 ± 0.0 | 0.0 ± 0.0 | 30.6 ± 2.1 |
| Overall | 26.2 ± 4.3 | 31.8 ± 1.9 | 37.5 ± 1.4 | 40.6 ± 1.2 | 40.9 ± 1.1 | 42.2 ± 2.1 | 37.0 ± 0.9 |

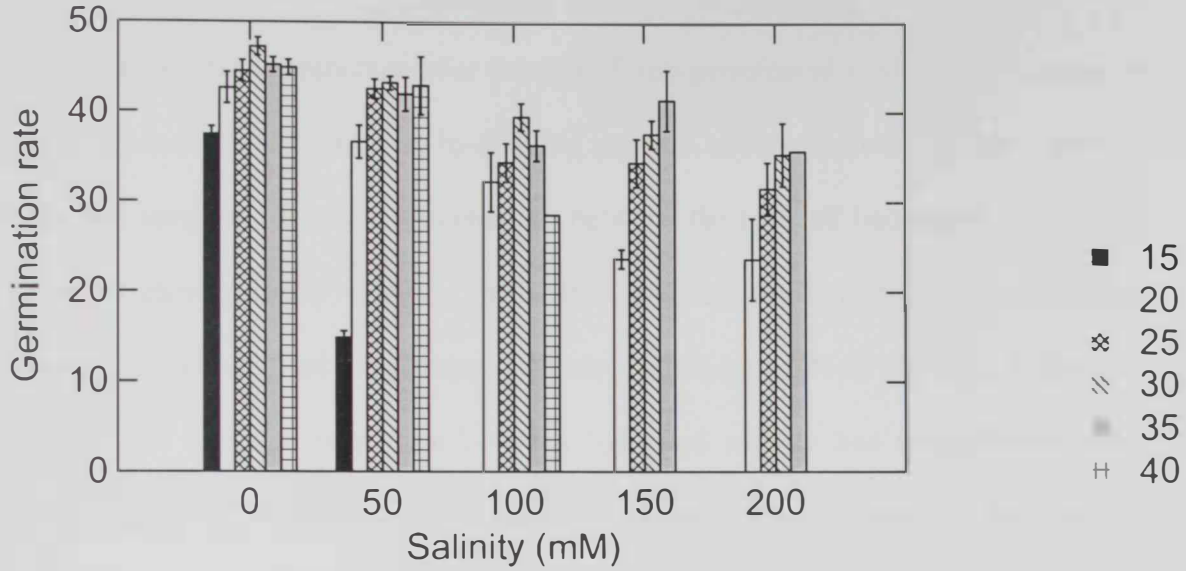



Figure 7: Effects of salinity and temperature (°C) of incubation on germination rate index (mean ± standard error) of *Lasiurus Scindicus* seeds

## 3.5. Effects of Salinity, Temperature and Light on Recovery Germination of *L. scindicus*

### 3.5.1. Effects on final germination

Recovery germination percentage after transfer of non-germinated seeds of *L. scindicus* at different concentrations of salinity to distilled water is shown in Table 16 and Figure 8. Salinity and temperature and the interaction between the two, all had significant effects on recovery germination ($P<0.001$). The interactions between light and temperature and between light, salinity and temperature had also significant effects ($P<0.01$, Table 15). However, light and the interaction between light and salinity had insignificant effect (($P>0.05$, Table 15). Recovery germination decreased with the increase in temperature. Recovery germination at 15°C (53.6%) was significantly greater than it at 20, 25 and 30°C (37.6%, 32.2% and 28.3%, respectively) and all were significantly greater values than at 35 and 40°C (13.6% and 2.8%, respectively). On the other hand, recovery germination decreased with the increase in salinity. It was significantly greater in 50, 100 and 150 mM NaCl (29.4%, 34.9% and 28.5%, respectively) than in 200 mM NaCl (19.3%, Table 16).

The significant salinity and temperature interaction further indicate that salinity tolerance of *L. scindicus* seeds depended on temperature. Recovery germination was significantly greater in salinities 50–150 mM NaCl at 15°C, compared to it at the other temperatures. In 200 mM NaCl, however, there was no significant difference between recoveries at temperatures 15–30°C. Recovery germination at 15°C was greater than it at 20°C by 39.2%, 69.6% and 50.4% in 50, 100 and 150 mM NaCl, respectively, but by only 5.5% in 200 mM NaCl (Figure 8c).

The interaction between salinity, temperature and light was significant indicating that salinity tolerance of *L. scindicus* seeds depended not only on temperature, but also on light of incubation. The greatest recovery was recorded at 15°C in darkness in both 100 and 150 mM NaCl. In both 100 and 150 mM NaCl, for example, whereas there was no significant difference between recovery germination in light at 15-30°C, recovery germination in dark was significantly greater at 15°C, compared to at the other temperatures (Table 16 and Figure 8).

### 3.5.2. Effects on germination rate

Germination rate index of the recovered seeds was much greater than it in saline treated seeds. Only temperature had significant effect on recovery germination rate of *L. scindicus* seeds ($P>0.001$, Table 17). Recovery germination was significantly greater at 30 and 35°C, compared to the other higher (40°C) and lower (15 and 20°C) temperatures (Table 18 and Figure 9).

Table 15: Three-way ANOVA showing the effects of salinity, temperature, light and their interactions on germination recovery of *Lasiurus scindicus* seeds.

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity (S) | 4 | 1.032 | 151.71 | <0.001 |
| Temperature (T) | 5 | 0.994 | 146.19 | <0.001 |
| Light (L) | 1 | 0.008 | 1.149 | ns |
| S*T | 20 | 0.090 | 13.18 | <0.001 |
| S*L | 4 | 0.010 | 1.4.3 | ns |
| T*L | 5 | 0.025 | 3.65 | <0.01 |
| S*T*L | 20 | 0.042 | 6.24 | <0.001 |
| Error | 180 | 0.007 | | |

ns = insignificant at $P \leq 0.05$

Table 16: Effects of salinity, temperature, and light on recovery germination percentage (mean ± standard error) of *Lasiurus scindicus* seeds

| Salinity | Light | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| 50 | Light | 52.4 ± 3.5 | 26.5 ± 3.4 | 30.5 ± 1.0 | 29.4 ± 2.6 | 18.4 ± 3.3 | 6.2 ± 2.6 | 27.2 ± 3.1 |
| | Dark | 54.2 ± 4.6 | 50.1 ± 6.0 | 31.8 ± 6.4 | 30.6 ± 4.0 | 20.4 ± 1.7 | 2.5 ± 1.4 | 31.6 ± 4.0 |
| | Overall | 53.3 ± 2.7 | 38.3 ± 5.5 | 31.1 ± 3.0 | 30.0 ± 2.2 | 19.4 ± 1.8 | 4.3 ± 1.5 | 29.4 ± 2.5 |
| 100 | Light | 57.5 ± 4.8 | 53.1 ± 5.1 | 45.7 ± 3.5 | 44.5 ± 3.4 | 20.9 ± 4.3 | 2.5 ± 2.5 | 37.4 ± 4.3 |
| | Dark | 83.3 ± 7.6 | 29.8 ± 5.3 | 29.4 ± 3.5 | 28.6 ± 3.2 | 15.4 ± 1.9 | 7.6 ± 3.3 | 32.4 ± 5.3 |
| | Overall | 70.4 ± 6.4 | 41.5 ± 5.6 | 37.5 ± 3.8 | 36.5 ± 3.7 | 18.2 ± 2.4 | 5.1 ± 2.1 | 34.9 ± 3.4 |
| 150 | Light | 46.3 ± 3.8 | 37.0 ± 2.5 | 36.9 ± 2.7 | 28.7 ± 2.6 | 15.7 ± 4.3 | 0.0 ± 0.0 | 27.4 ± 3.4 |
| | Dark | 62.9 ± 2.6 | 35.7 ± 5.1 | 32.2 ± 5.2 | 33.1 ± 3.7 | 11.4 ± 4.0 | 2.5 ± 1.4 | 26.6 ± 4.3 |
| | Overall | 54.6 ± 3.8 | 36.3 ± 2.7 | 34.5 ± 2.9 | 30.9 ± 2.3 | 13.5 ± 2.8 | 1.3 ± 0.8 | 28.5 ± 2.7 |
| 200 | Light | 42.5 ± 1.4 | 32.8 ± 0.5 | 19.2 ± 2.8 | 12.7 ± 1.3 | 6.4 ± 1.4 | 1.3 ± 1.3 | 19.1 ± 3.1 |
| | Dark | 30.0 ± 2.0 | 36.0 ± 2.9 | 32.1 ± 7.3 | 19.3 ± 3.2 | 0.0 ± 0.0 | 0.0 ± 0.0 | 19.6 ± 3.3 |
| | Overall | 36.3 ± 2.6 | 34.4 ± 1.5 | 25.6 ± 4.4 | 16.0 ± 2.1 | 3.2 ± 1.4 | 0.6 ± 0.6 | 19.3 ± 2.2 |
| Overall | Light | 49.7 ± 2.2 | 37.3 ± 2.9 | 33.0 ± 2.8 | 28.8 ± 3.1 | 15.3 ± 2.1 | 2.5 ± 1.0 | 27.8 ± 1.8 |
| | Dark | 57.6 ± 5.4 | 37.9 ± 2.9 | 31.4 ± 2.6 | 27.9 ± 2.1 | 11.8 ± 2.2 | 3.2 ± 1.1 | 28.3 ± 2.2 |
| | Overall | 53.6 ± 2.9 | 37.6 ± 2.0 | 32.2 ± 1.9 | 28.3± 1.9 | 13.6 ± 1.5 | 2.8 ± 0.8 | |

Table 17: Three-way ANOVA showing the effects of salinity, temperature and light on recovery germination rate of *Lasiurus scindicus* seeds.

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity | 4 | 0.044 | 2.44 | ns |
| Temperature | 5 | 0.290 | 22.95 | <0.001 |
| Light | 1 | 0.013 | 1.05 | ns |
| Error | 152 | 0.013 | | |

ns = insignificant at $P \leq 0.05$

Table 18: Effects of salinity, temperature and light on recovery germination rate (mean ± standard error) of *Lasiurus scindicus* seeds

| Salinity | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 35 | 40 | |
| 50 | 41.5 ± 0.9 | 41.7 ± 0.0 | 38.9 ± 2.8 | 44.4 ± 2.0 | 50.0 ± 0.0 | 41.7 ± 0.0 | 42.9 ± 1.0 |
| 100 | 39.8 ± 1.1 | 41.7 ± 0.0 | 41.7 ± 0.0 | 45.1 ± 2.1 | 49.1 ± 0.9 | 36.3 ± 1.3 | 42.5 ± 0.9 |
| 150 | 37.9 ± 2.0 | 41.7 ± 0.0 | 41.7 ± 0.0 | 43.8 ± 2.1 | 49.0 ± 1.0 | 27.6 ± 2.6 | 40.7 ± 1.3 |
| 200 | 33.0 ± 5.1 | 41.3 ± 0.3 | 41.7 ± 0.0 | 44.4 ± 2.8 | 50.0 ± 0.0 | 37.1 ± 1.0 | 40.6 ± 1.6 |
| Overall | 38.0 ± 1.5 | 41.6 ± 0.1 | 41.0 ± 0.7 | 44.4 ± 1.0 | 49.5 ± 0.3 | 34.2 ± 1.7 | 41.5 ± 0.6 |

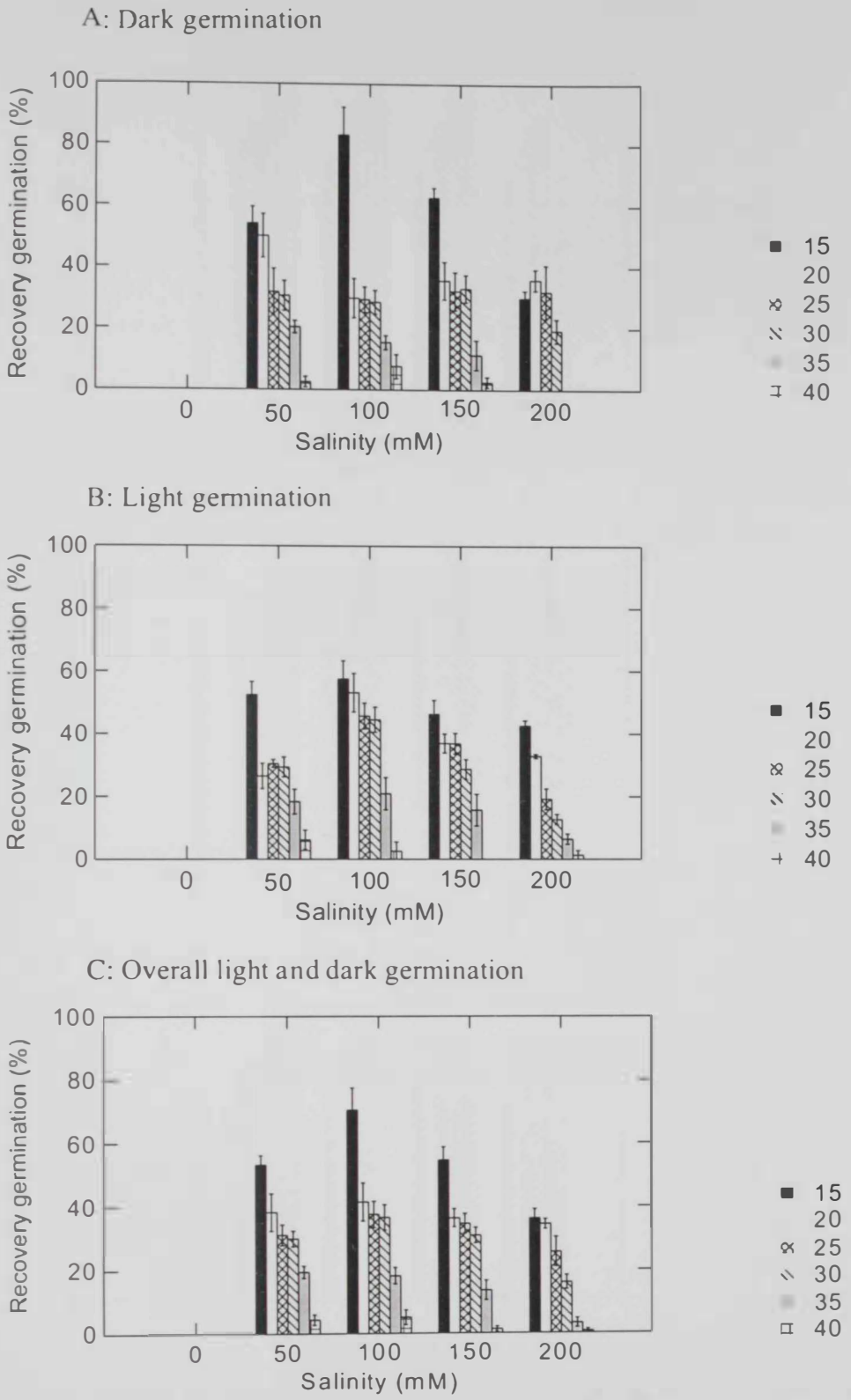



Figure 8: Effects of salinity, temperature (°C) and light on recovery germination percentage (mean ± standard error) of *Lasiurus scindicus* seeds

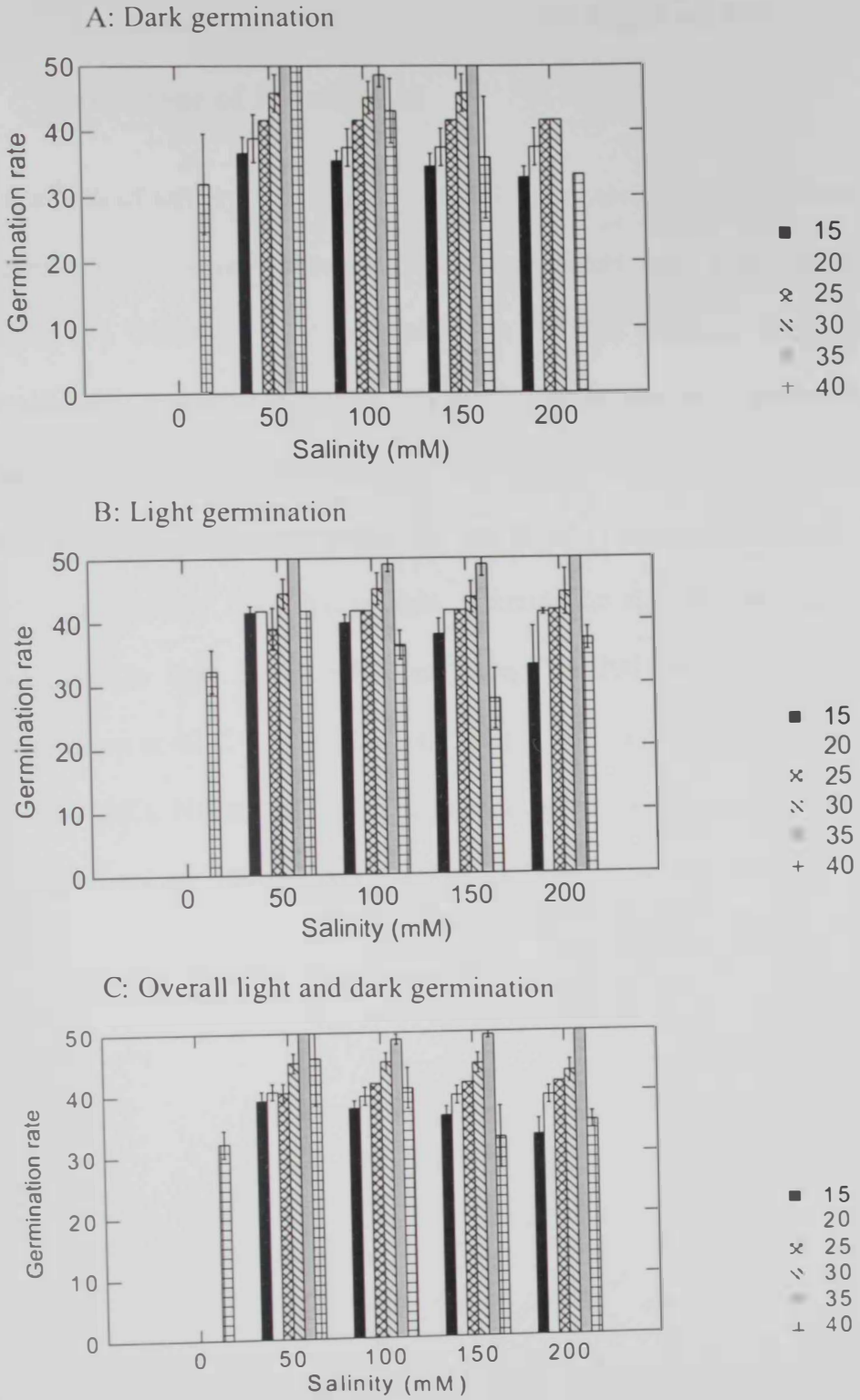



Figure 9: Effects of salinity, temperature (°C) and light on recovery germination rate index (mean ± standard error) of *Lasiurus scindicus* seeds

## 3.6. Effects of Salinity, Temperature and Light on Total Germination Percentage of *L. scindicus*

The effects of salinity, temperature and their interaction on total germination (germination during salt treatment + recovery in distilled water) were highly significant ($P<0.001$, Table. 19). Generally, total germination in distilled water, 50 and 100 mM NaCl was significantly greater than in 150 mM NaCl, and all attained significantly greater values than in 200 mM NaCl. Total germination was significantly greater at temperatures of 15–30°C than at higher temperatures (35 and 40°C). Total germination in darkness did not differ significantly from that in light. Germination at 15°C was significantly greater in dark than in light in all salinities, except in 200 mM NaCl. On the other hand, germination at 40°C was significantly greater in light, compared to in darkness at 0 and 50 mM NaCl. No or little germination was observed at 40°C in both light and dark at salinities between 100 and 200 mM NaCl, (Table 20 and Figure 10).

Table 19: Three-way ANOVA showing the effects of salinity, temperature, light and their interactions on total germination percentage (germination during salt treatment + recovery in distilled water, mean ± standard error) of *Lasiurus scindicus* seeds.

