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GERMINATION STUDIES OF CERTAIN DESERT PLANTS

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Abstract

Ecological studies with seeds of some desert species viz., *Achyranthes aspera* L., *Peristrophe bicalyculata* (Retz.) Nees, *Cassia holosericea* Fresn. and *Prosopis juliflora* Swartz are described. Seedling growth was directly proportional to the seed size. The seed weight distribution was homogeneous and concentrated around the mean with low variation which implied greater interaspecific competition in populations of these species. Smooth and black seed coat of *P. bicalyculata* and hard seed coat of *C. holosericea* and *P. juliflora* appeared to impose dormancy on seeds. *A. aspera* seeds germinated readily within 24 h and showed no dormancy. The dormancy of *P. bicalyculata* disappeared by dry storage for ca. 3 months. Chemical treatments to seeds of *Cassia* and *Prosopis* improved germination but not to the extent as by mechanical scarification. The impact of dense clustering of seeds on germination showed negative response to dense clustering of *C. holosericea* which suggested the possibility of leaching of toxins in relatively greater amount or number from germinating seeds. Hydration – dehydration – rehydration cycle did not affect germination of *A. aspera* and *P. bicalyculata* seeds. Optimum sowing depth for all the species was 0.5 cm. Role of temperature and NaCl– and Na_2SO_4– salinity in germination ecology of all the species were investigated and are discussed in ecological and physiological context.

Introduction

Autecological investigations utilize multidisciplinary approach to study behaviour of plants to a multitude of factors. Since seed is considered as a stored part of population, studies have been conducted to evaluate response of seed to environmental complex. Although much is known about the physiological processes of germination, but adaptive aspects of germination strategies have received relatively lesser attention (Kozlowski, 1972; Heydecker, 1973). These strategies are important in population dynamics (Cohen, 1967). Little autecological work has been done in Pakistan and only a few comprehensive reports are available on seed germination of species of the region (Ahmad, 1962; Habibun-Nisa & Qadir, 1969; Hussain & Qadir, 1970; Qaiser & Qadir, 1971; Iqbal & Qadir, 1973 etc.). In the present study an attempt was made to investigate the germination behaviour

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of four desert or semi-desert plants viz., *Achyranthes aspera* L., *Peristrophe bicalyculata* (Retz.) Nees, *Cassia holosericea* Fresn. and *Prosopis juliflora* Swartz. In view of current interest in development of arid zones for the production of biomass, such studies are imperative for planning, control and management of arid-zone ecosystems.

Materials and Methods

Seeds were collected from their respective populations from the University Campus, Karachi. The seeds of *A. aspera* and *P. bicalyculata* collected in September, 1978 and that of *C. holosericea* and *P. juliflora* in June, 1978 were stored in open poly-ethylene bags at room temperature (30±2°C).

a. Studies on seed-weight-distribution:

To follow the seed-weight-variation, 100 randomly selected seeds of each species were weighed repeatedly until constant weight indicated that the surface drying was completed. Seed weight frequency distribution for each species was worked out through Fisher statistics (1948).

b. Studies on germination:

i) *General experimental procedure:* Twenty freshly collected or variously treated seeds were surface sterilized with 2% sodium hypochlorite for 5 min. and placed on Whatman No. 1 filter paper in 9 cm. diam. sterile Petri plates and 5 ml. glass-distilled water was added to each. Light intensity at the top of Petri plates was 4000 Lux for 14 h day length. For dark treatment the plates were completely wrapped in black carbon paper and placed in incubator maintained at 30°C: The treatment were replicated thrice. Germination counts were made daily.

ii) *Chemical and physical scarification:* The seeds were scarified by i) Acid scarification of seeds with 10% HCl for 2 min. and 5 min., 1 N–H_2SO_4 for 2 min., 2 N–H_2SO_4 for 2 min. and 4 N–H_2SO_4 for 1 min., ii) Mechanical scarification with the help of sand paper No. 1.5. The seeds were germinated in light or dark.

iii) *Dry storage and viability of seeds:* Twenty seeds either fresh or stored for various duration of time (1-6 months) were germinated in Petri plates. In case of *C. holosericea* and *P. juliflora* slightly abraded seeds were employed since variously aged seeds of these species exhibited irregular germination without scarification.

iv) *Dense clustering of seeds and their germination:* To elucidate the effect of dense clustering of seeds on germination, the test were run following Linhart (1976) Five month old seeds were arranged in sets of increasing densities:

1. Singly, seeds separated from one another by 5-7 mm (N = 50);
2. in ten groups of five contiguous seeds;
3. in five groups of ten contiguous seeds;
4. in two groups of twenty five contiguous seeds.