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Salinity (S) | 4 | 1.545 | 163.67 | <0.001 |
| Temperature (T) | 5 | 2.242 | 237.38 | <0.001 |
| Light (L) | 1 | 0.022 | 2.30 | ns |
| S*T | 20 | 0.078 | 8.24 | <0.001 |
| S*L | 4 | 0.064 | 6.77 | <0.001 |
| T*L | 5 | 0.131 | 13.87 | <0.001 |
| S*T*L | 20 | 0.087 | 9.21 | <0.001 |
| Error | 180 | 0.009 | | |

ns = insignificant at $P \leq 0.05$

Table 20: Effects of salinity, temperature, and light on total germination percentage (germination during salt treatment + recovery in distilled water, mean ± standard error) of *Lasiurus scindicus* seeds

| Salinity | Light | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| Control | Light | 66.3 ± 3.1 | 75.0 ± 4.1 | 76.3 ± 4.3 | 67.5 ± 4.3 | 70.0 ± 3.5 | 50.0 ± 2.0 | 67.5 ± 2.2 |
| | Dark | 70.0 ± 3.5 | 56.3 ± 4.7 | 83.8 ± 4.3 | 78.8 ± 3.8 | 53.8 ± 10.3 | 26.3 ± 1.3 | 61.5 ± 4.4 |
| | Overall | 68.1 ± 2.3 | 65.6 ± 4.6 | 80.0 ± 3.1 | 73.1 ± 3.4 | 61.9 ± 5.9 | 38.1 ± 4.6 | 64.5 ± 2.5 |
| 50 | Light | 62.5 ± 3.2 | 66.3 ± 1.3 | 71.3 ± 3.8 | 72.5 ± 3.2 | 51.3 ± 1.3 | 23.8 ± 2.4 | 57.9 ± 3.6 |
| | Dark | 77.5 ± 3.2 | 85.0 ± 2.0 | 73.8 ± 5.2 | 71.3 ± 2.4 | 56.3 ± 2.4 | 3.8 ± 1.3 | 61.3 ± 5.8 |
| | Overall | 70.0 ± 3.5 | 75.6 ± 3.7 | 72.5 ± 3.0 | 71.9 ± 1.9 | 53.8 ± 1.6 | 13.8 ± 4.0 | 59.5 ± 3.4 |
| 100 | Light | 57.5 ± 4.8 | 78.8 ± 3.1 | 71.3 ± 3.1 | 68.8 ± 2.4 | 52.5 ± 3.2 | 3.8 ± 2.4 | 55.4 ± 5.3 |
| | Dark | 90.0 ± 4.6 | 68.8 ± 5.2 | 48.8 ± 3.1 | 41.3 ± 2.4 | 31.3 ± 2.4 | 10.0 ± 2.9 | 48.3 ± 5.5 |
| | Overall | 73.8 ± 6.9 | 73.8 ± 3.4 | 60.0 ± 4.7 | 55.0 ± 5.4 | 41.9 ± 4.4 | 6.9 ± 2.1 | 51.9 ± 3.8 |
| 150 | Light | 46.3 ± 3.8 | 57.5 ± 1.4 | 52.5 ± 3.2 | 53.8 ± 2.4 | 31.3 ± 5.2 | 0.0 ± 0.0 | 40.2 ± 4.3 |
| | Dark | 71.3 ± 2.4 | 72.5 ± 3.2 | 63.8 ± 2.4 | 52.5 ± 3.2 | 21.3 ± 4.3 | 2.5 ± 1.4 | 47.3 ± 5.6 |
| | Overall | 58.8 ± 5.2 | 65.0 ± 3.3 | 58.1 ± 2.8 | 53.1 ± 1.9 | 26.3 ± 3.6 | 1.3 ± 0.8 | 43.8 ± 3.5 |
| 200 | Light | 42.5 ± 1.4 | 41.3 ± 1.3 | 26.3 ± 3.1 | 22.5 ± 1.4 | 7.5 ± 2.5 | 1.3 ± 1.3 | 23.5 ± 3.3 |
| | Dark | 30.0 ± 2.0 | 52.5 ± 4.3 | 56.3 ± 6.3 | 31.3 ± 4.7 | 0.0 ± 0.0 | 0.0 ± 0.0 | 28.3 ± 4.8 |
| | Overall | 36.3 ± 2.6 | 46.9 ± 3.0 | 41.3 ± 6.5 | 26.9 ± 2.8 | 3.8 ± 1.8 | 0.6 ± 0.6 | 25.9 ± 2.9 |
| Overall | Light | 55.0 ± 2.5 | 63.8 ± 3.2 | 59.5 ± 4.5 | 57.0 ± 4.4 | 42.5 ± 5.1 | 15.8 ± 4.5 | 48.9 ± 2.2 |
| | Dark | 67.8 ± 4.8 | 67.0 ± 3.1 | 65.3 ± 3.4 | 55.0 ± 4.3 | 32.5 ± 5.2 | 8.5 ± 2.3 | 49.3 ± 2.6 |
| | Overall | 61.4 ± 2.9 | 65.4 ± 2.2 | 62.4 ± 2.8 | 56.0 ± 3.0 | 37.5 ± 3.7 | 12.1 ± 2.5 | |

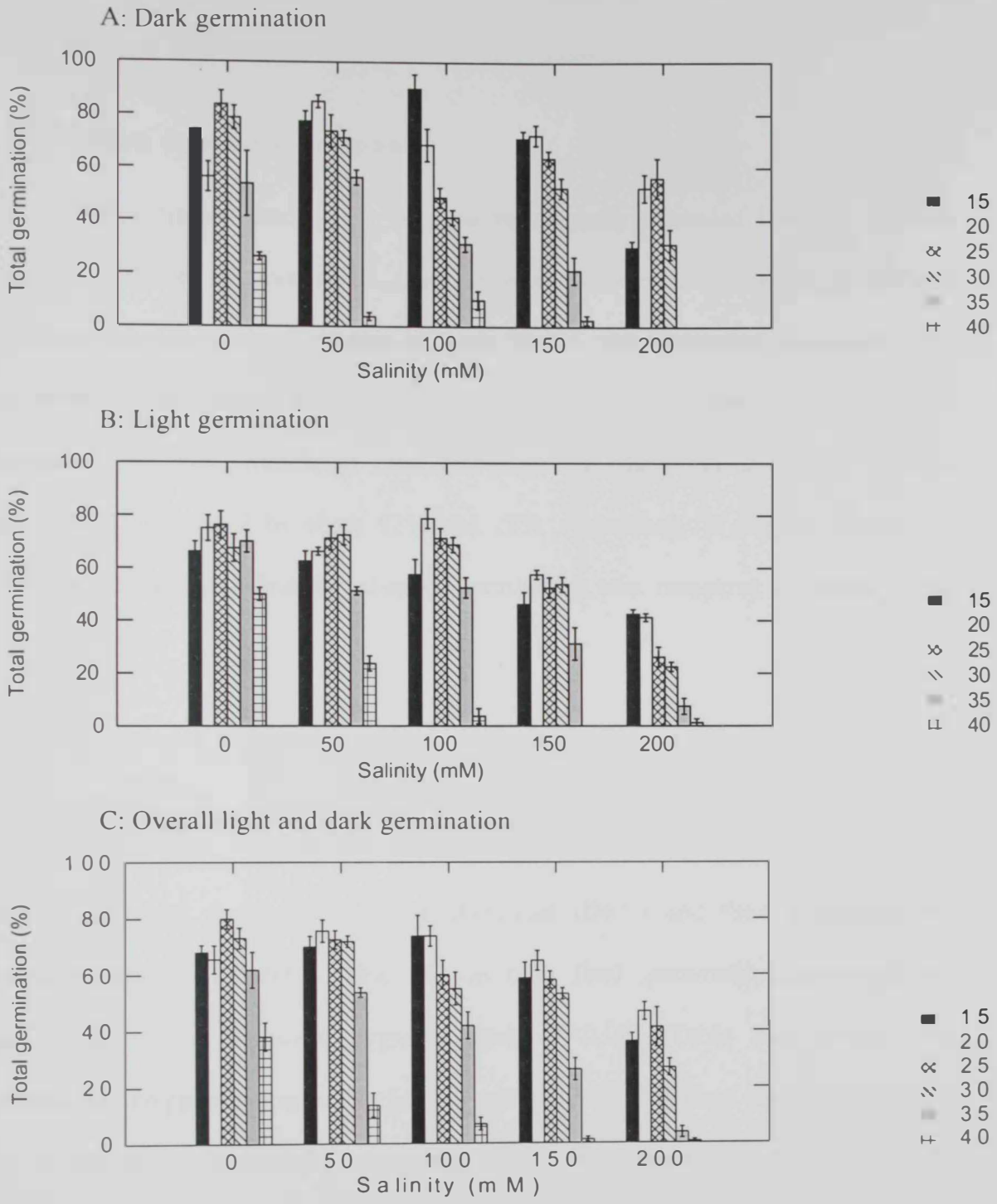



Figure 10: Effects of salinity, temperature (°C) and light on total germination percentage of *Lasiurus scindicus* seeds (germination during salt treatment +recovery in distilled water, mean ± standard error)

## 3.7. Effects Dormancy Regulating Chemicals of Innate and Salinity-Induced Dormancy of *Panicum turgidum*

### 3.7.1. Effects on innate dormancy

For non-saline treated seeds, only thiourea significantly increased final germination, compared to that of the control (i.e., distilled water). However, there was no significant difference between final germination of seeds treated with fusicoccin, $GA_3$ and nitrate and those of the control. Furthermore, ethephon and kinetin resulted in significant decreases of the final germination. Final germination of ethephon and kinetin was lower than that of the control by about 92% and 28%, respectively (Table 21, Figure 11). However, all DRC significantly enhanced germination rate, compared to control (Table 22, Figure 12).

### 3.7.2. Effects on salinity induced dormancy

Both salinity and dormancy relieving chemicals (DRC) and their interaction had significant effects ($P<0.001$, Table 23) on both final germination percentage and germination rate of *Panicum turgidum* seeds ($P<0.001$, Table 23). Overall final germination and germination rate in distilled water (0 mM NaCl) was significantly greater than in 100 mM NaCl. Overall final germination decreased from 57% in 0 NaCl to 31.4% in 100 mM NaCl (Table 21, Figure 11). Germination was almost inhibited in 200 and 300 mM NaCl. Similarly, germination rate decreased from 41.2 to 34.9 (Table 22, Figure 12).

For non-treated seeds, final germination was significantly reduced in 100 mM and completely inhibited in 200 and 300 mM NaCl. The reduction in 100 mM NaCl was completely alleviated by the application of $GA_3$, partially alleviated by the application of fusicoccin, kinetin and thiourea, but not affected by nitrate and completely inhibited by the application of ethephon. Final germination of non-treated seeds reduced from 65% in 0 NaCl to 20% in 100 mM NaCl, but increased again to 65%, 46%, 40% and 32% for seeds treated with $GA_3$, thiourea, kinetin and fusicoccin, respectively. Final germination in 100 mM NaCl did not differ significantly between control and seeds treated with nitrate, but it was completely inhibited for seeds treated with ethephon. In 200 NaCl, little germination took place in seeds treated with $GA_3$ (8%), fusicoccin (3%) and nitrate (3%, Table 21, Figure 11).

The response of germination rate to different salinities and DRC differ from that of final germination. In 100 mM NaCl, there was no significant difference in germination rate between non-treated seeds and those treated with nitrate and thiourea. Seeds treated with fusicoccin, $GA_3$ and kinetin germination was faster than non-treated seeds. There was no significant difference in germination rate between seeds treated with fusicoccin and those treated with $GA_3$ in 200 mM NaCl. Both attained significantly higher values than seeds treated with thiourea (Table 22, Figure 12).

Table 21: Effects of dormancy regulating chemicals (DRC) and NaCl concentration on final germination percentages (mean ± standard error) of *Panicum turgidum* seed

| DRS | NaCl conc.( mM ) | | | | |
|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | Overall |
| Control | 65.0 ± 3.4 | 20.0 ± 5.4 | 0.0 ± 0.0 | 0.0 ± 0.0 | 21.3 ± 7.0 |
| Ethephon | 5.0 ± 1.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 1.3 ± 0.6 |
| Fusicoccin | 67.0 ± 1.9 | 32.0 ± 2.3 | 3.0 ± 1.0 | 0.0 ± 0.0 | 25.5 ± 7.0 |
| $GA_3$ | 71.0 ± 3.8 | 65.0 ± 2.5 | 8.0 ± 1.6 | 0.0 ± 0.0 | 36.0 ± 8.4 |
| Kinetine | 47.0 ± 3.0 | 40.0 ± 1.6 | 0.0 ± 0.0 | 0.0 ± 0.0 | 21.8 ± 5.7 |
| Nitrate | 70.0 ± 2.0 | 17.0 ± 1.9 | 0.0 ± 0.0 | 0.0 ± 0.0 | 21.8 ± 7.4 |
| Thiourea | 74.0 ± 1.2 | 46.0 ± 2.6 | 3.0 ± 1.0 | 0.0 ± 0.0 | 30.8 ± 8.0 |
| Overall | 57.0 ± 4.5 | 31.4 ± 3.9 | 2.0 ± 0.6 | 0.0 ± 0.0 | |

Table 22: Effects of dormancy regulating chemicals (DRC) and NaCl concentration on germination rate (mean ± standard error) of *Panicum turgidum* seed

| DRS | NaCl conc.( mM ) | | | | |
|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | Overall |
| Control | 41.2 ± 0.6 | 34.9 ± 3.3 | 0.0 ± 0.0 | 0.0 ± 0.0 | 19.0 ± 5.0 |
| Ethephon | 46.4 ± 2.1 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 11.6 ± 5.2 |
| Fusicoccin | 48.3 ± 0.6 | 40.4 ± 1.1 | 30.4 ± 10.3 | 0.0 ± 0.0 | 29.8 ± 5.3 |
| $GA_3$ | 49.4 ± 0.2 | 43.9 ± 0.4 | 34.8 ± 0.9 | 0.0 ± 0.0 | 32.0 ± 5.0 |
| Kinetin | 47.9 ± 0.5 | 44.0 ± 0.7 | 0.0 ± 0.0 | 0.0 ± 0.0 | 23.0 ± 5.9 |
| Nitrate | 45.7 ± 1.3 | 39.0 ± 2.1 | 0.0 ± 0.0 | 0.0 ± 0.0 | 21.2 ± 5.5 |
| Thiourea | 48.9 ± 0.3 | 38.8 ± 1.0 | 17.9 ± 6.2 | 0.0 ± 0.0 | 26.4 ± 5.1 |
| Overall | 46.8 ± 0.6 | 34.4 ± 2.8 | 11.9 ± 3.2 | 0.0 ± 0.0 | |

Table 23: Two-way ANOVA showing the effect of NaCl concentrations and dormancy regulation chemicals (DRC) on final germination percentage and germination rate of *Panicum turgidum* and *Lasiurus scindicus* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| ***Panicum turgidum*** | | | | |
| **A**: Final germination percentage | | | | |
| Salinity | 3 | 2.46 | 1183.432 | <0.001 |
| DRC | 6 | 0.231 | 110.924 | <0.001 |
| Salinity * DRC | 18 | 0.099 | 47.635 | <0.001 |
| Error | 84 | 0.002 | | |
| **B**: Germination rate | | | | |
| Salinity | 3 | 86.863 | 404.129 | <0.001 |
| DRC | 6 | 6.25 | 29.08 | <0.001 |
| Salinity * DRC | 18 | 3.878 | 18.041 | <0.001 |
| Error | 84 | 0.215 | | |
| ***Lasiurus scindicus*** | | | | |
| **A**: Final germination percentage | | | | |
| Salinity | 4 | 0.965 | 160.771 | <0.001 |
| DRC | 6 | 0.632 | 105.365 | <0.001 |
| Salinity * DRC | 24 | 0.05 | 8.387 | <0.001 |
| Error | 105 | 0.006 | | |
| **B**: Germination rate | | | | |
| Salinity | 4 | 0.347 | 36.438 | <0.001 |
| DRC | 6 | 0.175 | 18.401 | <0.001 |
| Salinity * DRC | 24 | 0.017 | 1.737 | <0.05 |
| Error | 102 | 0.01 | | |

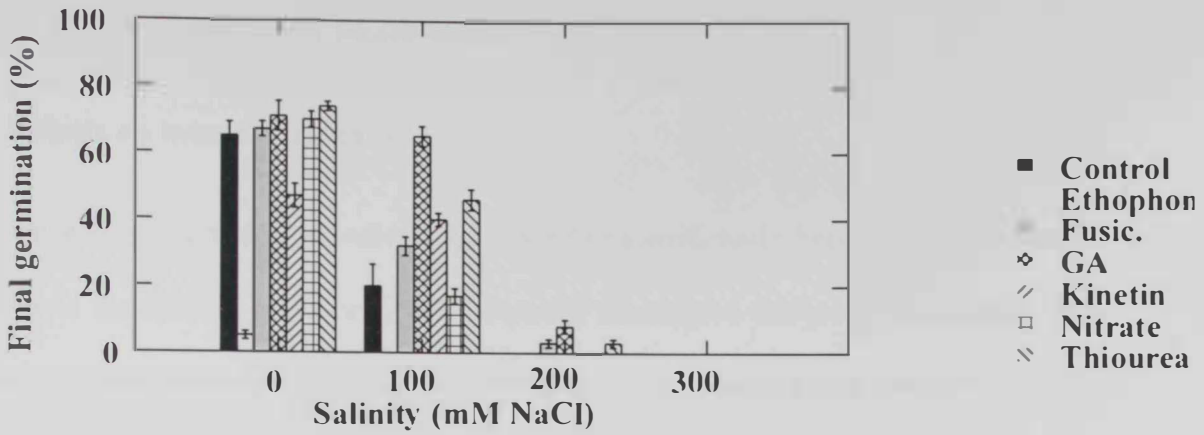



Figure 11: Effect of salinity and different dormancy reliving substances on final germination percentage (mean ± SE) of *Panicum turgidum* seeds

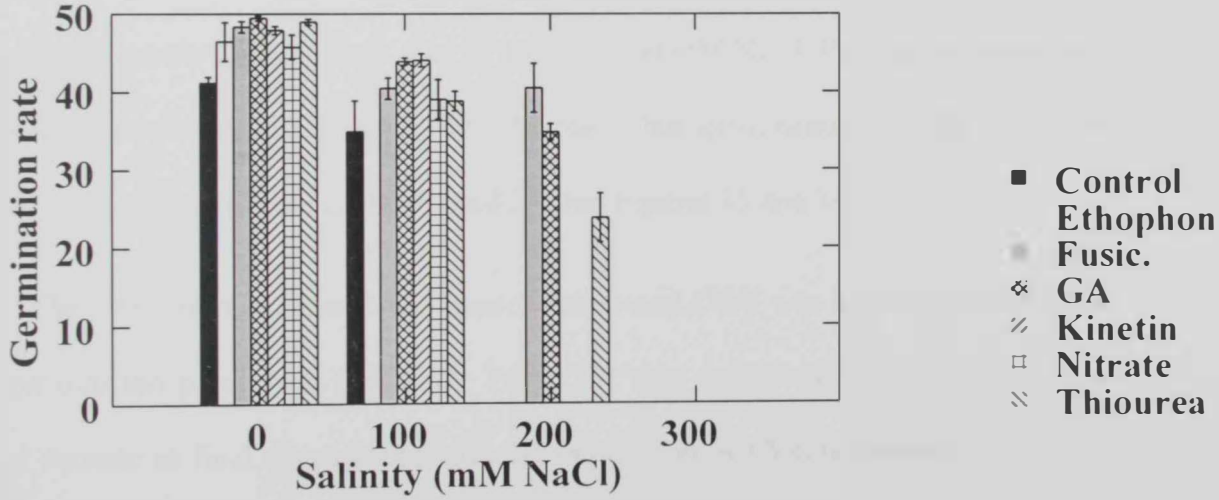



Figure 12: Effect of salinity and different dormancy reliving substances on germination rate (mean ± SE) of *Panicum turgidum* seeds

## 3.8. Effects Dormancy Regulating Chemicals on Innate and Salinity-Induced Dormancy of *Lasiurus scindicus*

### 3.8.1. Effects on innate dormancy

The final germination of *L. scindicus* did not differ significantly between control (water) and five of the DRCs (fusicoccin, $GA_3$, kinetin, nitrate and thiourea), but significantly reduced for seeds treated with ethephon ($P<0.001$). This indicates that none of the DRCs alleviated the lower innate dormancy of *L. scindicus* seeds (Table 24, Figure 13). The same showed also that all DRCs enhanced the germination rate compared to the control (Table 25, Figure 14).

### 3.8.2. Effects on salinity induced dormancy

Both NaCl concentration and DRC and their interaction affected final germination and germination rate of *L. scindicus* seeds ($P<0.01$, Table 23). Overall final germination and germination rate did not differ significantly between 0, 50 and 100 mM NaCl and all attained significantly higher values than in 150 and 200 mM NaCl. Final germination was significantly greater in 150 than in 200 mM NaCl, but germination rate did not differ between these two salinities (Tables 24 and 25, and Figures 13 and 14).

The interaction between NaCl concentration and DRC was highly significant for final germination percentage ($P<0.001$, Table 23). For non-treated seeds, there was a gradual decease in final germination with the increase in NaCl concentrations. All final germination values differed significantly from each other at the different concentrations. However, there was no significant difference in final germination between 0, 50 and 100 mM NaCl for seeds treated with fusicoccin, $GA_3$, nitrate and thiourea. These DRCs completely alleviated salinity induced dormancy in *L. scindicus*. For seeds treated with

the same DRCs, final germination in 150 and 200 mM NaCl were significantly lower than that in 0, 50 and 100 mM NaCl. These DRCs partially succeeded in alleviating salinity induced dormancy at higher salinities. For seeds treated with kinetin, final germination did not differ insignificantly between seeds treated in 0 and 50 mM NaCl, and it was significantly greater in these salinities than in 100, 150 and 200 mM NaCl. The alleviation in salinity induced dormancy by kinetin was complete in 50 mM, but was partial in 100, 150 and 150 NaCl. Application of ethephon resulted in significant reduction in final germination of *L. scindicus* in all salinities, including the control (Table 24, Figure 13).

There was a significant effect of the interaction between NaCl concentration and DRC on germination rate of percentage of *L. scindicus* ($P<0.05$, Table 23). Whereas germination rate was significantly reduced in 100, 150 and 200 mM NaCl, compared with 0 and 50 mM NaCl, for control, it did not significantly reduced in 100 and 150 mM NaCl for seeds for seeds treated with fusicoccin, kinetin and thiourea and in 100 mM NaCl for seeds treated with $GA_3$, nitrate and ethephon (Table 25, Figure 14).

Table 24: Effects of dormancy regulating chemicals (DRC) and NaCl on final germination percentages (mean ± standard error) of *Lasiurus scindicus* seed

| DRC | NaCl conc.( mM ) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 | Overall |
| Control | 76.3 ± 4.3 | 58.8 ± 5.2 | 47.5 ± 3.2 | 25.0 ± 2.0 | 8.8 ± 2.4 | 43.3 ± 5.7 |
| Ethephon | 26.3 ± 1.3 | 15.0 ± 2.0 | 11.3 ± 3.1 | 2.5 ± 1.4 | 3.8 ± 1.3 | 11.8 ± 2.1 |
| Fusicoccin | 70.0 ± 2.0 | 66.3 ± 2.4 | 65.0 ± 4.6 | 48.8 ± 2.4 | 43.8 ± 4.3 | 58.7 ± 2.7 |
| $GA_3$ | 65.0 ± 2.9 | 72.5 ± 4.8 | 68.8 ± 3.8 | 47.5 ± 1.4 | 17.5 ± 1.4 | 54.3 ± 4.8 |
| Kinetine | 68.8 ± 2.4 | 68.8 ± 3.8 | 52.5 ± 1.4 | 41.3 ± 1.3 | 38.8 ± 3.8 | 54.0 ± 3.2 |
| Nitrate | 68.8 ± 2.4 | 61.3 ± 2.4 | 66.3 ± 3.7 | 36.3 ± 3.1 | 10.0 ± 2.0 | 48.5 ± 5.3 |
| Thiourea | 62.5 ± 3.2 | 55.0 ± 2.9 | 65.0 ± 5.0 | 53.8 ± 2.4 | 42.5 ± 4.3 | 55.8 ± 2.3 |
| Overall | 62.5 ± 3.1 | 56.8 ± 3.6 | 53.7 ± 3.8 | 36.4 ± 3.2 | 23.6 ± 3.3 | |

Table 25: Effects of dormancy regulating chemicals (DRC) and NaCl on germination rate (mean ± standard error) of *Lasiurus scindicus* seed

| DRS | NaCl conc.( mM ) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 | Overall |
| Control | 44.5 ± 1.0 | 42.6 ± 0.9 | 34.4 ± 1.8 | 34.4 ± 2.2 | 31.5 ± 2.5 | 37.5 ± 1.4 |
| Ethephon | 49.3 ± 0.4 | 49.1 ± 0.9 | 46.4 ± 2.1 | 19.6 ± 12.2 | 32.1 ± 11.8 | 39.3 ± 4.1 |
| Fusicoccin | 49.7 ± 0.3 | 49.2 ± 0.3 | 47.5 ± 1.1 | 44.4 ± 1.7 | 40.9 ± 0.8 | 46.3 ± 0.9 |
| $GA_3$ | 47.7 ± 0.8 | 43.4 ± 1.3 | 41.6 ± 1.3 | 38.6 ± 1.8 | 28.9 ± 1.7 | 40.0 ± 1.6 |
| Kinetine | 49.7 ± 0.1 | 49.7 ± 0.1 | 48.3 ± 0.3 | 48.2 ± 0.8 | 44.4 ± 1.3 | 48.1 ± 0.5 |
| Nitrate | 49.6 ± 0.3 | 47.5 ± 0.5 | 43.5 ± 0.9 | 38.3 ± 2.5 | 35.4 ± 3.4 | 42.9 ± 1.5 |
| Thiourea | 49.4 ± 0.5 | 49.7 ± 0.3 | 49.2 ± 0.6 | 41.3 ± 2.8 | 40.5 ± 2.3 | 46.0 ± 1.2 |
| Overall | 48.6 ± 0.4 | 47.3 ± 0.6 | 44.4 ± 1.0 | 37.8 ± 2.3 | 36.3 ± 1.9 | |

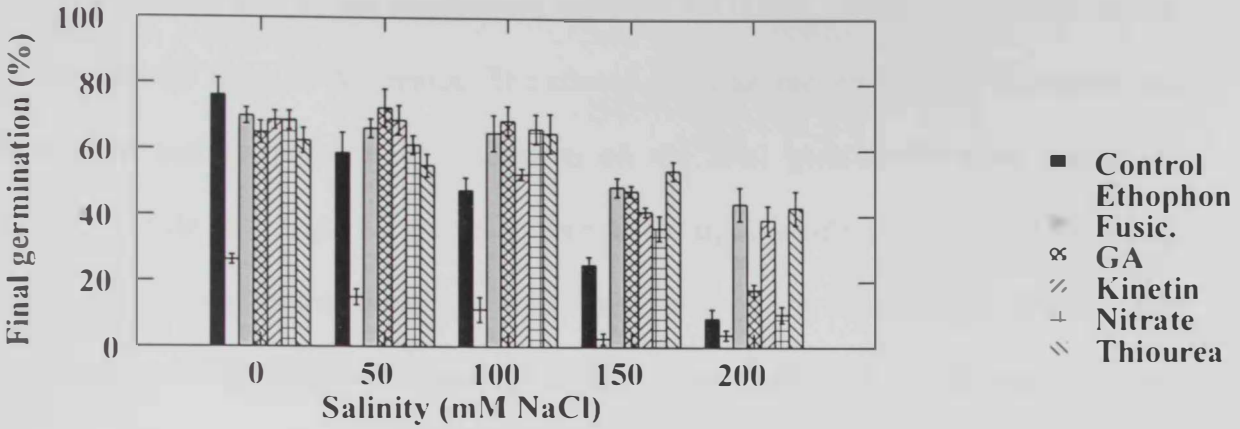



Figure 13: Effect of salinity and different dormancy reliving substances on final germination percentage (mean ± SE) of *Lasiurus scindicus* seeds

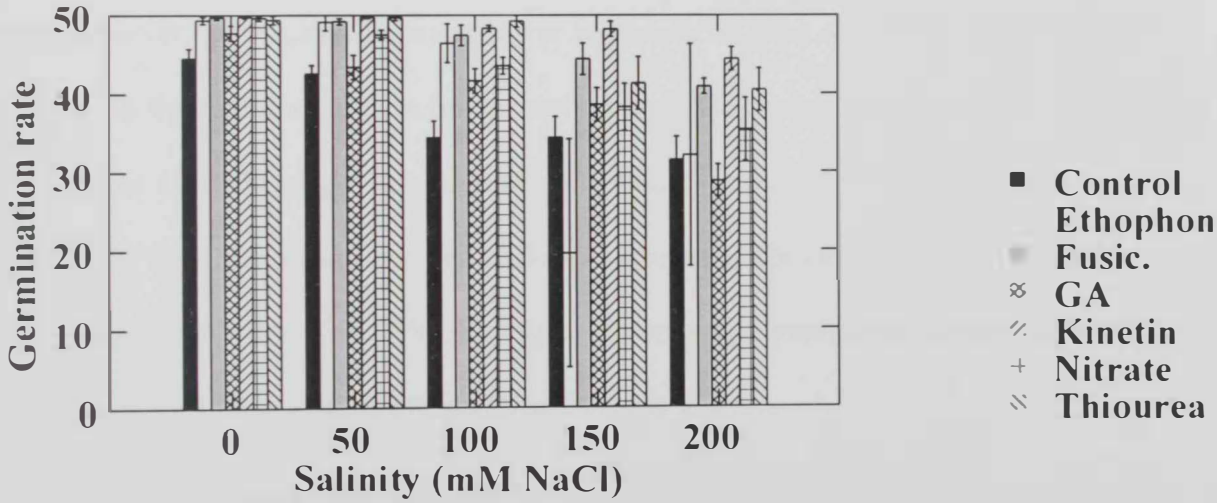



Figure 14: Effect of salinity and different dormancy reliving substances on germination rate (mean ± SE) of *Lasiurus scindicus* seeds

## 3.9. Effect of Fruit Color on Germination of *Lasiurus scindicus*

### 3.9.1. Effects on final germination

Fruit color affected light and temperature requirements during germination of *L. scindicus* seeds collected from Al-Ain region. The effects of the interaction between fruit color and both light and temperature of incubation on the final germination were significant ($P<0.01$, Table 26). Light brown seeds germinated significantly greater than dark brown seeds. Similarly, germination in light was significantly greater than in dark. The optimum temperature for germination is present at 25°C. Germination at 20, 25 and 30°C was significantly greater than it at 15 and 35°C and all attained greater germination than at 40°C.

The interaction between the fruit color, light and temperature of incubation was significant, indicating that light brown and dark brown seeds responded differently to both light and temperature of the incubation. Light brown seeds germinated better at higher temperatures (35 and 40°C) than at lower temperature (15°C) in light. Dark brown seeds, however, germinated better at lower temperatures than at 40°C in both light and darkness. In light condition, dark brown seeds germinated greater than light brown seeds by 26.3% at 15°C, but light brown seeds germinated greater than dark brown seeds by 66.6% at 40°C. In darkness, however, dark brown and light brown seeds attained almost a similar germination level at 15°C, but light brown seeds germinated greater than dark brown seeds by 53.8% at 40°C (Table 27 and Figure 15).

Optimum temperature for germination of the dark brown and light brown seeds differed according to both light and temperature of incubation. For light brown seeds, there was no significant difference between the temperatures ranged between 20–40°C in light, but optimum germination was at 20, 25 and 30°C in darkness. For dark brown

seeds, there was no significant difference between 15 and 35°C in light, but optimum germination was 25 and 30°C. This result indicates that light brown seeds germinated better at warmer temperatures than at cooler temperatures under light condition, but the reverse was true for dark brown seeds. In darkness, both dark brown and light brown fruits germinated better at a range of temperatures between 15 and 30°C, than at higher temperatures (35 and 40°C) (Table 27 and Figure 15).

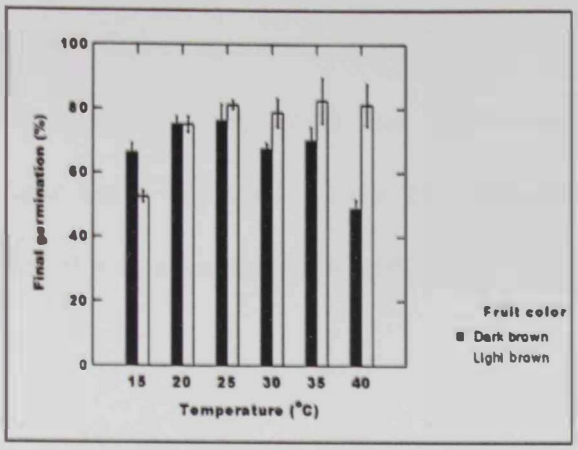
Table 26: Three-way ANOVA showing the effects of fruit color, temperature and light and their interactions on final germination percentage of *Lasiurus scindicus* seeds collected from natural habitats of Al-Ain region

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Fruit color (FC) | 1 | 0.071 | 5.23 | <0.05 |
| Light (L) | 1 | 0.150 | 11.12 | <0.01 |
| Temperature (T) | 5 | 0.228 | 16.86 | <0.001 |
| FC *L | 1 | 0.121 | 8.97 | <0.01 |
| FC*T | 5 | 0.103 | 7.61 | <0.001 |
| L*T | 5 | 0.120 | 8.89 | <0.001 |
| FC*L*T | 5 | 0.035 | 2.61 | <0.05 |
| Error | 72 | 0.014 | | |

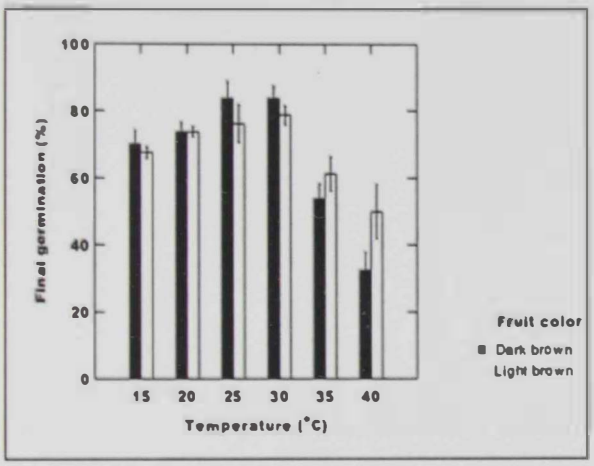
Table 27: Effects of fruit color, maternal habitat, temperature and light of incubation on final germination percentage (mean ± standard error) of *Lasiurus scindicus* seed

| Fruit origin | Fruit color | Light | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|---|
| | | | 15 | 20 | 25 | 30 | 35 | 40 | |
| Al-Ain | Light brown | Light | 52.5 ± 1.4 | 75.0 ± 2.0 | 81.3 ± 1.3 | 78.8 ± 3.8 | 82.5 ± 6.0 | 81.3 ± 5.5 | 75.2 ± 2.6 |
| | | Dark | 67.5 ± 1.4 | 73.8 ± 1.3 | 76.3 ± 4.7 | 63.8 ± 3.1 | 61.3 ± 4.3 | 50.0 ± 6.8 | 65.4 ± 2.3 |
| | | Overall | 60.0 ± 3.0 | 74.4 ± 1.1 | 78.8 ± 2.5 | 71.3 ± 3.6 | 71.9 ± 5.3 | 65.6 ± 7.2 | 70.3 ± 1.9 |
| | Dark brown | Light | 66.3 ± 2.4 | 75.0 ± 2.0 | 76.3 ± 4.3 | 67.5 ± 4.3 | 70.0 ± 3.5 | 48.8 ± 2.4 | 67.3 ± 2.2 |
| | | Dark | 70.0 ± 3.5 | 73.8 ± 2.4 | 83.8 ± 4.3 | 78.8 ± 3.8 | 53.8 ± 3.8 | 32.5 ± 4.3 | 65.4 ± 3.9 |
| | | Overall | 68.1 ± 2.1 | 74.4 ± 1.5 | 80.0 ± 3.1 | 73.1 ± 3.4 | 61.9 ± 3.9 | 40.6 ± 3.8 | 66.4 ± 2.2 |
| | Overall | Light | 59.4 ± 2.9 | 75.0 ± 1.3 | 78.8 ± 2.3 | 73.1 ± 3.4 | 76.2 ± 4 | 65.0 ± 6.7 | 71.3 ± 1.8 |
| | | Dark | 68.8 ± 1.8 | 73.8 ± 1.3 | 80.0 ± 3.3 | 71.3 ± 3.6 | 57.5 ± 3 | 41.3 ± 5 | 65.4 ± 2.2 |
| | | Overall | 64.1 ± 2.0 | 74.4 ± 0.9 | 79.3 ± 1.9 | 72.2 ± 2.4 | 66.9 ± 3.4 | 53.1 ± 5.1 | 68.3 ± 1.4 |
| Al-Dhaid | Light brown | Light | 22.5 ± 2.5 | 33.8 ± 3.1 | 21.3 ± 3.1 | 13.8 ± 1.3 | 7.5 ± 1.4 | 3.8 ± 2.4 | 17.1 ± 2.3 |
| | | Dark | 33.8 ± 3.8 | 22.5 ± 1.4 | 13.8 ± 2.4 | 5.0 ± 0.0 | 1.3 ± 1.3 | 1.3 ± 1.3 | 12.9 ± 2.9 |
| | | Overall | 28.1 ± 3.0 | 28.1 ± 2.7 | 17.5 ± 2.3 | 9.4 ± 1.8 | 4.4 ± 1.5 | 2.5 ± 1.3 | 15 ± 1.7 |

A: Germination in light




B: Germination in darkness




C: Overall light and dark germination

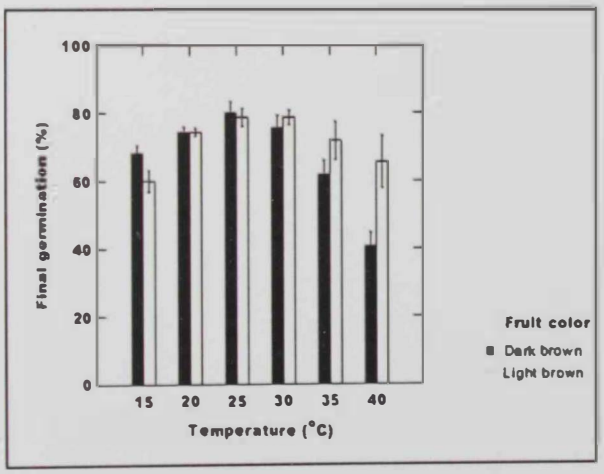



Figure 15: Effects of fruit color (dark brown and light brown fruits) on temperature and light requirements during germination of *Lasiurus scindicus* seeds (mean ± standard error) of final germination collected from natural habitats of Al Ain

### 3.9.2 Effects on germination rate index

Two-way ANOVA indicated that temperature of incubation, but not fruit color and the interaction between fruit color and temperature, had significant effects on germination rate index *of L. scindicus* seeds ($P<0.001$, Table 28). Germination was significantly slower at 15°C than at the other temperatures (20–40°C) (Figure 16, Table 29).

Table 28: Three-way ANOVA showing the effects of fruit color and temperature of incubation and their interactions on germination rate index of *Lasiurus scindicus* seed collected from natural habitats of Al-Ain region

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Fruit color (FC) | 1 | 0.004 | 2.385 | ns |
| Light (L) | 1 | 47094.459 | 31745.585 | <0.001 |
| Temperature (T) | 5 | 0.081 | 50.05 | <0.001 |
| FC *L | 1 | 8.775 | 5.915 | <0.05 |
| FC*T | 5 | 0.004 | 2.34 | ns |
| L*T | 5 | 70.918 | 47.804 | <0.001 |
| FC*L*T | 5 | 3.590 | 2.420 | <0.05 |
| Error | 36 | 0.002 | | |

ns = insignificant at P≤ 0.05

Table 29: Effects of fruit color, maternal habitat, temperature and light on germination rate index (mean ± standard error) of *Lasiurus scindicus* seeds

| Fruit origin | Fruit color | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| Al-Ain | Light brown | 32.8 ± 1.1 | 43.3 ± 0.6 | 45.2 ± 0.9 | 49.1 ± 0.3 | 49.4 ± 0.2 | 46.7 ± 1.2 | 44.9 ± 1.0 |
| | Dark brown | 37.4 ± 0.3 | 42.6 ± 1.3 | 44.5 ± 1.0 | 47.2 ± 0.8 | 45.2 ± 0.7 | 45.2 ± 0.9 | 43.7 ± 0.7 |
| | Overall | 36.6 ± 0.6 | 43.0 ± 0.7 | 44.8 ± 0.7 | 48.2 ± 0.5 | 47.3 ± 0.9 | 45.9 ± 0.8 | 45.7 ± 1.0 |
| Al-Dhaid | Light brown | 39.2 ± 1.5 | 42.3 ± 1.0 | 48.5 ± 0.5 | 50.0 ± 0.0 | 46.4 ± 2.1 | 50.0 ± 0.0 | 45.7 ± 1.0 |

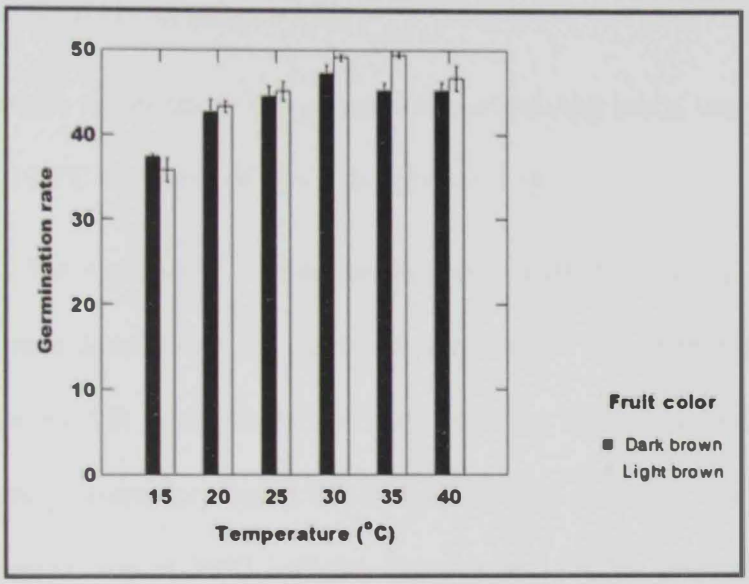



Figure 16: Effects of fruit color (dark brown and light brown fruits) and temperature on germination rate index (mean ± standard error) of *Lasiurus scindicus* seeds collected from natural habitats of Al Ain region

## 3.10. Effects of Maternal Habitat on Germination of *Lasiurus scindicus*

### 3.10.1. Effects on final germination

There was significant effects of maternal habitat, light and temperature of incubation on final germination of *L. scindicus* seeds ($P<0.001$). The effects of the interactions between these factors were also significant ($P<0.01$, Table 30). Seeds of natural population of Al-Ain germinated significantly greater (70.3%) than those matured under experimental conditions in Al-Dhaid (15%, (Figure 17)).

The optimum temperature for germination of Al-Ain seeds was at 20 and 25°C, but was at 15 and 20°C for seeds of Al-Dhaid (Figure 17).

Similarly, the significant interaction between maternal habitat, temperature and light of incubation indicates that the light and temperature requirements differed for the two seed lots. For Al-Ain seeds, there was no significant difference between 20–40°C in light, but optimum germination was at 20, 25 and 30°C in darkness. For Al-Dhaid seeds, optimum germination was at 20°C in light, but was at 15°C in dark. Little germination occurred at higher temperatures, especially in darkness (Figure 17).

### 3.10.2. Effects on germination rate index

Two-way ANOVA indicated that temperature of incubation and the interaction between maternal habitat and temperature, but not maternal habitat, had significant effect on germination rate index of *L. scindicus* seeds ($P<0.05$, Table 31). Germination was significantly slower at 15 and 20°C than at the other temperatures (25–40°C) (Figure 18, Table 32).

Table 30: Three-way ANOVA showing effects of maternal habitat, temperature and light on final germination percentage of *Lasiurus scindicus* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Maternal habitat (M) | 1 | 10.018 | 1101.58 | <0.001 |
| Light (L) | 1 | 0.222 | 24.37 | <0.001 |
| Temperature (T) | 5 | 0.072 | 7.87 | <0.001 |
| M *L | 1 | 0.070 | 7.73 | <0.01 |
| M*T | 5 | 0.103 | 11.31 | <0.001 |
| L*T | 5 | 0.077 | 8.49 | <0.001 |
| M*L*T | 5 | 0.042 | 4.67 | <0.01 |
| Error | 72 | 0.009 | | |

Table 31: Three-way ANOVA showing effects of maternal habitat and temperature of incubation on germination rate index of *Lasiurus scindicus*.