Seeds were sown on Whatman No. 1 filter paper in Petri plates and replicated 4 times. Seeds arranged in groups were in monolayers so that all seeds were in contact with wet filter paper. To ensure germination of *Cassia* and *Prosopis,* their seeds were slightly abraded prior to their sowing. Differences in total germination between the four sets were tested for significance with χ^2-test.

v) *Temperature:* Twenty seeds (5-month old) of each species were germinated on moist filter papers in Petri plates at 20, 25, 30, 35 and 40°C in an incubator for 4 days. The seeds of *Cassia* and *Prosopis* were slightly abraded prior to their sowing. At the end of the experiment seedling growth was also measured.

vi) *Hydration and dehydration cycles:* In order to determine the behaviour of *A. aspera* and *P. bicalyculata* seeds to hydration and dehydration cycles common in arid regions, 30 seeds (5-month old) of each species were placed on wet Whatman No. 1 filter paper in 9 cm diam. Petri plates and were allowed to imbibe water for 1, 2 and 4 h, after which the seeds were transferred onto dry filter papers and allowed to dry for 24 h. After a lapse of 24 h of dehydration the seeds were allowed to imbibe water for 3 days. The germination percentage was recorded daily. Controls were kept constantly wet.

vii) *Seed size:* To investigate the relationship of seed size/seed weight to height and vigour of young seedlings, 20 seeds each of larger and smaller (than the mean) classes were screened from 5-month old seed populations of the selected species and were allowed to germinate on moistened filter paper. After three days root and shoot lengths were measured to the nearest mm and then seedlings were oven-dried and weighed.

viii) *Sowing depth:* In June, 1979, sets of 20 seeds of the selected species were either sown through broadcasting on the soil surface or at 0.5, 1, 2, 4 and 6 cm depth in 20 cm diameter pots. The soil used was sandy loam maintained at 50% MHC. Emergence counts were made daily for a week. The treatments were replicated thrice.

ix) *Salt stress:* Twenty surface sterilized seeds (ca. 6-month old) of each species were placed to germinate in Petri plates in a series of concentration of NaCl and Na_2SO_4 (−1 to −10 bar) prepared in accordance with Meiri *et al.,* (1971). Germination counts were made daily and after an incubation of 5 days, seedling growth was measured. In case of *P. juliflora* and *C. holosericea* abraded seeds were employed.

Results

a. Seed-weight variation:

Seed-weight variability of all species was low (Fig. 1), with the lowest in *A. aspera* (6.823%) and the highest for *P. juliflora* (16.83%). The seed weight distributions are characterized by insignificant skewness (g_1) and highly significant kurtosis (g_2). In all species seed weight was concentrated around the mean value.

b. Studies on germination:

i) *Chemical and physical scarification:* Fresh untreated seeds of *A. aspera* germinated (100%) rapidly and regularly within 24 h equally in light and dark (Fig. 2a). Therefore, germination of this species was not tested with other treatments. In light as well as in dark, fresh seeds of *P. bicalyculata* exhibited almost no germination (Fig. 2b). Scarification with 10% HCl for 2 min. resulted in low germination in light only, however, when the treatment prolonged upto 5 min. the germination increased upto 25%. Germination was, however, greater in light than darkness. Scarification with 1N-H_2SO_4 for 2