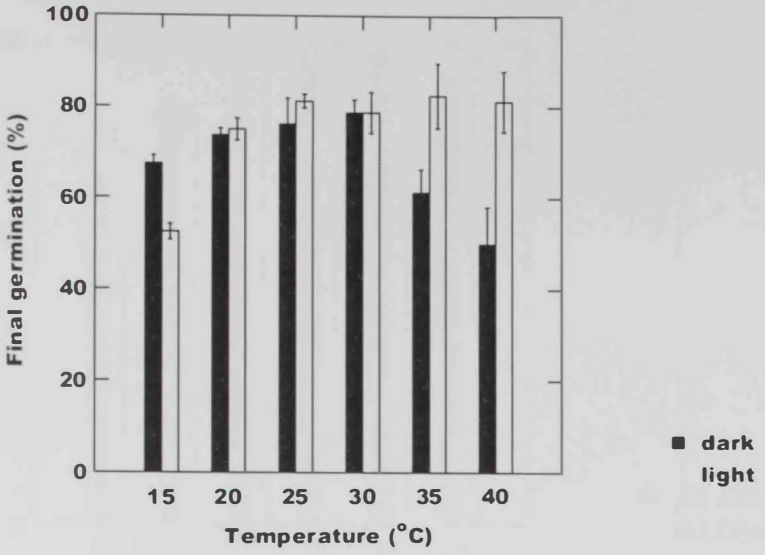
| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Maternal habitat (M) | 1 | 0.008 | 3.49 | ns |
| Temperature (T) | 5 | 0.088 | 37.91 | <0.001 |
| M *L | 5 | 0.007 | 3.16 | <0.05 |
| M *L | 34 | 0.002 | | |
| Error | | | | |

ns = insignificant at P≤ 0.05

Table 32: Effects of fruit color, origin, temperature and light on germination rate index (mean ± standard error) of *Lasiurus scindicus* seeds

| Fruit origin | Fruit color | Temperature | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 15 | 20 | 25 | 30 | 35 | 40 | |
| Al-Ain | Light | 32.8 ± 1.1 | 43.3 ± 0.6 | 45.2 ± 0.9 | 49.1 ± 0.3 | 49.4 ± 0.2 | 46.7 ± 1.2 | 44.9 ± 1.0 |
| | Dark | 37.4 ± 0.3 | 42.6 ± 1.3 | 44.5 ± 1.0 | 47.2 ± 0.8 | 45.2 ± 0.7 | 45.2 ± 0.9 | 43.7 ± 0.7 |
| | Overall | 36.6 ± 0.6 | 43.0 ± 0.7 | 44.8 ± 0.7 | 48.2 ± 0.5 | 47.3 ± 0.9 | 45.9 ± 0.8 | 45.7 ± 1.0 |
| Al-Dhaid | Light | 39.2 ± 1.5 | 42.3 ± 1.0 | 48.5 ± 0.5 | 50.0 ± 0.0 | 46.4 ± 2.1 | 50.0 ± 0.0 | 45.7 ± 1.0 |

A: Fruits matured in natural habitats of Al-Ain




B: Fruits matured under experimental conditions in Al-Dhaid

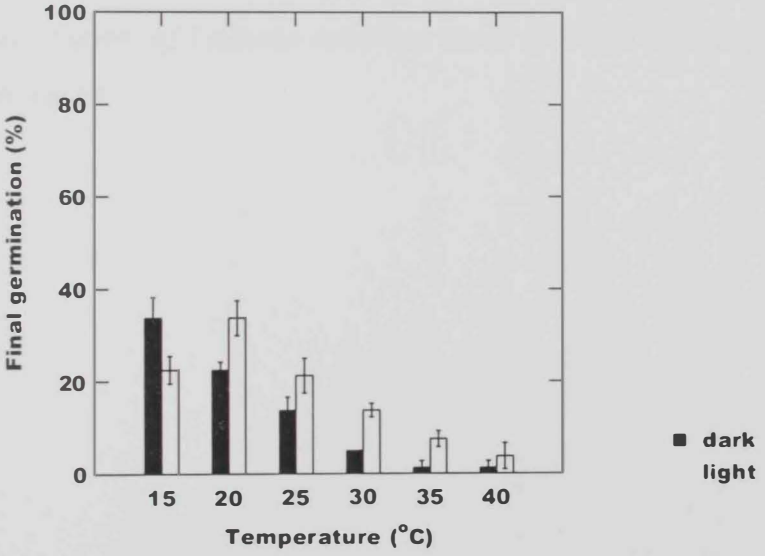



Figure 17: Effects of maternal habitat on temperature and light requirements during germination of *Lasiurus scindicus* seeds (mean ± standard error) of final germination percentage

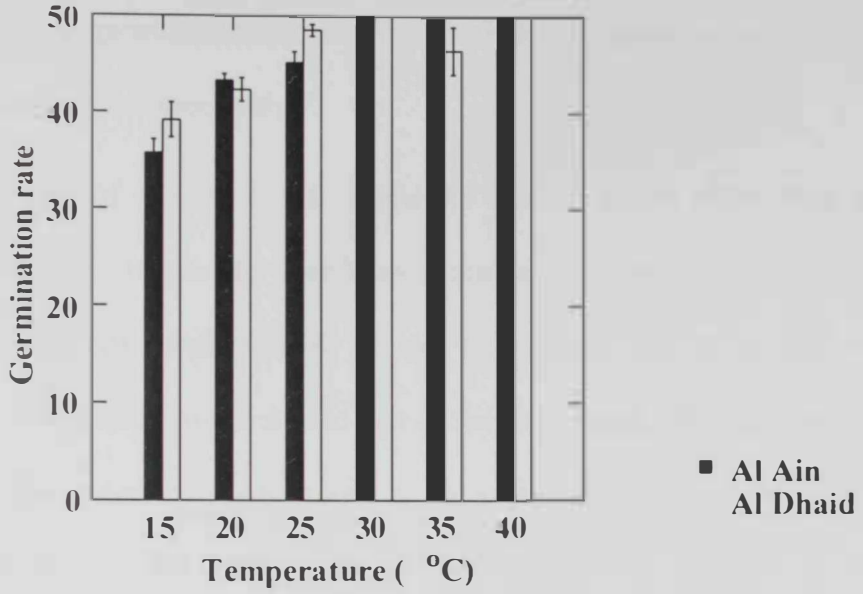



Figure 18: Effects of maternal habitat and temperature on germination rate index (mean ± standard error) of *Lasiurus scindicus* seeds collected from natural habitats of Al Ain region

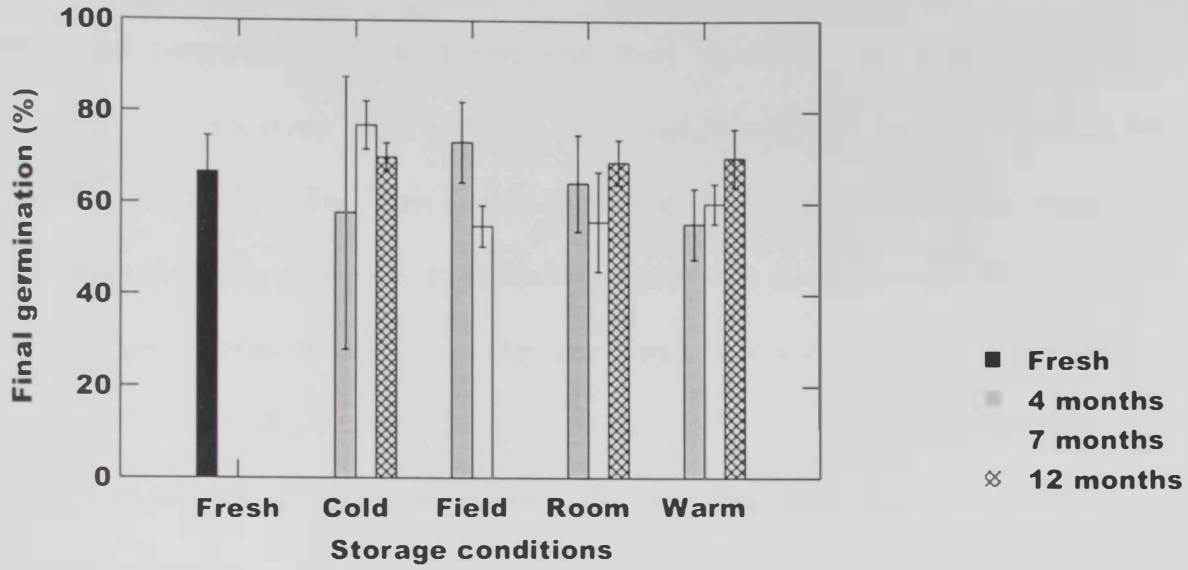
## 3.11. Effect of Seed Storage in *Lasiurus scindicus*

Fresh seeds of *L. scindicus* didn't show great innate dormancy and attained fast germination. Final germination and the Timson index of germination rate of fresh seeds were 66.7% and 40.3, respectively.

The effect of storage for 4, 7 and 12 months didn't affect final germination percentage ($P>0.05$), but led to significant increase in germination rate ($P<0.01$). Final germination of seeds stored for 4, 7 and 12 months was 62.8, 62.7 and 69.7%, respectively, which was comparable to that of the fresh seeds (66.7%). However, Timson germination rate index for seeds stored at the same periods increased over that of the fresh seeds by 13%, 19.3% and 17%, respectively (Figure 19).

Different storage conditions did not affect significantly either final germination percentage or germination rate ($P>0.05$). Final germination of seeds stored in cold, field, room temperatures and warm were 69.2%, 62.9%, 63% and 62.4%, respectively, compared to 66.7% for the fresh seeds. Similarly, germination rate index of seeds stored in cold, field, room temperatures and warm were 46.5, 46.5, 46.6 and 47, respectively, compared to 40 for the fresh seeds (Figure 19).

A: Final germination




B: Germination rate

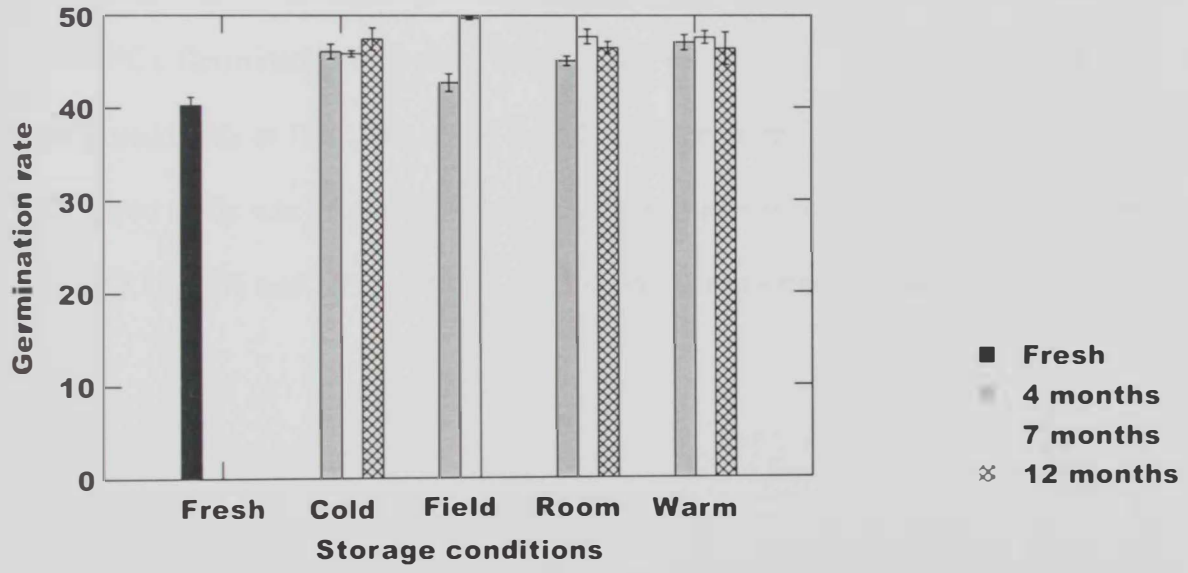
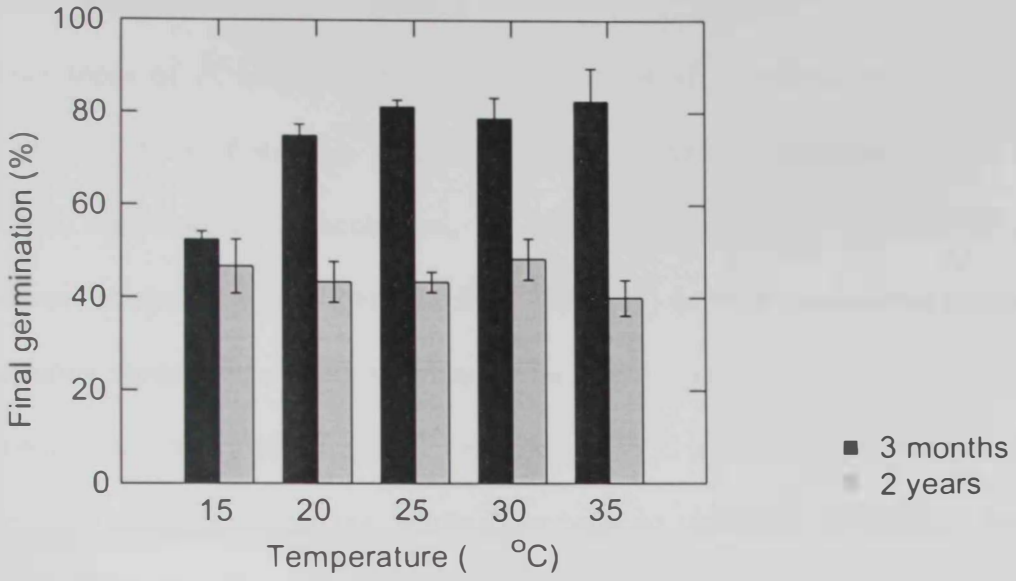



Figure 19: Effects of storage condition and storage duration on final germination percentage and germination rate index (mean ± standard error) of *Lasiurus scindicus* seeds

The temperature requirement was assessed for seeds stored in room temperatures for three months and two years. Two-way ANOVA showed significant effects for storage period and temperature of incubation and their interaction on final germination percentage of *L. scindicus* seeds ($P<0.01$). Generally, storage for two years resulted in significant reduction in final germination. This was clear at all temperatures, except at 15°C, where there was no significant effect between the two storage periods. At 20, 25, 30 and 35°C, germination of 3-months stored seeds was greater than that of 2-years stored seeds by 73.2%, 87.7%, 70.2% and 106%, respectively (Figure 20a). This indicates that the high temperature and light requirement for 3-months stored seeds was lost after 2 years of seed storage.

There was significant effects of storage period and temperature of incubation and their interaction on germination rate index of *L. scindicus* seeds ($P<0.01$). Germination at lower temperatures (15 and 20°C) was significantly slower than it at higher temperatures (30 and 35°C). Germination of 2-years stored seeds was significantly faster than that of 3-months stored seeds at 15°C, but not at the other temperatures. Germination rate index of 2-years stored seeds was greater than that of 3-months stored seeds by 20.4% at 15°C, but by 11.8%, 7.1%, 2% and 1.2% at 20, 25, 30 and 35°C, respectively (Figure 20 b).

A: Final germination percentage




B: Germination rate

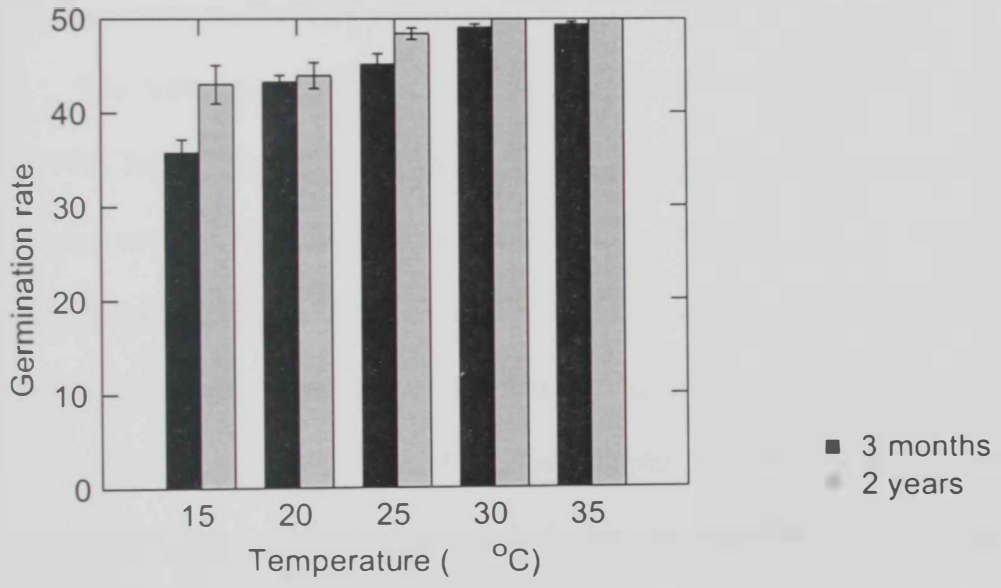



Figure 20: Effects of storage period and temperature of incubation on final germination percentage and germination rate (mean ± standard error) of *Lasiurus scindicus* seeds

## 3.12. Effects of Seed Storage in *Panicum turgidum*

### 3.12.1. Effects on final germination

Fresh seeds of *P. turgidum* did not germinate at all. Germination increased with the increase of time of storage. Three-way ANOVA showed significant effects for storage period, temperature of incubation, the interaction between them and the interaction between temperature and light ($P<0.001<$ Table 33) on final germination percentage of *P. turgidum* seeds. The overall germination increased from 14.2% after 1-year of storage to 23.4% after 2-years of storage. Germination at 15°C was significantly lower than that of the other higher temperatures. While there were no significant differences between final germination after one- and two-years seeds at both low (15°C) and high (40°C). Final germination was significantly greater for two-years, compared to one-year seeds at the other temperatures (Table 34 and Figure 21).

The interaction between light and temperature of incubation was significant ($P<0.001$, Table 33), indicating that the response of germination at different temperatures depended on light of incubation. At 15°C, final germination was very low and there was no significant difference between light and dark germination (7.5% and 5.0%, respectively). At 20 and 25°C, germination was greater in dark than in light, so the difference was significant only at 20°C. Germination in dark was greater than in light by 240% at 20°C, but by 49.5% at 25°C. At higher temperatures (30–40°C), germination in light was greater, compared to in dark, so the difference was significant only at 40°C. Germination in light was greater than in dark by 246% at 40°C, but by 18% and 43% at 30°C and 35°C, respectively (Table 34).

The interaction between storage period and temperature was significant, indicating that the response of the final germination to temperature of incubation depended on

storage period. At 15°C, final germination was very low and was significantly greater for 1-year stored seeds (10.6%), compared to 2-years seeds (1.9%). At 20-30°C, germination for 2-years stored seeds was greater than 1-year stored seeds, so the difference was insignificant at 20°C. Final germination at 20°C, 25°C, 30°C and 35°C was 18.8%, 12.5%, 13.8% and 8.8%, respectively, for 1-year stored seeds, and was 26.3%, 34.4%, 31.3% and 26.3%, respectively for 2-years stored seeds. At 40°C, there was insignificant difference between final germination of 1-year stored seeds (20.6%) and 2-years stored seeds (20.0%). The overall result indicates that optimum germination for 2-years seeds was at moderate temperatures (20–35°C), but there was no obvious trend for optimum germination of 1-year stored seeds (Table 34 and Figure 21).

### 3.12.2. Effects on germination rate

There was significant effects for storage period ($P<0.05$) and temperature of incubation ($P<0.01$), but not for their interaction ($P>0.05$) on Timson index of germination rate (Table 35). Germination was faster for seeds stored for two years, compared to it for seeds stored for one year (germination rate index was 45.6 and 44.1, respectively). In addition, germination speed increase with the increase in temperature of incubation (Figure 22, Table 34). Germination rate index was 41.5, 43.7, 43.9, 46.5, 46.5 and 45.8 for seeds germinated at 15, 20, 25, 30, 35 and 40°C, respectively.

Table 33: Three-way ANOVA testing the effects of storage period, and temperature and light of incubation on final germination percentage (mean ± standard error) of *Panicum turgidum* seeds

| Source of variation | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Storage period (S) | 1 | 0.215 | 63.40 | <0.001 |
| Temperature (T) | 5 | 0.071 | 20.86 | <0.001 |
| Light (L) | 1 | 0.002 | 0.56 | ns |
| S*T | 5 | 0.061 | 17.92 | <0.001 |
| S*L | 1 | 0.004 | 1.31 | ns |
| T*L | 5 | 0.117 | 34.37 | <0.001 |
| S*T*L | 5 | 0.008 | 2.26 | ns |
| Error | 72 | 0.003 | | |

ns = insignificant at P≤ 0.05

Table 34: Effects of storage period, and light and temperature of incubation on final germination percentage and germination rate index (mean ± standard error) of *Panicum turgidum* seeds

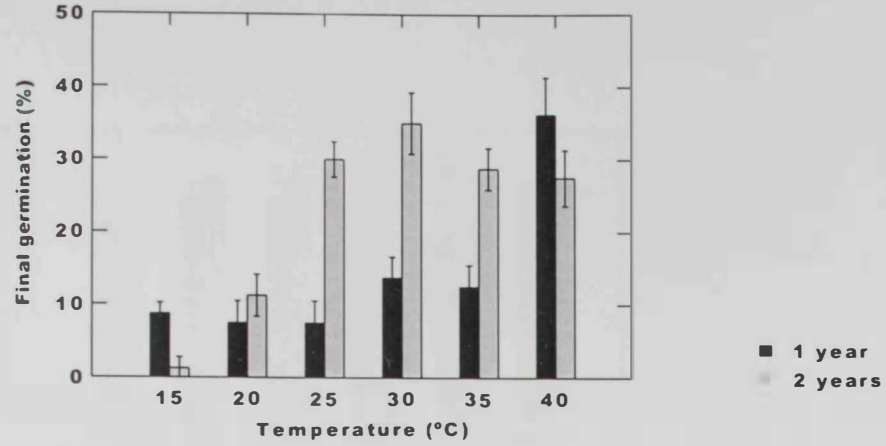
| Storage period | Temperature | Final Germination (%) | | | Germination rate |
|---|---|---|---|---|---|
| | | Light | Dark | Overall | |
| 1-year | 15 | 8.8+1.3 | 12.5±1.4 | 10.6±1.1 | 40.6±0.6 |
| | 20 | 7.5±2.5 | 30.0±3.5 | 18.8±4.7 | 42.5±1.4 |
| | 25 | 7.5±2.5 | 17.5±3.2 | 12.5±2.7 | 42.5±2.9 |
| | 30 | 13.8±2.4 | 13.8±3.1 | 13.8±1.8 | 46.3±1.3 |
| | 35 | 12.5±2.5 | 5.0±2.0 | 8.8±2.1 | 47.9±1.3 |
| | 40 | 36.3±4.3 | 5.0±3.5 | 20.6±6.4 | 44.6±1.0 |
| | Overall | 14.4±2.3 | 14.0±2.1 | 14.2±2.2 | 44.1±0.7 |
| 2-year | 15 | 1.3±1.3 | 2.5±2.5 | 1.9±1.3 | 45.0±0.0 |
| | 20 | 11.3±2.4 | 41.3±3.1 | 26.3±6.0 | 44.6±0.4 |
| | 25 | 30.0±2.0 | 38.8±3.8 | 34.4±2.6 | 45.0±0.0 |
| | 30 | 35.0±3.5 | 27.5±1.4 | 31.3±2.3 | 46.7±0.2 |
| | 35 | 28.8±2.4 | 23.8±4.3 | 26.3±2.5 | 45.1±0.8 |
| | 40 | 27.5±3.2 | 12.5±1.4 | 20.0±3.3 | 47.0±0.8 |
| | Overall | 22.3±2.7 | 24.4±3.0 | 23.4±2.9 | 45.6±0.3 |

Table 35: Two-way ANOVA testing the effects of storage period and temperature of incubation on germination rate of *Panicum turgidum* seeds

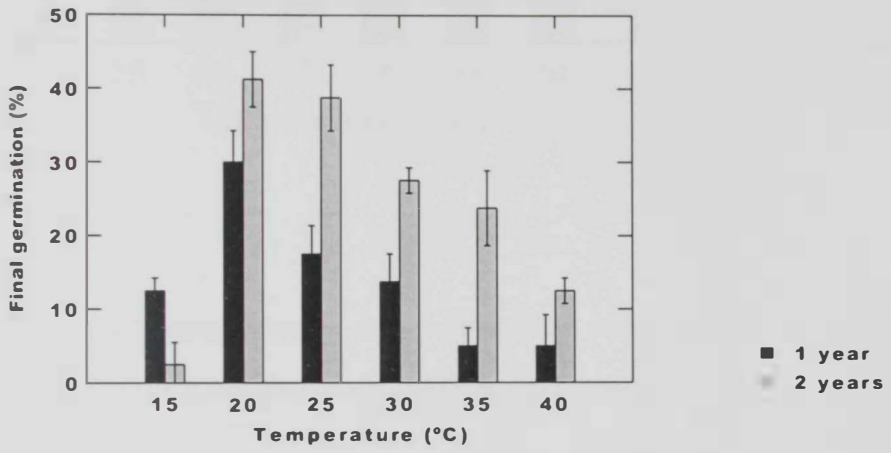
| Source | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|
| Storage period (S) | 1 | 0.012 | 5.467 | <0.05 |
| Temperature (T) | 5 | 0.008 | 3.716 | <0.01 |
| S*T | 5 | 0.005 | 2.200 | ns |
| Error | 31 | 0.002 | | |

ns = insignificant at $P \leq 0.05$

A: Germination in light




B: Germination in dark




C: Overall germination in light and dark

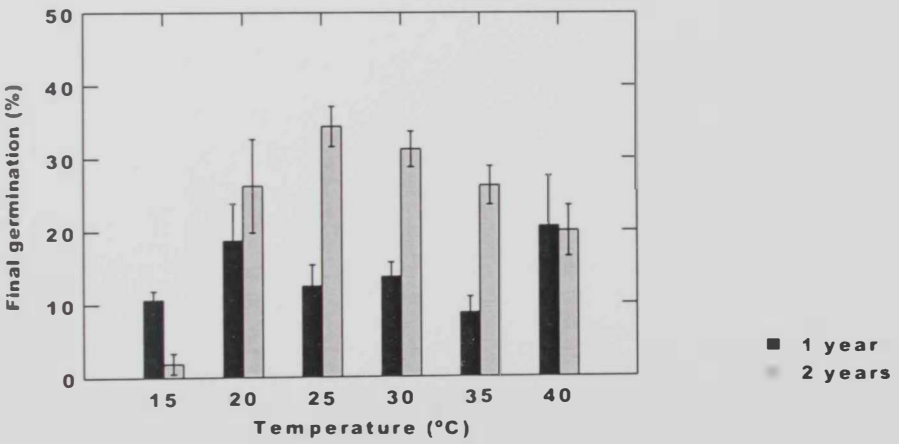



Figure 21: Effects of storage period, and light and temperature of incubation on final germination percentage (mean ± standard error) of *Panicum turgidum* seeds

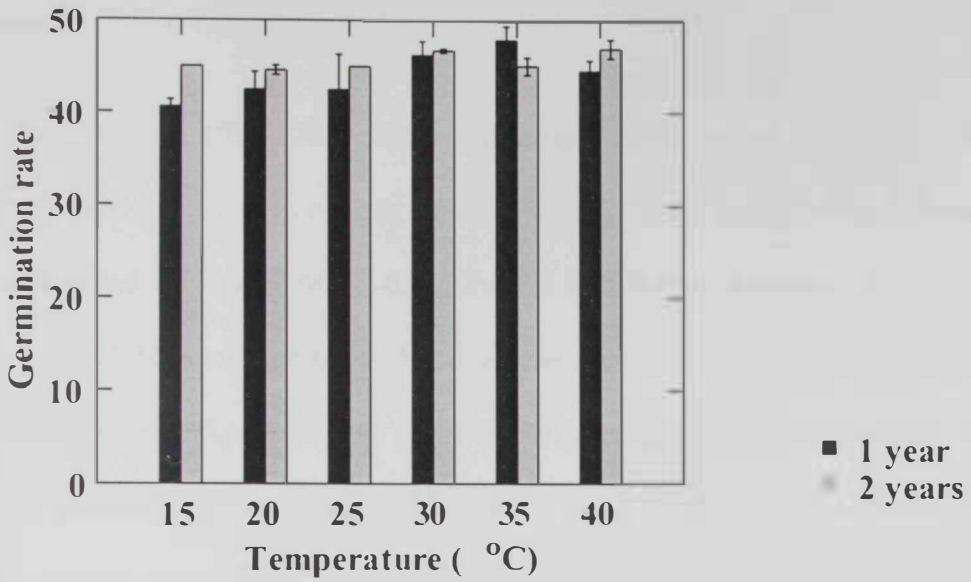



Figure 22: Effects of storage period and temperature of incubation on germination rate index (mean ± standard error) of *Panicum turgidum* seeds

## 3.13. Effect of Polyethylene Osmotic Pressure on Final Germination and Germination Rate of *Lasiurus scindicus* and *Panicum turgidum* Seeds

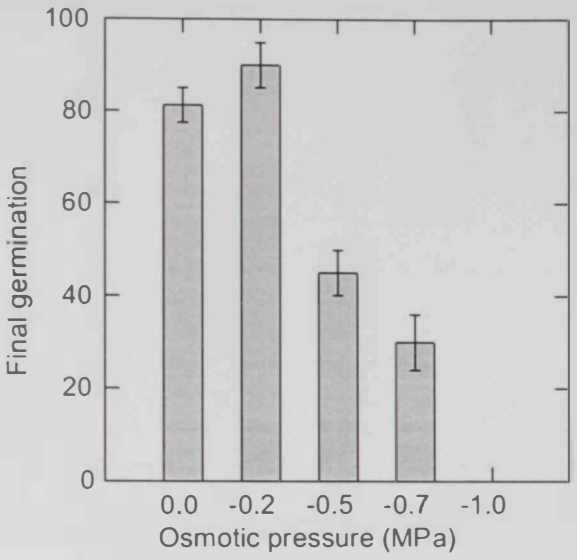
There was significant effects for polyethylene osmotic pressure on both final germination and germination rate of *L. scindicus* seeds ($P<0.01$). Final germination increased from 81.3% in distilled water to 90% in -0.2 MPa and then further decreased to 45% and 30% in -0.5 and -0.7 MPa, respectively. Final germination was completely inhibited in -1.0 MPa (Table 36 and Figure 23). In addition, Timson germination rate index decreased from 48.7 in distilled water to 47.1, 39.3, 27.5 and 0 in -0.2, -0.5, -0.7 and -1.0 PMa, respectively (Table 36 and Figure 23).

There was significant effects for polyethylene osmotic pressure on both final germination and germination rate of *P. turgidum* seeds ($P<0.01$). Generally, seeds of *P. turgidum* were less drought tolerant than those of *L. scindicus*. Seeds of *L. scindicus* germinated to 30% in -0.7 PMa, while those of *P. turgidum* were completely inhibited at -0.5 MPa. In addition, only 1.3% of the seeds germinated in -0.2 MPa. Germination speed of *P. turgidum* seeds was greatly reduced in -0.2 MPa (Table 36 and Figure 24).

Table 36: Effect of Polyethylene osmotic pressure on final germination and germination rate index (mean ± standard error) of *Lasiurus scindicus* and *Panicum turgidum* seeds

| Species | Osmotic pressure (MPa) | Final germination | | Germination rate | |
|---|---|---|---|---|---|
| | | Mean | SE | Mean | SE |
| *Lasiurus scindicus* | 0 | 81.3 | 3.1 | 48.7 | 0.1 |
| | -0.2 | 90 | 4.1 | 47.1 | 1.2 |
| | -0.5 | 45 | 4.1 | 39.3 | 0.7 |
| | -0.7 | 30 | 5 | 27.5 | 0.9 |
| | -1 | 0 | 0 | 0 | 0 |
| *Panicum turgidum* | 0 | 48.8 | 4.7 | 43.1 | 0.7 |
| | -0.2 | 1.3 | 1.3 | 7.5 | 7.5 |
| | -0.5 | 1.3 | 1.3 | 0 | 0 |

A: Final germination




B: Germination rate

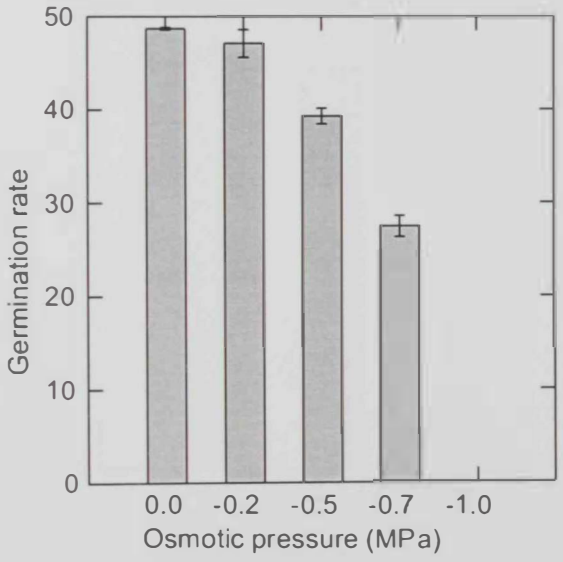



Figure 23: Effect of Polyethylene osmotic pressure on final germination and germination rate index (mean ± standard error) of *Lasiurus scindicus* seeds

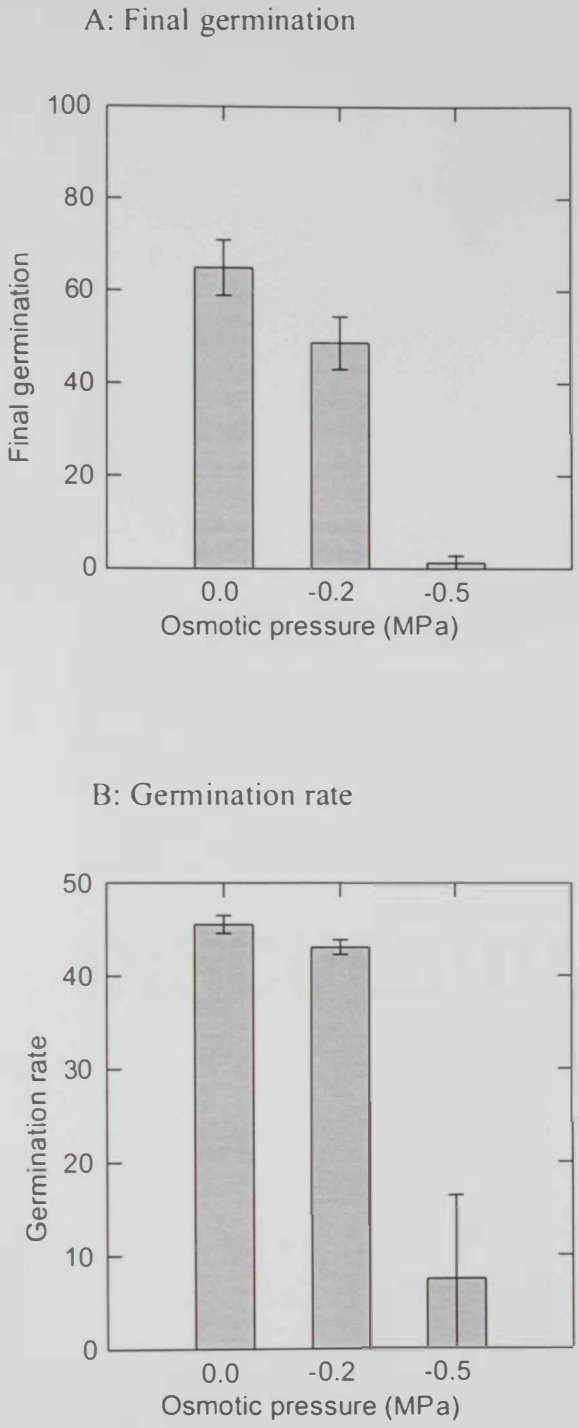



Figure 24: Effect of Polyethylene osmotic pressure on final germination and germination rate index (mean ± standard error) of *Panicum turgidum* seeds

# CHAPTER 4

# DISCUSSION

# 4. DISCUSSION

## 4.1. Impacts of Temperature and Light of Incubation

Baskin and Baskin, (1998) surveyed the light and temperature requirements for germination of 91 halophytes of salt marshes and salt deserts and found that light requirements for germination were reported for 23 species: four required light for germination, four germinated to higher percentages in light than in dark, 13 germinated equally well in light and dark, and two germinated to higher percentages in dark than in light. In addition, absence of light almost completely inhibited seed germination of *Triglochin maritima* (Khan and Ungar, 1999) and *Sporobolus indicus* (Andrews, 1997), partially inhibited germination in *Apium graveolens* (Garcia *et al.*, 1995), *Allium staticiforme*, *Brassica tournefortii*, *Cakile maritima*, and *Onanthus maritimus* (Thanos *et al.*, 1991). However, germination in *Atriplex stocksii* was not affected by the absence of light (Khan and Rizvi, 1994). In the present study, the response to light during germination of non-saline treated seeds of both *L. scindicus* and *P. turgidum* was depended on temperature of incubation. Seeds of *L. scindicus* are not sensitive to light at temperature up to 30°C (seeds germinated equally well in light and dark), but were sensitive to light at higher temperatures (35 and 40°C), as germination in light was greater than in dark. Similar results were recorded in the invasive *Prosopis juliflora* in the UAE deserts; there was no-significant difference between light and dark germination at 15°C and 25°C, but germination in light was significantly greater than in darkness at 40°C (El-Keblawy and Al-Rawai 2006). In *P. turgidum*, germination in dark was significantly greater than in light at the lower temperatures (15–25°C), but the reverse was true at higher temperatures (35 and 40°C).

Light is one of the environmental factors that regulate germination. Seeds requiring light will not germinate when they are buried under soil or leaf litter, but will germinate when they fall on the soil surface. It is generally noted that a light requirement prevents germination of seeds buried too deep for seedling to emerge because physiologically active light flux densities rarely penetrate more than a few millimeters into soil (Pons, 1992). The present study showed that the light requirement for non-saline treated seeds depended on temperature of the incubation. In both *P. turgidum* and *L. scindicus*, germination in light was greater than in dark at higher temperatures (35 and 40°C), but the reverse was true at the lowest temperature (15°C). This result has a significant adaptation for species inhabiting the subtropical deserts of the UAE. The greater dark requirement at higher temperatures would prevent most of the seeds of the two species to emergence from the surface layer of the soil after an effective rainfall precipitation at the end of the growing season (April–May), when the average temperatures are high (35-40°C, Ministry of Communications, Dept. of Meteorology, UAE, 1996). Emerged seedlings from the surface layer at that time would be at greater risk as that layer is rapidly drying at the high temperatures because of high evaporative rate. On the other hand, greater germination in light at lower temperatures would enable seedling emergence from the surface soil during winter. At the time, soils could be saturated with water for several days, providing greater chance for seedling survival (El-Keblawy *et al.*, 2009).

A light requirement for germination is one of the main determinants of the ability of species to accumulate a persistent soil seed bank (Pons, 1991; Milberg *et al.*, 2000). Seeds of some species have an initial light requirement for germination (Grime *et al.*, 1981), while those of other species seem to acquire a light requirement only after burial in

the soil (Wesson and Wareing, 1969; Scopel, *et al.*, 1991; Derkx and Karssen, 1993; Noronha *et al.*, 1997). In both *P. turgidum* and *L. scindicus*, the germination was greater in light than in dark at higher temperatures (35 and 40°C), and the reverse at the lowest temperature (15°C). This result has a significant adaptation for C4 grasses inhabiting the subtropical deserts of the UAE. The optimum growth and reproduction of the two species are taking place mainly during early summer, when the maximum temperatures reach more than 40°C.

## 4.2. Salinity Effects on Germination and Dormancy

Maximum halophyte seed germination occurs in distilled water or under reduced salinity stress (Khan *et al.*, 2001a; El-Keblawy, 2004). However, some halophytes can germinate in very high concentrations of NaCl (Khan and Weber, 1986; Khan *et al.*, 2000; Khan *et al.*, 2001c; Huang *et al.*, 2003; El-Keblawy *et al.*, 2007; El-Keblawy and Al Shamsi, 2008). Seed germination of halophytic grasses is usually inhibited at concentrations ranging from 200 to 500 mM NaCl, indicating that they are not very highly tolerant to salinity during germination, compared to other halophytic species (Lombardi *et al.*, 1998; Khan and Ungar, 2001b). For examples, the limit of tolerance were 200 mM NaCl in *Halopyrum mucronatum* and *Sporobolus arabicus* (Gulzar *et al.*, 2001), 344 mM in *Puccinellia nuttalliana* (Macke and Ungar, 1971), 400 mM in *Diplachne fusca* (Morgan and Myers, 1989), 344 mM in *Hordeum vulgare* (Badger and Ungar, 1989), 310 mM in *Briza maxima* (Lombardi *et al.*, 1998), 310 mM in *Typha latifolia* (Lombardi *et al.*, 1997), and 500 mM NaCl in *Urochondra setulosa* seeds (Gulzar *et al.*, 2001). Results of the present study indicated that seed germination of the two desert grasses *L. scindicus*

and *P. turgidum* is even less tolerant, compared to most of the other studied grasses. The first was more tolerant than the latter; about 9% of *L. scindicus* seeds germinated in 200 mM NaCl, but 17% of *P. turgidum* seeds germinated in 100 mM NaCl. However, *L. scindicus* and *P. turgidum* are more salt tolerant, compared to other grasses growing the subtropical desert of the UAE, such as *Dichanthium annulatum*, *Cenchrus ciliaris* and *Pennisetum divisum* (El-Keblawy, 2006). It is interesting to note that seeds of *P. turgidum* collected from Egyptian population (the present study) are less tolerant to salinity during germination than those of UAE population (El-Keblawy, 2004) and seeds of both populations are less tolerant than those of Saudi Arabia population (Al-Khateeb, 2006). Whereas germination was inhibited in 200 mM NaCl at all temperatures in the seeds of Egypt while about 30% of the UAE seeds germinated in 200 mM NaCl (none seeds germinated in 300 mM NaCl, El-Keblawy, 2004), and about 37% and 4% of the Saudi Arabia seeds germinated in 200 and 400 mM NaCl, respectively (Al-Khateeb, 2006).

Seed germination of desert species is regulated by factors such as water, temperature, light, soil salinity, and their interactions; however, each species responds to the abiotic environment in a unique manner (Baskin and Baskin, 1998; Khan and Gulzar, 2003). The ability of seeds to germinate at increased levels of salinity is partly dependent on the temperature of incubation. In a number of halophytic grass species, including *Hordeum jubatum* (Badger and Ungar, 1989), *Iva annua* (Ungar and Hogan, 1970), *Diplachne fusca* (Myers and Morgan, 1989), and *Briza maxima* (Lombardi *et al.*, 1998), *Aeluropus lagopoides* (Gulzar and Khan, 2001), *Aeluropus lagopoides*, *Sporobolus ioclados* and *Urochondra setulosa* (Gulzar *et al.*, 2001) germination percentages of seeds incubated at high salinity levels increased at the optimal temperature and decreased when

temperature was further increased or decreased. The results of the present study are in line with these findings. Salinity tolerance was greatest at moderate temperatures in both *L. scindicus* and *P. turgidum*; no germination occurred at 15°C, 35 and 40°C in higher salinities. Al-Khateeb (2006) arrived to a similar result in *P. turgidum* seeds of Saudi Arabia. The optimum temperature for seed germination in saline solution was 15–25°C followed by 20–30°C. Seed germination was significantly lower under extreme temperatures of 10–20°C and 25–35°C (Al-Khateeb, 2006).

Light and salinity interact during germination in a number of plants. For example, an increase in NaCl concentration may inhibit seed germination more in dark than in light in several species such as *Triglochin maritima* (Khan and Ungar, 1999) and *Sporobolus indicus* (Andrews, 1997), *Apium graveolens* (Garcia *et al.*, 1995) *Limonium stocksii* (Zia & Khan, 2004) and *Prosopis juliflora* (El-Keblawy and Al-Rawai, 2005). In four grasses of Subtropical deserts of Pakistan, absence of light had no effect on the seed germination of *Urochondra setulosa* and *Halopyrum mucronatum*, but germination in dark was substantially inhibited in *Aeluropus lagopoides* and *Sporobolus ioclados* (Khan and Gulzar, 2003). In our study, however, dark germination of *P. turgidum* seeds was significantly greater than light germination in saline solutions at all temperatures. Under natural habitats, dark condition required for germination in salt-affected soils would be available only during rainy days of winter or for buried seeds. Both conditions secure enough moisture for non-dormant seeds to germinate and salinity-induced dormant seeds to recover their germination. In *L. scindicus*, dark germination in most of the saline solutions was depended on temperature of incubation. It was significantly greater than light germination at lower temperatures (15 and 20°C), but the reverse was true at higher temperatures (35 and 40°C). This indicates that germination in salt-affected soils would

happen in the absence of light when temperatures are low (i.e., during rainy days of winter or for buried seeds) or in the presence of light when temperatures are high (i.e., after monsoon rains of summer).

### 4.3. Recovery Germination from Saline Solution

Seeds of halophytes could be distinguished from those of glycophytes by their ability to maintain seed viability after exposure to hyper-saline conditions and then initiate germination when salinity stress is reduced (Woodell, 1985; Keiffer and Ungar, 1995; Pujol *et al.*, 2000). Halophytic species show a range of responses from partial to complete germination recovery when salinity stress is alleviated. Recovery germination from higher salinities was very low in some species (e.g., *Zygophyllum simplex*, Khan and Ungar, 1997a; *Halogeton glomeratus*, Khan *et al.*, 2001c; *Sporobolus ioclades*, Khan and Gulzar, 2003). However, high salinity did not permanently injure seeds and germination fully recovered when seeds were transferred to distilled water in several other halophytes, including *Atriplex patula* (Ungar, 1996), *Suaeda fruticosa* (Khan and Unger, 1997a), *Arthrocnemum macrostachyum, Sarcocornia fruticosa* and *Salicornia ramoissim* (Pujol *et al.*, 2000) *Salicornia rubra* (Khan *et al.*, 2000). Results of the present study indicated that about 30% of *P. turgidum* seeds recovered their germination, when transferred from different salinities (100–400 mM NaCl) to distilled water. In addition, significant proportions of *L. scindicus* salinity-induced dormant seeds recovered germination (19–35%) when transferred from different salinities (50-200 mM NaCl) to distilled water.

The variation in recovery responses was attributed to differences in the temperature regime to which they are exposed (Gulzar *et al.*, 2001; El-Keblawy *et al.*,

2007). Greater ability to recover germination has been reported at cooler temperatures for some species (e.g., *Suaeda fruticosa*, Khan and Ungar, 1997a; *Salsola imbricata*, El-Keblawy *et al.*, 2007; *Haloxylon salicornicum*, El-Keblawy and Al Shamsi, 2008), but at warmer temperatures in other species (e.g., *Aeluropus lagopoides*, Gulzar and Khan, 2001; *Halogeton glomeratus*, Khan *et al.*, 2001c). Our results showed that the recovery germination in *L. scindicus* was higher at cooler, compared to at higher temperatures. Overall germination recovery was 53.6% at 15°C, compared to 37.6%, 32.2%, 28.3%, 13.6% and 2.8% at 20, 25, 30, 35 and 40°C, respectively. In *P. turgidum*, optimum recovery germination was at the moderate temperatures (20-25°C). and decreased at both low and high temperatures (15 and 40°C). Recovery germination decreased from 38.3%, 35.5%, 34.0%, and 32.8% at 20, 25, 30 and 35°C, respectively, to 21.1% and 12.4% at 15 and 40°C, respectively.

Seeds of both *P. turgidum* and *L. scindicus* incubated under high temperatures with high NaCl concentration seemed to be subjected to more environmental stress, which is indicated by reduced germination percentages and delayed germination. Under such conditions, changes in the incubation temperature particularly under high salt concentration may result in malfunctioning of enzymatic systems. This situation would lead to limitations in many physiological processes vital to seed germination. Similar results have been documented in other halophytes, including *Haloxylon recurvum* (Khan and Ungar, 1996), and some *Atriplex* species (Khan and Ungar, 1984; Aiazzi *et al.*, 2002). The detrimental effect of NaCl at higher temperatures has been attributed to toxicity of Na+ that usually causes irreversible damage (Bewley and Black, 1994; Khan and Ungar, 1996).

The success of halophytic plants under warm and dry conditions of subtropical arid deserts, like that of the UAE, is primarily dependent on optimal conditions for germination and recruitment (Khan and Ungar, 2001c; Khan and Gulzar, 2003, El-Keblawy 2004). In many species of saline habitats, germination occurs when salt content of the habitat reaches its lowest level, e.g., toward the end of or after the rainy period (Ismail, 1990, Khan and Ungar, 1996). The ability of *P. turgidum* and *L. scindicus* seeds to germinate and to recover their germination after exposure to higher concentrations of salinities suggests that these seed could able to germinate under the salt affected agricultural lands after effective rainfalls of winter. Under natural habitats of the UAE, seed germination of the two species would occur in the saline habitats during seasons of high precipitation, when soil salinity levels are usually reduced (Ungar, 1995; El-Keblawy, 2004; El-Keblawy and Al-Rawai, 2005).

Two processes mediate germination reduction in seeds experience higher levels of salinity: osmotic effects due to declining soil solute potential, creating a water stress for the plant, and ionic effects due to seed or seedling ion uptake and/or accumulation (Waisel, 1972; Ungar, 1991). Ionic effects may be distinguished from osmotic effects by comparing the effects of salt solutions and isotonic solutions of an inert osmotic medium such PEG (polyethylene glycol) that cannot penetrate into the cell wall. Inhibition of germination in PEG-treated seeds is attributed to osmotic effects, and any difference in germination of salt-treated relative to PEG-treated seeds is attributed to ionic effects. The general lack of ion toxicity for halophytes has been alternatively confirmed by almost complete recovery of germination potential after salt-treated seeds are returned to fresh water (Ungar, 1996; Egan *et al.*, 1997). In the present study, the osmotic effect would be the main cause of salinity intolerance in solutions with 100mM or more in *P. turgidum*; greater proportion of ungerminated seeds in 400mM NaCl were able to recover their

germination when they transferred to distilled water (32.9% in the dark). In addition, seeds were unable to germinate in -0.5 MPa PEG 6000. On the other hand, the toxicity effect would be the main cause of salinity intolerance in *L. scindicus*; ungerminated seeds in 200 mM NaCl were recovered their germination partially when they transferred to distilled water (19.6%). In addition, about 42% of seeds were able to germinate in -0.5 MPa PEG 6000. The toxicity effect of salinity compromise enzyme function and disrupt metabolic processes, resulting in seed or seedling death (Baldwin *et al., 1996*).

Salinity-induced declines in germination are usually due to only osmotic effects for halophytes, whereas glycophytes are more likely to exhibit additional ion toxicity (Havward and Bernstein, 1958; Ungar and Hogan, 1970; Macke and Ungar, 1971; Cluff *et al.*, 1983; Romo and Haferkamp, 1987; but see Dodd and Donovan, 1999). The explanation of salinity intolerance to osmotic effects in *P. turgidum* indicates that seeds of this species are among salt tolerant grasses. However, the explanation of salinity intolerance to ionic toxicity in *L. scindicus* seeds indicates that seeds of this species are among glycophyte species.

Osmotic seed priming (osmopriming) is used to increase germination efficiency. Osmopriming is a cheap seed physiological enhancement technique used to enhance speed of seedlings emergence and protect seedlings establishment and growth under the changeable environments of the deserts, which are characterized by high temperatures and rapid soil drying seedbeds (Halmer, 2004). Under priming conditions, seeds are partially hydrated and begin the processes of germination, but emergence does not occur, and the seeds are subsequently dried. Priming has several effects on the physiology of seeds, including developmental advancement, decreased membrane permeability, dormancy breaking, and the induction of DNA and protein synthesis (Hudson *et al.*, 2007). In our study, osmopriming of *P. turgidum* and *L. scindicus* seeds resulted in

germination enhancement. Up to 47% of *P. turgidum* seeds recovered their germination within two days when they were transferred to distilled water at 20°C in dark; Timson index of germination rate was 48.2 (maximum value for this index is 50) . In addition, 42.5% of *L. scindicus* seeds recovered their germination at 15°C in light, but rate of the recovery was slower, compared to the case of *P. turgidum*; Timson index of germination rate was 33. A similar rapid response to decrease in soil osmotic potential after seeds were exposed to low water potentials has been reported in many halophytic and glycophytic plants (Katembe *et al.*, 1998; Gul and Weber, 1999; Zia and Khan, 2004; El-Keblawy *et al.*, 2007; El-Keblawy and Al Shamsi, 2008). For example, osmotic pre-treatment significantly stimulated germination recovery of seeds of two *Atriplex* species, and their germination was 90% 2 days after transfer to distilled water (Katembe *et al.*, 1998). Such rapid response, which was recorded in the present study for *P. turgidum* is an important adaptation. It would ensure that ungerminated seeds exposed to saline conditions could germinate during periods of precipitation when stress was temporarily alleviated. This is particularly important in the unpredictable heterogeneous deserts of arid regions. In such environment germination bed are characterized by wide seasonal and daily fluctuations of temperature, high soil moisture tension and sometime high salt content (El-Keblawy, 2004).

## 4.4. Impacts of Dormancy Regulating Substances on Salinity-Induced Dormancy

The results of the present study indicated that the role of dormancy regulating chemicals in alleviating salinity-induced germination inhibition was greater in *L. scindicus*, compared to it in *P. turgidum*. The dormancy regulating chemicals alleviated salinity induced inhibition in 100mM NaCl in *P. turgidum*, but alleviated it higher salinities (200mM NaCl) in *L. scindicus*. This result suggests greater role for dormancy regulating chemicals when toxicity effects are responsible for germination inhibition in higher salinities (i.e., in *L. scindicus*), compared to its effect when osmotic effects are responsible for the inhibition (i.e., in *P. turgidum*). This further indicates that the role of dormancy regulating chemicals is greater in glycophytes, compared to its role in halophytes. Further studies are needed to confirm this in other halophytes and glycophytes.

Seed dormancy and germination are complex developmental processes that are regulated by a variety of endogenous and environmental signals. Plant growth regulators such as gibberellic acid ($GA_3$), abscisic acid (ABA), kinetin and ethylene are known to influence the dormancy status of seeds (Karssen, 1995). Khan and Gul (2006) reviewed the effect of various germination regulating chemicals like proline, betaine, gibberellic acid, kinetin, fusicoccin, ethephon, thiourea and nitrate on the innate dormancy of a number of sub-tropical and Great Basin halophytes. They found that germination regulating chemicals had either no effect or a negative effect on innate dormancy on seeds of sub-tropical perennial species, such as *Aeluropus lagopoides, Halopyrum mucronatum, Limonium stocksii, Salsola imbricata, Sporobolous ioclados*, and *Urochondra setulosa* (Khan and Gul, 2006). Similarly, innate dormancy of *Prosopis juliflora* in the UAE was

not affected by $GA_3$, kinetin, thiourea or fusicoccin (El-Keblawy *et al.*, 2005). In other species, little effect has been recorded for betaine, gibberellic acid, and fusicoccin on *Arthrocnemum macrostachyum*, for betaine and gibberellic acid on *Haloxylon stocksii*, and for fusicoccin, ethephon, thiourea and nitrate on *Sporobolous arabicus* (Khan and Gul, 2006). In the present study, all of the studied dormancy regulating chemicals, except thiourea, did not succeed to improve germination of non-saline treated seeds of both *L. scindicus* and *P. turgidum*, compared to the control. In addition, negative impact on the germination was observed for ethephon and kinetin on seeds of *P. turgidum* and for ethephon and $GA_3$ on seeds of *L.* scindicus. It seems that other factors, such as light and temperature of the incubation, would be important than dormancy regulating chemicals in regulating dormancy of stored seeds of these species. Seed of *L. scindicus* stored for one month germinated to 83.8% at 25°C in dark and seeds of *P. turgidum* stored for five year germinated to 85% in dark at 30°C.

Kabar (1987) suggested that endogenous hormone level is affected by many environmental stresses, such as salinity. According to the growth regulator theory, the control of dormancy has been attributed to various growth regulators – inhibitors, such as ABA, and promoters, such as gibberellins, cytokinins and ethylene. Consequently, dormancy is maintained (or induced) by inhibitors such as ABA, and it can be released only when the inhibitors are removed or when promoters overcome it (Bewley and Black, 1994). In the present study, $GA_3$, fusicoccin, kinetin and thiourea were able to alleviate, partially or completely, germination inhibition in 100 mM NaCl in *P. turgidum*. In addition, fusicoccin, kinetin and thiourea alleviated the inhibition of 200 mM NaCl in *L. scindicus*. Germination under saline conditions is stimulated by applying dormancy-relieving compounds, which would counteract the negative change in growth regulator balance in seeds when they are exposed to salt stress (Khan and Gul, 2006).

Dormancy regulating chemicals are thought to alleviate salinity effects on the germination by acting as an osmoregulator or osmoprotectants of proteins in the cytoplasm (Poljakoff-Mayber *et al.*, 1994; Gorham, 1995) and/or counteracting the effect of reduced promoter (cytokinins and gibberellins) and increased inhibitor substances, such as abscisic acid in seeds under high salinity (Kabar and Baltepe, 1990). Kabar (1987) suggested that endogenous hormone level is affected by many environmental stresses, but external application of appropriate growth regulator optimizes physical metabolic conditions for germination. In our study, $GA_3$ played a greater role, compared to the other substances, in alleviating germination inhibition in *P. turgidum*, compared to it in *L. scindicus*. Seeds of *P. turgidum* inhibited in 100 mM NaCl while, germinated to 65% when $GA_3$ was added, but to 46%, 40% and 32% when thiourea, kinetin and fusicoccin, respectively were added. However, seeds of *L. scindicus* inhibited in 200 mM NaCl while, germinated to 17.5% when were added $GA_3$, but to 44%, 42.5% and 38.5% when treated with fusicoccin, kinetin and thiourea, respectively. This result indicates that $GA_3$ might play greater role in seeds with physical dormancy than it in seeds have low dormancy. Fresh seeds of *L. scindicus* didn't show great innate dormancy; final germination was 66.7%, but fresh seeds of *P. turgidum*, which have physical dormancy because of their hard coat, did not germinate at all, even after one year of storage at room temperatures. It has been reported that $GA_3$ increases the growth potential of the embryo and it is necessary to overcome the mechanical restraint conferred by the seed-covering layers by weakening of the tissues surrounding the radicle (Kucera *et al.*, 2007).

Nitrogenous compounds, such as thiourea and nitrate, are known to counteract the inhibitory effect of ABA and the decline in cytokinin concentration associated with salinity stress, and consequently alleviates salinity induced inhibition of germination (Esashi *et al.*, 1979). Several studies have shown the ability of Nitrogenous compounds to

alleviate salinity induced dormancy in many species. Nitrate and thiourea were able to counteract the inhibition produced by salinity treatments in *Allenrolfea occidentalis*, although they were relatively less effective, compared to other chemicals such as fusicoccin and ethephon (Gul and Weber, 1998). Thiourea was effective in alleviating salinity induced dormancy in saltgrass (Shahba *et al.*, 2008), *Triglochin maritime* (Khan and Ungar, 2001b), *Sporobolus arabicus* (Khan and Ungar, 2001a) and *Aeluropus lagopoides* (Gulzar and Khan, 2002). Compared to other five dormancy regulating chemicals, nitrate was the most effective in *Sporobolus spicatus* (El-Keblawy, 2008). In our study, thiourea successfully alleviated germination inhibition in both *L. scindicus* and *P. turgidum*, but nitrate not. In a review for Khan and Gul (2006) on the effect of different dormancy regulating chemicals on salinity induced dormancy, nitrate alleviated the germination inhibition in *Zygophyllum simplex* and *Sporobolus arabicus* out of 12 examined species of the subtropical halophytes and in *Halogeton glomeratus* and *Suaeda moquinii* out of 10 examined species of the Great Basin halophytes.

In many species of saline habitats, germination occurs when salt content of the habitat reaches its lowest level, e.g., toward the end of or after the rainy period (Ismail, 1990, Khan and Ungar, 1996). However, high evaporation rate in the subtropical deserts would return back the high salinity level shortly after the rainy period. This further support the importance of the germination stage as the most critical stage in the life cycle of the plants and once it passed plants would able to establish themselves. In our study, germination inhibition in salty solutions was alleviated, partially or completely, by fusicoccin, kinetin and thiourea in *L. scindicus* and by fusicoccin, kinetin and thiourea and $GA_3$ in *P. turgidum*. This result indicates that seeds of the two species could germinate and hence establish themselves in soils with such salinity levels, when they pre-treated with these dormancy regulating chemicals. It has been reported that salinity

tolerance is greater 10 to 100 times in mature plants, than at the germination stage of development (Mayer and Poljakoff-Mayber, 1975).

## 4.5. Seed Dormancy of *Panicum turgidum* and *Lasiurus scindicus*

Seed dormancy is hypothesized to be a risk-spreading strategy that maximizes plant fitness. Many species produce seeds that do not germinate shortly after dispersal and require a period of species-specific after-ripening through dry storage (Bewley and Black, 1982; Simpson, 1990; Baskin and Baskin, 1998). The seeds of most Mediterranean and desert species have dormancy characteristics or structural properties that prevent immediate germination of at least a proportion of the seeds (Gutterman, 1994; Bell *et al.*, 1995). In the present study, fresh seeds of *L. scindicus* didn't show great innate dormancy and attained fast germination. Final germination and Timson index of germination rate of fresh harvested seeds were 66.7% and 40.3, respectively, indicating that about one-third of the seeds retained dormancy. Seeds of *P. turgidum*, however, showed great innate dormancy. No germination occurred for the fresh harvested seeds and 14.2% and 23.3% of the seeds germinated after one and two years of storage, respectively. Another seed lot of *P. turgidum* germinated to about 84% at 25°C in darkness after 5 years of dry storage. The ability of a considerable fraction of seeds to maintain dormancy ensures the buildup and persistence of a soil seed bank which is considered vital for species in unpredictable environments of deserts (Venable and Lawlor, 1980).

Seed dormancy is thought to have evolved in response to environmental unpredictable environmental variability and uncertainty (Evans and Cabin, 1995). In the desert habitats, the favorable conditions for germination and completion of plants life

cycle are unpredictable over space and time. Seed dormancy is thus thought to have evolved to lead to the existence of seed banks (Mandujano *et al.*, 1997). In a survey including 105 central Australian species, Jurado & Westoby (1992) found that for 103 of them, at least 20% of their seeds were still ungerminated after 10 days. Since seeds of all tested species were after-ripened in their survey, the dormant fraction of fresh matured seeds is probably much higher in many species. The low dormancy of fresh harvested seeds observed in *Lasiurus scindicus* is thus not common in desert plants. In the present study, germination was performed on naked seeds (i.e., structures surrounding the seeds were removed). The removal of the surrounding structures around the seeds would be the main reason for lower dormancy observed in *L. scindicus*. Non-dormant seeds are also found in some desert species of *Atriplex*, but they are prevented from germination by high contents of germination-inhibiting chloride in the bracteols (Beadle, 1952). Innate dormancy produced by the presence of endogenous inhibitory compounds has been reported in bracts or other structures enclosing the seeds in some species (wheat and rye, Trethowan *et al., 1993; Atriplex halimus* and *Salsola vermiculata*, Osman and Ghassali, 1997).

## 4.6. Maternal Effects on Seed Dormancy and Germination

It has been proposed that the environmental conditions under which plants are grown can affect seed germination by affecting their chemical composition and seed provisioning (e.g., mineral, photosynthetic and phytohormone resources) throughout the growing season (Roach and Wulff, 1987, Baskin and Baskin, 1988, Sultan, 1996). In addition, several studies documented that water addition in the maternal environment caused a

significant decrease in germination percentage and rate of several species, such as *Sinapis arvensis* (Wright *et al.*, 1999; Luzuriaga *et al.*, 2006), *Malva parviflora* (Michael *et al.*, 2006), For example, seeds of *Malva parviflora* from areas of low rainfall were more responsive to fluctuating temperatures, releasing physical dormancy earlier than those from areas of high rainfall (Michael *et al.*, 2006). The results of the present study are in line with these findings. Seeds of *Lasiurus scindicus* from natural habitats germinated to higher level and rate, compared to those collected from plants grown in experimental conditions and received more water. Wright *et al.* (1999) proposed that adequate moisture during seed formation is expected to result in the production of more dormant seeds than in drier conditions, probably because better developed seeds are produced.

The effect of maternal environment on the dormancy level and germination rate and time has been attributed to several mechanisms, including the quantity and/or quality of the resources supplied (Roach and Wulff, 1987; Baskin and Baskin, 1998; Galloway, 2002), the structure and thickness of the seed coat (Lacey *et al.*, 1997; Luzuriaga *et al.*, 2006), and the levels of hormones, enzymes, etc. Furthermore, color of surrounding tissues can affect the light quality that reaches the seeds during development and hence the status of phytochrome present as the seeds dry out during maturation, which would affect dormancy level (Zheng *et al.*, 2005). In the present study, seeds of *L. scindicus* produced under natural conditions of Al-Ain site have light brown and dark brown colors. Dormancy and germination requirements differ between the two colors. Light brown seeds germinated better at higher temperatures (35 and 40°C) than at lower temperature (15°C) in light. Dark brown seeds, however, germinated better at lower temperatures than at 40°C in both light and darkness. Variation in seed dormancy can be an important factor for increasing genetic diversity in populations of this species, enabling it to respond to

environmental changes. In addition, plasticity of seed germination may spread germination over time and thus reduce the risk to species survival (El-Keblawy, 2003a).

## 4.7. Impact of Seed Storage

Generally, after-ripening decreases the ABA concentration and sensitivity and increases in $GA_3$ sensitivity or loss of $GA_3$ requirement. Consequently, after-ripened seeds lose species-specific germination requirements which are required for fresh harvested seeds, such as nitrate and light (Li *et al.*, 2005; Kucera *et al.*, 2007). In addition, after-ripening widens the temperature range for germination for seeds of many species. For example, seeds of the desert herb *Plantago coronopus* stored for two months germinated under narrow range of lower temperatures (5-15°C), but germinated under wider range of high temperatures (15-30°C) when stored in their inflorescences under natural desert habitats for one year (Gutterman *et al.*, 1998). Similarly, fresh harvested seeds of the weedy *Sicyos deppei* developed under sunlight have a partially negative photoblastic response; both red and far-red light inhibited germination. After six months of storage, the seed permeability increased and the partially negative photoblastic response was lost (Orozco-Segovia *et al.*, 2000). Furthermore, in the invasive exotic *Prosopis juliflora* in the UAE, the need for high temperature and light to achieve greater germination in the fresh seeds was significantly reduced after seed storage (El-Keblawy and Al Rawai, 2006). In the present study, 3-months stored seeds of *L. scindicus* germinated significantly greater at higher (20–35°C), than at lower temperature (15°C). However, after 2 years of storage, there was no difference in final germination between all temperatures, indicating that the higher temperature required for greater germination of 3-months stored seeds was lost after 2 years of seed storage.

# CHAPTER 5

# CONCLUSIONS & RECOMMENDATION

# 5. CONCLUSIONS and RECOMMENDATION

*L. scindicus* didn't show great innate dormancy. A significant proportion of fresh harvested seeds germinated under a wide range of temperatures and in both light and dark conditions. Consequently, fresh seeds could be used for reseeding the degraded deserts and rangelands, without the need for storage. This particularly true if the reseeding program happen at temperatures ranged from 20–35°C. However, if the reseeding program happen during the cold period of the year (i.e., temperature as low as 15°C), seed stored for two years are required. The results of the present study indicated that the higher temperature required for greater germination of 3-months stored seeds was lost after 2 years of seed storage.

Fresh seeds of *P. turgidum*, however, showed great innate dormancy. Consequently, long term storage for *P. turgidum* seeds is required before their use in any restoration program for the degraded deserts. A minimum of four years of seed storage is required before using the seeds of *P. turgidum*.

All of the studied dormancy regulating chemicals, except thiourea, did not succeed to improve germination of non-saline treated seeds of both *L. scindicus* and *P. turgidum*, compared to the control. It seems that other factors, such as light and temperature of the incubation, would be important than dormancy regulating chemicals in regulating dormancy of stored seeds of these species.

In both *P. turgidum* and *L. scindicus*, germination in light was greater than in dark at higher temperatures (35 and 40°C), but the reverse was true at the lowest temperature

(15°C). This result has a significant adaptation for species inhabiting the subtropical deserts of the UAE.

Seeds of *L. scindicus* from natural habitats germinated to higher level and rate, compared to those collected from plants grown in experimental conditions and received more watering. This result suggests that seeds of the natural habitats would be better in restoration programs of the degraded deserts and rangelands.

Salinity tolerance during germination of the two desert grasses *L. scindicus* and *P. turgidum* is less than most of the other studied grasses, so the first was more tolerant than the latter species. Salinity tolerance was greatest at moderate temperatures in both *L. scindicus* and *P. turgidum*; no germination occurred at the extreme temperatures (i.e., both low and high temperatures).

Germination of *P. turgidum* seeds in saline solutions was significantly greater in darkness, compared to it in light. In *L. scindicus*, dark germination was significantly greater than light germination at lower temperatures (15 and 20°C), but the reverse was true at higher temperatures (35 and 40°C). This indicates that germination in salt-affected soils would happen in absence of light when temperatures are low (i.e., during rainy days of winter or for buried seeds) or in presence of light when temperatures are high (i.e., after monsoon rains of summer).

Significant proportions of salinity-induced dormant seeds in the two species recovered their germination, when transformed from different salinities (100–400mM NaCl) to distilled water. In addition, significant proportions of *L. scindicus* (19–35%) recovered their germination when transferred from different salinities concentrations to distilled water. Optimum recovery germination was at the moderate temperatures (20-25°C) and decreased at both low and high temperatures.

The ability of *P. turgidum* and *L. scindicus* seeds to germinate and to recover their germination after exposure to higher concentrations of salinities suggests that these seed are able to germinate under the salt affected agricultural lands after effective rainfalls of winter. Under natural habitats of the UAE, seed germination of the two species would occur in the saline habitats during seasons of high precipitation, when soil salinity levels are usually reduced.

The osmotic effect would be the main cause of salinity intolerance in *P. turgidum*; but the toxicity effect would be the main cause of salinity intolerance in *L. scindicus*.

The salinity-induced germination reduction in *P. turgidum* was completely alleviated by the application of $GA_3$, partially alleviated by the application of fusicoccin, kinetin and thiourea, but not affected by nitrate. In *L. scindicus*, the germination inhibition was completely alleviated by fusicoccin, $GA_3$, nitrate and thiourea, but partially alleviated by kinetin. Germination was completely inhibited by the application of ethephon in the two species. This result indicates that seeds of the two species could germinate and hence establish themselves in soils with such salinity levels, when they pre-treated with these dormancy regulating chemicals. It has been reported that salinity tolerance is greater 10 to 100 times in mature plants, than at the germination stage of development.

# REFERENCES

# REFERENCES


Aamlid, T.S. and Arntsen, D. (1998). Effects of light and temperature on seed germination of *Poa pratensis* from high latitudes. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science* 48:239-247.

Aiazzi, M.T., Carpane, P.D., Rienzo, J.A. and di. Arguello, J.A. (2002). Effects of salinity and temperature on the germination and early seedling growth of *Atriplex cordobensis* Gandoger et Stuckert (Chenopodiaceae). *Seed Science Technology* 30: 329-338.

Al-Hadramy, G.A., Ibrahim, A.S., karim, F.M., Ali, F.Y. and Daadoua, A. (2000). Range plants in the United Arab Emirates. Description and composition. United Arab Emirates University Press. UAE. 211 p.

Ali-Rachedi, S., Bouinot, D., Wagner, M.H., Bonnet, M., Sotta, B., Grappin, P. and Jullien, M. (2004). Changes in endogenous abscisic acid levels during dormancy release and maintenance of mature seeds: studies with the Cape Verde Islands ecotype, the dormant model of *Arabidopsis thaliana*. *Planta* 219: 479–488.

Al-Khateeb, S.A. (2006). Effect of salinity and temperature on germination, growth and ion relations of *Panicum turgidum* Forssk. *Bioresource Technology* 97: 292-298.

Andrews, T. S. (1997). Factors affecting the germination of Giant Parramatta grass. *Australian Journal of Experimental Agriculture* 37: 439-446.

Badger, K.S.and Ungar, I.A. (1989). The effects of salinity and temperature on the germination of the inland halophyte *Hordeum jubatum*. *Canadian Journal of Botany* 67: 1420–1425.

Bair, N.B., Meyer, S.E. and Allen, P.S. (2006). A hydrothermal after-ripening model for seed dormancy loss in *Bromus tectorum* L. *Seed Science Research* 16: 17-28.

Baldwin, A.H., McKee, K.L. and Mendelssohn, I.A. (1996). The influence of vegetation, salinity, and inundation on seed banks of oligohaline coastal marshes. *American Journal of Botany* 83: 470-479.

Ballio, A. and Scalorbi, D. (1981). Fusicoccin structure-activity relationship: In vitro binding to microsomal preparations of maize coleoptiles. *Plant Physiology* 52: 476-481.

Barnabas B, Jager K. and Feher A. (2008) The effect of drought and heat stress on reproductive processes in cereals. *Plant Cell and Environment* 31:11–38.

Baskin, C.C. and Baskin, J.M. (1988). Germination ecophysiology of herbaceous plant species in a temperate region. *American Journal of Botany* 75: 286-305.

Baskin, C.C. and Baskin, J.M. (1998). *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press. San Diego, US. 666 p.

Baskin, J.M. and Baskin, C.C. (2004). A classification system for seed dormancy. *Seed Science Research* 14: 1-16.

Batanouny, K.H. (2002). Biodiversity strategy and rangelands in the Arab world. In: Hamzah, R., Alaa El-Din, S.A. and Mohammed, M.N. (eds). *National Biodiversity*

*Planning in the Arab World.* Arabian Gulf University Publication. Bahrain. pp. 121-142.

Battaglia, M., Solorzano, R.M., Hernandez, M., Cuellar-Ortiz, S., Garcia-Gomez, B., Marquez, J. and Covarrubias, A.A. (2007). Proline-rich cell wall proteins accumulate in growing regions and phloem tissue in response to water deficit in common bean seedlings. *Planta* 225: 1121–1133.

Beadle, N.C.W. (1952). Studies on halophytes. I. The germination of the seeds and establishment of the seedlings of five species of *Atriplex* in Australia. *Ecology* 33: 49–62.

Bell, D.T., Rokich, D.P., Chensney, M.C. and Plummer., J. A. (1995). Effect of gibberellic acid on seed germination of 43 species native to Western Australia. *Journal of Vegetation Science* 6: 797-806.

Bewley, J.D. and Black, M. (1982). Physiology and Biochemistry of Seeds in Relation to Germination, Viability, Dormancy and Environmental Control, Berlin. Springer, Germany. 359p.

Bewley, J.D. and Black, M. (1994). Seeds: Physiology of development and germination. Plenum Press, London. 421p.

Boer, B. (1997). An introduction to the climate in the UAE. *Journal of Arid Environments* 35: 3-16.

Bokhari, U.G., Alyaeesh, F. and Al-Noori, M. (1990). Nutritional characteristics of important desert grasses in Saudi Arabia. *Journal of range management.* 43(3): 202-204.

Boorman, L.A. (1968). Some aspects of the reproductive biology of *Limonium vulgare* Mill. and *L. humile* mill. *Annals of Botany* 32: 803-824.

Boyer, J.S. (1982) Plant productivity and environment. *Science* 218: 443-448.

Breen, C.M., Everson, C. and Rogers, K. (1997). Ecological studies on *Sporobolus virginicus* (L.) Kunth with particular reference to salinity and inundation. *Hydrobiologia* 54: 135–140.

Brown, G. and Sakkir, S. (2004). The vascular plants of Abu Dhabi Emirate, Internal report, Terrestrial Environment Research Centre, Environmental Research & Wildlife Development Agency, UAE.

Cadman, C.S.C., Toorop, P.E., Hilhorst, H.W.M. and Finch-Savage, W.E. (2006). Gene expression profiles of Arabidopsis Cvi seeds during dormancy cycling indicate a common underlying dormancy control mechanism. *Plant Journal* 46: 805–822.

Capon, B. and Van Asdall, W. (1967). Heat pre-treatment as a means of increasing germination of desert annual seeds. *Ecology* 48: 305-306.

Chauhan, S.S. (2003). Desertification control and management of land degradation in the Thar desert of India, *Environmentalist* 23: 219–227.

Chowdhurya, S. P., Schmidb, M., Hartmannb, A. and Tripathi, A. K. (2009). Diversity of 16S-rRNA and nifH genes derived from rhizosphere soil and roots of an endemic drought tolerant grass, *Lasiurus scindicus. European Journal of Soil Biology* 45: 114 – 122.

Climatological Data, 1993. Ministry of Agriculture and Fishery, Department of Soil and Water, UAE.

Cluff, G. J., Evans, R. A. and Young, J. A. (1983). Desert saltgrass seed germination and seedbed ecology. *Journal of Range Management* 36: 419–422.

Del Arco, M.J.S., Torner, C. and Quintanilla, C.F. (1995). Seed dynamics in populations of *Avena sterilis* spp. *ludoviciana. Weed Research* 35: 477–487.

Derkx, M.P.M. and Karssen, C.M. (1993). Variability in light-, gibberellin- and nitrate requirement of *Arabidopsis thaliana* seeds due to harvest time and conditions of dry storage. *Journal of Plant Physiology* 141: 574-582.

Dodd, G.L and Donovan, L.A. (1999). Water potential and effects on germination and seedling growth of two cold desert shrubs. *American Journal of Botany* 86: 1146–1153.

Dunbabin, M.T. and Cocks, P.S. (1999). Ecotypic variation for seed dormancy contributes to the success of capeweed (*Arctotheca calendula*) in Western Australia. *Australian Journal of Agricultural Research* 50:1451-1458.

Egan, T. P., Ungar, I. A. and Meekins, J. F. (1997). The effect of different salts of sodium and potassium on the germination of *Atriplex prostrata* (Chenopodiaceae). *Journal of Plant Nutrition* 20: 1723–1730.

Egley, G.H. (1995). Seed germination in soil: Dormancy cycles. In: Kigel, J., Galili, G. (eds). *Seed development and germination*. Marcel and Dekker Inc., New York. 853p.

El-Keblawy, A. (2003a). Effects of achene dimorphism on dormancy and progeny traits the two ephemerals *Hedypnois cretica* (L.) Dum.-Cours. and *Crepis aspera* L. (Asteracea). *Canadian Journal of Botany* 81 (6): 550-559.

El-Keblawy, A. (2003b). Effect of protection from grazing on species diversity, abundance and productivity in two regions of Abu-Dhabi Emirate, UAE. In: Desertification in the Third Millennium. Edited by A.S. Alsharhan, W.W. Wood, A.S. Goudie, A. Fowler and E. Abdellatif. Swets & Zeitlinger Publisher, Lisse, The Netherlands. P. 217-226.

El-Keblawy, A. (2004). Salinity effects on seed germination of the common desert range grass, *Panicum turgidum*. *Seed Science and Technology* 32: 943-948.

El-Keblawy, A. (2006). Overcoming innate dormancy and determination of germination requirements of economic salt tolerant native plants of the UAE. *In:* the proceeding of the 7th Annual Conference for Research Funded by UAE University, Al-Ain, United Arab Emirates, pp. SCI 97-107.

El-Keblawy, A. (2008). Overcoming salinity induced dormancy in UAE native forage grasses. *In:* the proceeding of the 9th Annual Conference for Research Funded by UAE University, Al-Ain, United Arab Emirates pp. 38

El-Keblawy, A. and Al-Ansari, F. (2000). Effects of site of origin, time of seed maturation, and seed age on germination behavior of *Portulaca oleracea* from Old and New World. *Canadian Journal of Botany* 78:1-9.

El-Keblawy, A. and Al-Rawai, A. (2005). Effects of salinity, temperature and light on germination of invasive *Prosopis juliflora* (SW.) D.C. *Journal of Arid Environments* 61: 555-565.

El-Keblawy, A. and Al-Rawai, A. (2006). Effects of seed maturation time and dry storage on light and temperature requirements during germination in invasive *Prosopis juliflora*. *Flora* 201: 135-143.

El-Keblawy, A. and AL Shamsi, N. (2008). Effects of salinity, temperature and light on seed germination of *Haloxylon salicornicum*, a common perennial shrub of the Arabian deserts. *Seed Science & Technology* 36: 679-688.

El-Keblawy, A., Al-Ansari, F. and Al-Rawai, A. (2005). Effects of dormancy regulating chemicals on innate and salinity induced dormancy in the invasive multipurpose *Prosopis juliflora* (Sw.) DC. Shrub. *Plant Growth Regulations* 46:161-168.

El-Keblawy, A., Al-Ansari, F., Hassan, N. and Al-Shamsi, N. (2007). Salinity, temperature and light affect germination of *Salsola imbricata*. *Seed Science & Technology* 35: 272-281.

El-Keblawy, A., Al-Sodany, Y. M. and Al-Hadad, F. A. (2009). Effects of time of seed maturation on dormancy and germination requirements of *Sporobolus spicatus* (Vahl) Kunth: a native desert grass of the United Arab Emirates. *Grassland Science* 55: 11-17.

Emmerich, W.E., and Hardegree, S.P. (1990). Polyethylene glycol solution contract effects on seed germination. *Agronomy Journal* 82: 1103-1107.

Esashi, Y., Ohhara, Y., Okazaki, M. and Hishinuma, K. (1979). Control of cocklebur seed germination by nitrogenous compounds: nitrite, nitrate, hydroxylamine, thiourea, azide, and cyanide. *Plant and Cell Physiology* 20: 349–361.

Evans, A.S. and Cabin, R.J. (1995). Can dormancy affect the evolution of post-germination traits? The case of *Lesquerella fendleri*. *Ecology* 76: 344-356.

Finch-Savage, W.E. and Leubner-Metzger, G. (2006). Seed dormancy and the control of germination. *New Phytopathology* 171: 501–523.

Fowler, J.L. (1991). Interaction of salinity and temperature on the germination of *Crambe abyssinica*. *Agronomy Journal* 83: 169-172.

Galloway, L.F. (2002). The effect of maternal phenology on offspring characters in the herbaceous plant *Campanula americana*. *Journal of Ecology* 90: 851–858.

Garcia, F., Pita B., and Iriondo, J. M. (1995). Effect of light, temperature and seed priming on germination of celery seeds (*Apium graveolens* L). *Seed Science and Technology* 23: 377-383.

Ghazanfar, S.A. and Fisher, M. (1998). *Vegetation of the Arabian Peninsula*. London, UK: Kluwer Academic Publishers. London. 362 pp.

Gorai, M. and Neffati, M. (2007). Germination responses of *Reaumuria vermiculata* to salinity and temperature. *Annals of Applied Biology* 151: 53-59.

Gorham, J., (1995). Mechanisum of salt tolerance of halophytes. In: Choukr-Allah R, Malcolm CV, Hamdy A, eds. Halopytes and biosaline agriculture. New York: Marcel Dekker, Inc., 31-53.

Grappin, P., Bouinot, D., Sotta, B. Miginiac, E. and Jullien, M. (2000). Control of seed dormancy in *Nicotiana plumbaginifolia*: post-imbibition abscisic acid synthesis imposes dormancy maintenance. *Planta* 210: 279-285.

Grime, J.P., Mason, G. and Curtis, A.V. (1981). A comparative study of germination characteristics in a local flora. *Journal of Ecology* 69: 1017–1059.

Gul, B., Khan, M.A. (1998). Population characteristics of a coastal halophyte *Arthrocnemum macrostachyum*. *Pakistan Journal of Botany* 30: 189-197.

Gul, B., and Weber, D.J. (1998). Effect of dormancy compounds on the seed germination of non-dormant *Allenrolfea occidentalis* under salinity stress. *Annals of Botany* 82: 555–560.

Gul, B. and Weber, D.J. (1999). Effect of salinity, light and temperature on germination in *Allenrolfea occidentalis*. *Canadian Journal of Botany* 77: 240-246.

Gulzar, S. and Khan, M.A. (2002). Alleviation of Salinity-Induced Dormancy in Perennial Grasses. *Biologia Plantarum* 45: 617-619.

Gulzar, S., Khan, M.A. and Ungar, I.A. (2001). Effect of salinity and temperature on the germination of *Urochondra setulosa* (Trin) C.E. Hubbard. *Seed Science and Technology* 29: 21-29.

Gutterman, Y. (1996). Effect of day length during plant development and caryopsis maturation on flowering and germination, in addition to temperature during dry storage and light during wetting, of *Schismus arabicus* (Poaceae) in the Negev desert, Israel. *Journal of Arid Environments* 33: 439-448.

Gutterman, Y. (1994). Strategies of seed dispersal and germination in plants inhabiting deserts. *Botanical Review* 60: 373-425.

Gutterman, Y. (1992). Maternal effects on seeds during development. pp. 27-59 *In* Fenner, M. (ed.) *Seeds: the Ecology of Regenration in Plant Communities*. Wallingford, UK, CAB International.

Gutterman, Y., Corbineau, F. and Come, D. (1996). Dormancy of *Hordeum spontaneum* caryopsis from a population on the Negev Desert highlands. *Journal of Arid Environments* 33: 337-345.

Gutterman, Y., Shem-Tov, S. and Gozlan, S. (1998). The effect of post-maturation temperatures and duration on seed germinability of *Plantago coronopus* occurring in natural populations in the Negev desert highlands, Israel. *Journal of Arid Environments* 38: 451-463.

Halmer, P. (2004). Methods to improve seed performance in the field. In: Benech-Arnold, R.L. and Sanchez, R. (eds). *Handbook of Seed Physiology*. Food Product Press, NY, US. pp. 125–156.

Haywand, H. E. and Bernstein, L. (1958). Plant-growth relationships on salt-affected soils. *Botanical Review* 24: 584–635.

Hester, M.W., Mendelssohn, I.A. and McKee, K.L. (1998). Intraspecific variation in salt tolerance and morphology in *Panicum hemitomon* and *Spartina alterniflora* (Poaceae). *International Journal of Plant Sciences* 159 (1): 127–139.

Huang, Z.Y., Zhang, X.S., Zheng, G.H., Gutterman, Y. (2003). Influence of light, temperature, salinity and storage on seed germination of *Haloxylon ammodendron*. *Journal of Arid Environments* 55: 453–464.

Hudson, M.E., Bruggink, T., Chang, S. H., Yu, W., Han, B., Wang, X., Toorn, P. and Zhu, T. (2007). Analysis of Gene Expression during Brassica Seed Germination Using a Cross-Species Microarray Platform. *Crop Science* 47: 96-112.

Ismail, A.M.A. (1990). Germination ecophysiology in population of *Zygophyllum qatarense* Hadidi from contrasting habitats: Effect of temperature, salinity and growth regulators with special reference to fusicoccin. *Journal of Arid Environments* 18: 185-194.

Jongbloed, M. (2003). The Comprehensive Guide to the Wildflowers of the UAE. Published by Environmental Research and Wildlife Development Agency, Abu Dhabi, UAE.

Jorgensena,. D.G. and Al-Tikiriti, W.Y. (2003). A hydrologic and archeologic study of climate change in Al Ain, United Arab Emirates . *Global and Planetary Change* 35: 37-49.

Jurado, E. and Westoby, M. (1992). Germination biology of selected central Australian plants. *Australian Journal of Ecology* 17:341–348.

Kabar, K. (1987). Alleviation on salinity stress by plant growth regulators on seed germination. *Journal of Plant Physiology* 128: 179-183.

Kabar, K. and Baltepe, S. (1989). Effect of kinetin and gibberellic acid in overcoming high temperature and salinity (NaCl) stresses on the germination of barley and lettuce seeds. *Phytopathology* 30: 30-65.

Kabar, K. and Baltepe, S. (1990). Effect of kinetin and gibberellic acid in overcoming high temperature and salinity (NaCl) stresses on the germination of barley and lettuce seeds. *Phytopathology* 30: 65-74.

Karssen, C.M. (1976). Two sites of hormonal action during germination of *Chenopodium album* seeds. *Physiologia Plantarum* 36: 264-270.

Karssen, C.M., (1995). Hormanal regulation of seed development, dormancy, and germination studied by genetic control. In: Kigel, J. and Galili, G. (eds). *Seed development and germination*. Marcel Dekker, New York. pp 333-350.

Karssen, C.M. and Lacka, E. (1986). A revision of the hormone balance theory of seed dormancy: studies on gibberellin and/or abscisic acid-deficient mutants of *Arabidopsis thaliana*. *In*: Bopp, M. (eds). *Plant growth substances*. Springer-Verlag Berlin, Heidelberg, Germany. pp 315-323.

Katembe, W.J., Ungar, I.A. and Mitchell, J.P. (1998). Effect of salinity on germination and seedling growth of two *Atriplex* species (Chenopodiaceae). *Annuals Botany* 82: 167-175.

Keiffer, C. H. and Ungar, I. A. (1995). Germination response of halophyte seeds exposed to prolonged hypersaline conditions. In: Khan, M. A. and Ungar, I. A. (eds.). *Biology of Salt Tolerant Plants*. Department of Botany, University of Karachi Press, Karachi, Pakistan. pp 43-50.

Khan, M.A. (1977). Seed dormancy: Changing concepts and theories. In: Khan, M.A. (eds). *The Physiology and Biochemistry of Seed Dormancy and Germination. Elsevier*. North-Holland, Biomedical Press, Amsterdam, Holland. pp. 29-50.

Khan, M.A. and Gul, B. (2006). Halophyte seed germination. In Khan, M. A. and Weber, D. J. (eds). *Eco-physiology of High Salinity Tolerant Plants*. Springer Publication, Netherlands. pp. 11-30.

Khan, M.A. and Gulzar, S. (2003). Light, salinity, and temperature effects on the seed germination of perennial grasses. *American Journal of Botany* 90: 131-134.

Khan, M.A. and Rizvi, Y. (1994). Effect of salinity, temperature, and growth regulators on the germination and early seedling growth of *Atriplex griffithii* var. *stocksii*. *Canadian Journal of Botany* 72: 475-479.

Khan, M.A. and Ungar, I.A. (1984). The effect of salinity and temperature on the germination of polymorphic seeds and growth of *Atriplex triangularis* Willd. *American Journal of Botany* 71: 481–489.

Khan, M.A. and Ungar, I.A. (1996). Effects of light, salinity, and thermoperiod on the seed germination of halophytes. *Canadian Journal of Botany* 75: 835-841.

Khan, M.A. and Ungar, I.A. (1997a). Effects of thermoperiod on recovery of seed germination of halophytes from saline conditions. *American Journal of Botany* 84: 279-283.

Khan, M.A. and Ungar, I.A. (1997b). Alleviation of seed dormancy in the desert forb *Zygophyllum simplex* L. from Pakistan. *Annals of Botany* 75: 835-841.

Khan, M.A., and Ungar, I.A. (1999). Seed germination and recovery of *Triglochin maritima* from salt stress under different thermoperiods. *Great Basin Naturalist* 59: 144–150.

Khan, M.A. and Ungar, I.A. (2000). Alleviation of salinity-enforced dormancy in *Atriplex griffithii* Moq. var. *stocksii* Boiss. *Seed Science Technology* 28: 29–37.

Khan, M.A. and Ungar, I.A. (2001a). Role of dormancy regulating chemicals in release of innate and salinity-induced dormancy in *Sporobolus arabicus*. *Seed Science Technology* 29: 299–306.

Khan, M.A. and Ungar, I.A. (2001b). Effect of dormancy regulating chemicals on the germination of *Triglochin maritima*. *Plant Biology* 44: 301–303.

Khan, M.A. and Ungar, I.A. (2001c). Alleviation of salinity stress and the response to temperature in two seed morphs of *Halopyrum mucronatum* (Poaceae). *Ausalian Journal of Botany* 49: 777–783.

Khan, M.A. and Ungar, I.A. (2002). Role of dormancy-relieving compounds and salinity on the germination of *Zygophyllum simplex* L. *Seed Science Technology* 30: 16–20.

Khan, M.A. and Weber, D.J. (1986). Factors influencing seed germination in *Salicornia pacifica* var. *utahensis*. *American Journal of Botany* 73: 1163-1167.

Khan, M.A., Gul, B. and Weber, D.J. (2000). Germination responses to *Salicornia rubra* to temperature and salinity. *Journal of Arid Environments* 45: 207–214.

Khan, M.A., Gul, B. and Weber, D.J. (2001a). Germination of diamorphic seeds of *Suaeda moquinii* under high salinity stress. *Ausalian Journal of Botany* 49: 185–192.

Khan, M.A., Gul, B. and Weber, D.J. (2001b). Effect of salinity and temperature on the germination of *Kochia scoparia*. Wetl. *Forest Ecology and Management* 9: 483–489.

Khan, M.A., Gul, B. and Weber, D.J. (2001c). Seed germination characteristics of *Halogeton glomeratus*. *Canadian Journal of Botany* 79: 1189– 1194.

Khan, T.I. and Frost, S. (2001). Floral biodiversity: a question of survival in the Indian Thar desert, *Environmentalist* 21: 231–236.

Kitajima, K. and Fenne, M. (2000). Seeds: the ecology of regeneration in plant communities, CAB International, Wallingford, UK.

Kucera, B., Cohn, M.A. and Leubner-Metzger, G. (2007). Plant hormone interactions during seed dormancy release and germination. *Seed Science Research* 15: 281–307.

Lacey, E.P., Smith, S. and Case, A.L. (1997). Parental effects on seed mass: seed coat but not embryo/endosperm effects. *American Journal of Botany* 84: 1617–1620.

Leubner-Metzger, G. (2003). Functions and regulation of ß-1,3-glucanase during seed germination, dormancy release and after-ripening. *Seed Science Research* 13: 17–34.

Li, W., Liu, X., Khan, M.A. and Yamaguchi, S. (2005). The effect of plant growth regulators, nitric oxide, nitrate, nitrite and light on the germination of dimorphic seeds of *Suaeda salsa* under saline conditions. *Journal of Plant Research* 118: 207–214.

Lombardi, T., Fochetti, T. and Onnis, A. (1998). Germination of *Briza maxima* L. seeds: effects of temperature, light, salinity and seed harvesting time. *Seed Science and Technology* 26: 463–470.

Lombardi, T., Fochetti, T., Andrea, B. and Onnis, A. (1997). Germination requirements in a population of Typha latifolia. *Aquatic Botany* 56: 1-10.

Luzuriaga, A.L., Escudero, A. and Pérez-García, F. (2006). Environmental maternal effects on seed morphology and germination in *Sinapsis arvensis* (Cruciferae). *Weed Research* 46: 163–174.

Macke, A. and Ungar, I.A. (1971). The effect of salinity on germination and early growth of Puccinella nuttalliana. *Canadian Journal of Botany* 49: 515-520.

Mandujano, M. C., Golubov, J. and Montana, C. (1997). Dormancy and endozoochorous dispersal of *Opuntia rastrera* seeds in the southern Chihuahuan Desert. *Journal of Arid Environments* 36: 259–266.

Marre, E. (1979). Fusicoccin: a tool in plant physiology. *Annual Review of Plant Physiology* 30: 273–278.

Marre, E., Lado, P. and Rasi-Caldogno, F. (1974). Correlation between proton extrusion and stimulation of cell enlargement. Effects of fusicoccin and cytokinins on leaf fragments and isolated cotyledons. *Plant Science Letters* 2: 139-150.

Mayer, A.M. and Poljakoff-Mayber, A. (1975). *The germination of seeds*. New York: Pergamon Press.

Meyer, S.E., and Monsen, S.B. (1991). Habitat-Correlated Variation in Mountain Big Sagebrush (Artemisia Tridentata SSP. Vaseyana) Seed Germination Patterns. *Ecology* 72: 739-742.

Michael, P.J., Steadman, K. J. and Plummer, J. A. (2006). Climatic regulation of seed dormancy and emergence of diverse *Malva parviflora* populations from a Mediterranean-type environment. *Seed Science Research* 16: 273-281.

Michel, B.E. and Kaufman, M.R. (1973). The osmotic pressure of polyethylene glycol 6000, *Plant Physiology* 51: 914–916.

Milberg, P., Andersson L. and Thompson , K. (2000). Large-seeded species are less dependent on light for germination than small-seeded ones. *Seed Science Research* 10: 99–104.

Ministry of Communications, Dept of Meteorology, UAE (1996). UAE Climate Cultural Foundation Publications, Abu Dhabi, U.A.E.

Mohammad, N. (1984). Improvement potential of D.G. Khan rangelands. *Progressive Farming* 4: 31–35.

Morgan, W.C. and Myers, B.A. (1989). Germination characteristics of the salt tolerant grass *Diplachne fusca*.I. Dormancy and temperature responses. *Australian Journal of Botany* 37: 225-237.

Munns, R. (2002) Comparative physiology of salt and water stress. *Plant Cell and Environment* 25: 239–250.

Myers, B.A. and Morgan, W.C. (1989). Germination of the salt-tolerant grass Diplachne fusca. II. Salinity responses. *Australian Journal of Botany* 37: 239-251.

Naidoo, G. and Naicker, K. (1992). Seed germination in the coastal halophytes *Triglochin bulbosa* and *Triglochin striata*. *Aquatic Botany* 42: 217–229.

Noor, M. and Khan, M.A. (1995). Factors affecting germination of summer and winter seeds of *Halopyrum mucronatum* under salt stress. In: Khan, M.A. and Ungar, I.A. (eds). *Biology of salt tolerant plants*. University of Karachi, Pakistan. pp 51-58.

Noronha, A., Vicente, M., and Felippe, G.M. (1976). Effect of storage and growth condition on photoblasticity of seed of *Cucumis anguria*. *Hoehnea* 6: 7-10.

Orozco-Segovia, A.E., Brechú-Franco, L., Zambrano-Polanco, R., Osuna-Fernández, G., Laguna-Hernández and Sánchez-Coronado, M.E. (2000). Effects of maternal light environment on germination and morphological characteristics of *Sicyos deppei* seeds. *Weed Research* 40: 495-506.

Osman, A.E. and Ghassali, F. (1997). Effects of storage conditions and presence of fruiting bracts on the germination of *Atriplex halimus* and *Salsola vermiculata*. *Experimental Agriculture* 33: 149-155.

Peacock, J.M., Ferguson, M.E., Alhadrami, G.A., Cann, M.c., Al Hajoj, A.A., Saleh, R. and Karnik, R. (2003). Conservation Through Utilization: A Case Study of the Indigenous Forage Grasses of the Arabian Peninsula. *Journal of Arid Evironments* 54: 15-28. 2003

Perez, T., Moreno, C., Seffino, G.L., Grunber, A. and Bravo, Z. (1998). Salinity effects on the early development stages of *Panicum coloratum*: Cultivar differences, *Grass Forage Science* 53 (3): 270-278.

Pita Villamil, J. M., Perez-Garcia, F. and Martinez-Laborde, J. B. (2002). Time of collection and germination in rocket, *Eruca vesicaria* (L.) Cav. (Brassicaceae). *Genetic Resources and Crop Evolution* 45: 47-51.

Poljakoff-Mayber, A., Somers, G.F., Werker, E. and Gallagher, J.L. (1994). Seeds of *Kosteletzkya virginica* (Malvacae): their structure, germination and salt tolerance. II. Germination and salt tolerance. *American Journal of Botany* 81: 54–59.

Pons, T. L. (1991). Introduction of dark dormancy in seeds: its importance for the seed bank in the soil. *Functional Ecology* 5: 669-675.

Pons, T. L. (1992). Seed responses to light. In: Fenner, M. (eds). *Seeds: the Ecology of Regeneration in Plant Communities.* CAB International, Southampton, UK. pp 259-284.

Probert, R. J. (2000). The role of temperature in germination ecophysiology. In: Fenner, M. (eds). *Seeds: the Ecology of Regeneration in Plant Communities.* CAB International, Wallingford, UK. pp 285-325.

Pujol, J.A., Calvo, J.F. and Ramirez-Diaz, L. (2000). Recovery of germination from different osmotic conditions by four halophytes from southeastern Spain. *Annals of Botany* 85: 279-286.

Pyler, D.B. and Proseus, T.E. (1996). A comparison of seed dormancy characteristics of *Spartina patens* and *Spartina alterniflora* (Poaceae). *American Journal of Botany* 83: 11-14.

Roach, A. and Wulff, R.D. (1987). Maternal Effects in Plants. *Annual Review of Ecology and Systematics* 18: 209-235.

Romo, J. T. and Haferkamp, M. R. (1987). Effects of osmotic potential, potassium chloride, and sodium chloride on germination of greasewood (*Sarcobatus vermiculatus*). *Great Basin Naturalist* 47: 110–116.

Sandro, A.M., Joaquim, A.G., Tania, D., Iza, M.A., Deborah, L. and Ricardo, A. (2006). Salinity tolerance of halophyte *Atriplex nummularia* L. grown under increasing NaCl levels. *Agriambi* 10(4): 848-854.

Schutz, W., Milberg, P. and Lamont, B.B. (2002). Seed dormancy, after-ripening and light requirements of four annual Asterace in South-western Australia. *Annals of Botany* 90: 704–717.

Scopel, A.L., Ballare, C.L. and Sanchez, R.A. (1991). Induction of extreme light sensitivity in buried weed seeds and its role in the perception of soil cultivations. *Plant, Cell and Environment* 14: 501–508.

Shahba, M. A., Qian, Y. L. and Lair, K. D. (2008). Improving Seed Germination of Saltgrass under Saline Conditions.*Crop science.* 48: 756-762.

Shaheen, S.E., (1998). Geoenvironmental studies on El-Bardawil lagoon and its surroundings, North Sinai, Egypt. Ph.D. Thesis, Mansoura University, Mansoura, Egypt.

Simpson, G.M. (1990). *Seed Dormancy in Grasses.* Cambridge University Press. Cambridge, UK. 297p.

Singh K. C., Rao A.S.A. (1996) short note on water use and production potential of *Lasiurus scindicus* Henr. in the Thar desert of Rajasthan, India. *Journal of Arid Environments* 33: 261-262.

Sosa, L., Llanes, A., Reinoso, H., Reginato, M. and Luna, V. (2005). Osmotic and specific ion effects on the germinationof *Prosopis strombulifera*. *Annals of Botany* 96: 261-267.

Sultan, S.E. (1996). phenotypic plasticity for offspring traits in *Polygonum persicaria*. *Ecology* 77: 1791-1807.

Sutcliff, M.A. and Whitehead, C.S. (1995). Role of ethylene and short chain saturated fatty acids in the smoke-stimulated germination of *Cyclopea* seeds. *Journal of Plant Physiology* 145: 271–271.

SYSTAT 11 for Windows. (2004). Systat Software, Inc. Chicago,US.

Thanos, C.A., Georghiou, K., Douma, D.J. and Marangaki, C.J. (1991). Photoinhibition of seed germination in Mediterranean maritime plants. *Annals of Botany* 68: 469-475.

Tlig, T., Gorai, M. and Naffati, M. (2008). Germination responses of *Diplotaxis harra* to temperature and salinity. *Flora* 203: 421-428.

Trethowan, R.M., Pfeiffer, W.H., Pena, R.J. and Abdalla, O.S. (1993). Preharvest sprouting tolerance in three triticale biotypes. *Australian Journal of Agricultural Research* 44: 1789-1798

Ungar, I.A. (1978). Halophyte seed germination. *The Botanical Review* 44: 233–264.

Ungar, I.A., (1988). Effects of the parental environment on the temperature requirements of *Spergularia marina* seeds. *Botanical Gazette* 194: 432-436.

Ungar, I.A. (1991). Ecophysiology of Vascular Halopytes. CRC Press, Boca Raton, Louisiana, US. 209p.

Ungar, I.A. (1995). Seed germination and seed-bank ecology in halophytes. In: Kigel, J. and Galili, G. (eds). *Seed development and germination*. Marcel Dekker, New York. pp 599–628.

Ungar, I.A. (1996). Effects of salinity on seed germination, growth, and ion accumulation of *Atriplex patula* (Chenopodiaceae). *American Journal of Botany* 83: 604–607.

Ungar, I. A.and Hogan, W. C. (1970). Seed germination in *Iva annua* L. *Ecology* 51: 150-154.

Venable, D.L. and Lawlayer, L. (1980). Delayed germination and dispersal in desert annuals: escape in space and time. *Oecologia* 46: 272-282.

Verdoy, D., Lucas, M.M., Manrique, E., Covarrubias, A.A.,De Felipe, R.and Pueyo J.J. (2004). Differential organ-specific response to salt stress and water deficit in nodulated bean (Phaseolus vulgaris).*Plant Cell & Environment* 27: 757–767.

Waisel, Y. (1972). Biology of Halophytes, Academic Press, New York, US pp. 141–165.

Wesson, G. and Wareing, P.F. (1969). The induction of light sensitivity in weed seeds by burial. *Journal of Experimental Botany* 20: 414–425.

Western, A.R. (1989). The Flora of the United Arab Emirates: An Introduction. 188 pp. United Arab Emirates University Press, Al-Ain.

Williams, J. T. and Farias, R. M. (1972). Utilisation and taxonomy of the desert grass *Panicum turgidum*. *Economic Botany* 26: 13 – 20.

Woodell, S.R.J. (1985). Salinity and seed germination patterns in coastal plants. *Vegetatio* 61: 223-229.

Wright, K.J., Seavers, G.P., Peters, N.C.B. and Marshall, M.A. (1999). Influence of soil moisture on the competitive ability and seed dormancy of Sinapis arvensis in spring wheat. *Weed Research* 39: 309–317.

Yadav, M.S. (1997). Pasture establishment techniques. In: Yadav, M. S., Singh, M., Sharma, S. K., Tewari, J.C. and Burman, U. (Eds). *Silvipastoral Systems in Arid and Semi-Arid Ecosystems*. Jodhpur, India. pp 193-206.

Yadav, M.S. and Rajora, M.P. (1999). Technology for seed production. In: Faroda, A. S., Joshi, N.L., Kathju, S. and Kar, A. (Eds). *Management of Arid Ecosystem*Arid Zone. Research Association of India and Scientific Publishers. Jodhpur, India. pp. 333-338.

Zahran, M.A. (1997). Ecology of the United Arab Emirates. In: Barakat, H.N. and Hegazy, A. K. (Eds). *Reviews in Ecology: Desert Conservation and Development*. Metropole, Egypt. pp 297-331.

Zahran, M. and Willis, A.J. (1992). The vegetation of Egypt. Chapman & Hall. London, UK. 424p.

Zhao, K., Fan, H. and Ungar, I.A. (2002). Survey of halophyte species in China. *Plant Science* 163: 491–498

Zheng, Y., Xie, Z., Gao, Y., Jiang, L., Xing, X., Shimizu, H. and Rimmington, G.M. (2005). Effects of light, temperature and water stress on germination of *Artemisia sphaerocephala*. *Annals of Applied Biology* 146: 327-335.

Zia, S. and Khan, M.A. (2004). Effect of light, salinity and temperature on the seed germination of *Limonium stocksii*. *Canadian Journal of Botany* 82: 151-157.

أما بالنسبة لنبات الضعي، البذور المثبطة استعادت قدرتها على الإنبات تماما باستخدام الفيوسيكوسين و حمض الجبريليك والنترات والثيويوريا ، وجزئيا باستخدام الكاينتين. بينما الإنبات ثبط تماما باستخدام الإيثوفون في بذور النباتين قيد الاختبار.

بذور الضعي أكثر تحملا للجفاف من بذور الثمام. ظهرت بذور الضعي انباتا بنسبة 30% باستخدام0.7 – ميجا باسكال، بينما بذور الثمام ثبط تماما باستخدام 0.5– ميجا باسكال. أشارت هذه النتيجة إلى أن السمية هي السبب الرئيسي في عدم تحمل بذور الضعي للملوحة. والقدرة المنخفضة لبذور الضعي على استعادة قدرتها على الإنبات مقارنة ببذور الثمام يدعم الفرضية السابقة الذكر.

أعطت بذور الضعي المجمعة من البيئة الطبيعية نسبة إنبات وسرعة أعلى من مثيلتها التي جمعت من المركز البحثي والتي حصلت على مياه أكثر. البذور التي جمعت من البيئة الطبيعية احتوت على لونين (بني فاتح وبني غامق). أثبتت التجارب أن الكمون ومتطلبات الإنبات مختلف للونين.

متطلبات بذور الثمام من الحرارة أثناء فترة الإنبات مختلفة بالنسبة للبذور المخزونة لفترات متفاوتة. وأظهرت بذور الضعي التي خزنت لمدة ثلاثة أشهر نسبة إنبات أعلى في درجات الحرارة المعتدلة (20-30°م) مقارنة بدرجات الحرارة المنخفضة (15°م)، من ناحية أخرى لم تظهر البذور التي خزنت لمدة عامين تفاوت في نسبة الإنبات النهائي في درجات الحرارة المختلفة.

أعطت البذور المخزنة لمدة خمسة سنوات نسبة عالية من الإنبات في الظلام مقارنة بالإضاءة في درجات الحرارة المنخفضة (15-25 °م) بينما العكس كان صحيحا في درجات الحرارة المرتفعة (35-40 °م) .

انخفضت نسبة الإنبات بدرجة ملحوظة للبذور التي عولجت بالمحلول الملحي تركيز 100مل مول، بينما نسبة الإنبات ثبطت تماما عندما عولجت البذور بتركيز ملحي 200مل مول، تحققت النسبة المثلى للإنبات عند 30 °م. قاومت بذور الثمام الملوحة بدرجة أفضل عند إنباته تحت 35°م ، بينما انخفضت سرعة الإنبات بارتفاع التراكيز الملحية ولكنها ارتفعت بارتفاع درجة الحاضنة (الإنبات).

لم تظهر بذور الضعي الحديثة النضج كمون طبيعي كما إنها حققت سرعة عالية في الإنبات.

أظهرت البذور غير المعالجة بمحاليل الأملاح نسبة عالية من الإنبات في درجات الحرارة المختلفة تحت ظروف الظلام والإضاءة، بالرغم من أن بذور الثمام لم تعطي أي إنبات في المحلول الملحي 200مل مول وأكثر، إلا أنها استعادت قدرتها على الإنبات (حوالي 30%) بعد نقلها إلى ماء مقطر. أظهرت البذور قدرة مثلى لاستعادة قدرتها على الإنبات في درجات الحرارة المعتدلة مقارنة بدرجات الحرارة العالية والمنخفضة. وهذا يدل أن قدرة استعادة الإنبات للبذور الخاضعة لتراكيز ملحية مختلفة تعتمد على درجة حرارة الحاضنة.

انخفضت نسبة الإنبات لبذور الضعي بزيادة تركيز كلوريد الصوديوم. مقاومة البذور للتراكيز الملحية أثناء الإنبات يعتمد على درجة حرارة الحاضنة، كما أظهرت البذور مقاومة أعلى للملوحة أثناء الإنبات في درجات الحرارة المتوسطة (20-30°م) مقارنة بكلتا الدرجتين المرتفعة والمنخفضة. انخفضت سرعة الإنبات بارتفاع تركيز المحلول الملحي، ولكنها ارتفعت بارتفاع درجة حرارة الحاضنة. وانخفضت القدرة على استعادة الإنبات بارتفاع الحرارة،ولكن انخفضت بارتفاع تركيز المحلول الملحي. وكانت سرعة البذور التي استعادت قدرتها على الإنبات أعلى بشكل ملحوظ من سرعة البذور التي عولجت أو لم تعالج بالمحلول الملحي.

جميع منظمات النمو قيد الدراسة ماعدا الثيويوريا لم تنجح في تحسين نسبة الإنبات للبذور الغير معالجة بالمحلول الملحي لكلا النوعين الثمام والضعي، مقارنة بالبذور حديثة النضج (التجربة الضابطة).

بذور الثمام التي انخفضت نسبة إنباتها بسبب المحلول الملحي استعادت قدرتها على الإنبات تماما باستخدام حمض الجبريليك، وجزيئا باستخدام الفيوسيكوسين والكاينتين والثيويوريا، ولم تتأثر باستخدام النترات.

# الملخـــص باللـــغة الـــعربية


تقع دولة الإمارات العربية المتحدة ضمن حزام المناخ الصحراوي الجاف الذي يتصف بقلة الأمطار وارتفاع درجات الحرارة وزيادة معدل التبخر وبالتالي ارتفاع نسبة الأملاح بالتربة. لذا من الأفضل الاستفادة من النباتات البرية الطبيعية وزراعتها لغرض استخدامها كأعلاف للماشية بدلا من النباتات الدخيلة التي تتطلب زراعتها كميات كبيرة من مياه الري.

يصنف نبات الضعي (*Lasiurus scindicus*) ونبات الثمام (*Panicum turgidum*) ضمن النباتات البرية الرعوية المقاومة للجفاف خلال فترة النمو الخضري ومرحلة التكاثر، وقد تم استزراع هذين النباتين تحت ظروف مخبرية في من دولة الإمارات العربية المتحدة ودول أخرى من العالم، واستخدمت بنجاح كعلف للماشية.

تفتقر الدراسات المتوفرة حاليا للكثير من المعلومات التي تخص هذين النباتين مثل ظاهرة الكمون والعوامل البيئة التي تؤثر على إنبات بذورها.

تم التركيز في هذا البحث على دراسة الكمون الطبيعي في البذور بالإضافة إلى متطلبات الإنبات من الحرارة والإضاءة والمقاومة للجفاف والملوحة وكذلك تم تحديد تأثير منظمات النمو على إنبات البذور للنوعين، بالإضافة إلى دراسة تأثير الخزن وبيئة النبات الأم( البيئة التي تم فيها نضج البذور قيد التجربة) على فترة الكمون ومتطلبات الإنبات للنباتين.

تم جمع البذور حديثة النضج لنبات الضعي خلال شهر مايو 2007 من التجمعات الطبيعية (البرية) في منطقة العين، وأخرى تم جمعها من محطة الأبحاث الزراعية بالذيد في أبريل 2004. أما بذور الثمام فقد جمعت من محمية الزرانيق الواقعة بالجانب الشرقي لبحيرة بردامیل بمصر.

خضعت البذور الحديثة النضج والمخزونة لفترات متفاوتة وظروف مختلفة لتجربة الإنبات. أيضا أخضعت البذور لتراكيز مختلفة من الضغط الأسموزي باستخدام تراكيز مختلفة من الملح (كلوريد الصوديوم) وجلايكول 6000 (PEG 6000). تمت معظم تجارب الإنبات تحت درجات حرارة وإضاءة مختلفة.

أظهرت بذور نبات الثمام كمون طبيعي مرتفع حيث أن البذور حديثة النضج لم تعطي أي إنبات. أن القدرة الكبيرة لبذور نبات الثمام لإبقاء جزء كبير منها في مرحلة الكمون يضمن للنبات تراكم تلك البذور الحية في التربة تحت ظروف بيئية صحراوية لا يمكن التنبؤ بها لحفظ واستمرار النوع.

جامعة الإمارات العربية المتحدة
عمادة الدراسات العليا
برنامج ماجستير علوم البيئة

# دراسة بيئية عن إنبات بذور نوعين من الحشائش الرعوية المحلية: الضعي و الثمام

رسالة مقدمة من الطالبة:

نعيمة سلطان عبدالله الشامسي

إلى

جامعة الإمارات العربية المتحدة
استكمالا لمتطلبات الحصول على درجة الماجستير في علوم البيئة

2009