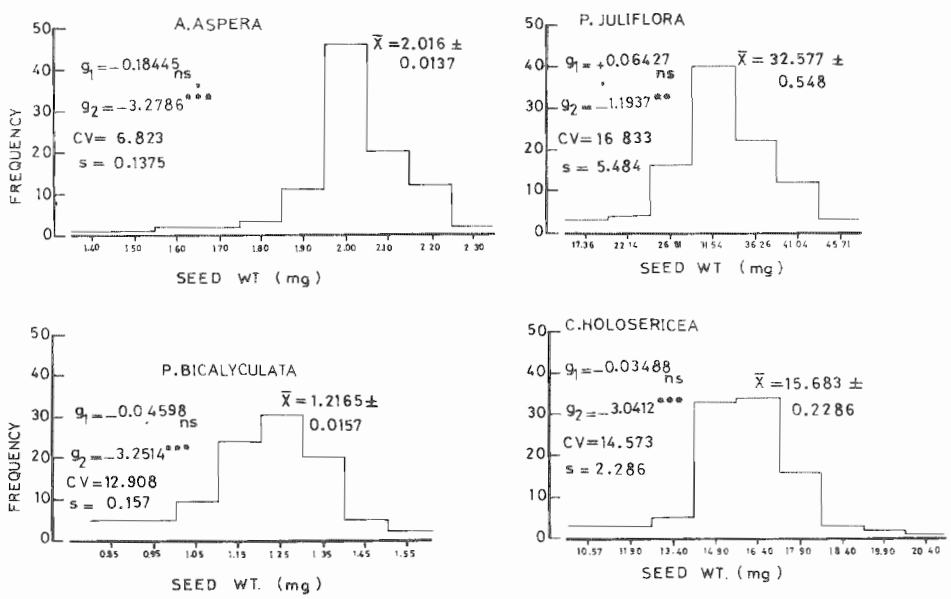

Fig. 1. Seed weight frequency distribution for the selected species. s, standard deviation; c.v., % coefficient of variation and g_1 and g_2 are skewness and kurtosis respectively as calculated by Fisher's statistics. ns, non-significant; **, $P < 0.01$; ***, $P < 0.001$.

$$Sg_1 = \sqrt{\frac{6N(N-1)}{(N-2)(N+1)(N+3)}} = 0.2414 \qquad Sg_2 = \sqrt{\frac{24N(N-1)}{(N-3)(N-2)(N+3)(N+5)}} = 0.4783.$$

min. and 2N–H_2SO_4 for 2 min. further increased the germination. The germination of fresh seeds was maximum when seeds were scarified with 4N–H_2SO_4 for 1 min.

Fresh untreated seeds of *C. holosericea* (Fig. 2c) showed almost no germination either in light or dark. Chemical scarification with 10% HCl for 2 min. and 5 min. increased the germination upto ca. 12 and 20%, respectively. Treatment with 1N, 2N and 4N–H_2SO_4 for 2, 2 and 1 min. steadily increased the germination of seeds upto ca. 26, 46 and 56%, respectively. In all treatments, light seems to enhance the rate as well as the germination percentages of seeds as compared to those in darkness. Abrasion of seed coat showed approximately 96% germination.

Like *Cassia, Prosopis* showed irregular germination (Fig. 2d). In six days, germination reached upto 13.33% in light and 3.33% in dark. The scarification with 10% HCl for 2 min. was ineffective, however, treatment of upto 5 min. resulted in germination comparable to that of untreated seeds in light and in dark the germination remained

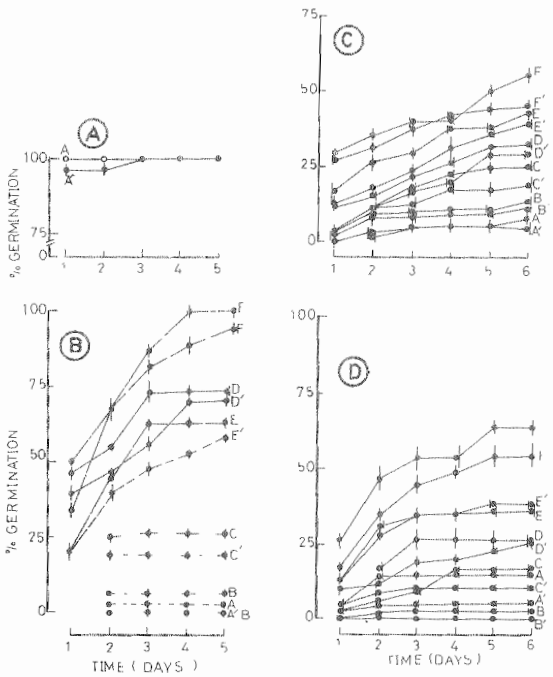

Fig. 2. Germination behaviour of fresh seeds of (A) *A. aspera;* (B), *P. bicalyculata;* (C) *C. holosericea* and (D), *P. juliflora.* Key to the symbols:
A, in light (no treatment); A', same in dark; B, 10% HCl scarification (2 min.) and light; B', same in dark; C, 10% HCl (5 min.) and light; C', same in dark; D, 1N-H_2SO_4 (2 min.) and light, D', same in dark; E, 2N-H_2SO_4 (2 min.) and light, E', same in dark; F, 4N– H_2SO_4 (1 min.) and light and E', same in dark.

lower. Treatment with 2N – and 4N–H_2SO_4 for 2 and 1 min., respectively, showed an increase in germination of upto 33.33 and 66.66% respectively. Slight abrasion of the testa of fresh seeds of *P. juliflora* proved to be the most successful dormancy breaking treatment.

ii) *Effect of storage on germination:* It is apparent from Fig. 3a(i) that the period of storage upto 6 months did not alter the final germination of *Achyranthes,* though the rate slightly impeded with the increase in duration of storage period. The germination of *Peristrophe* increased with increase in storage-duration (Fig. 3a(ii)). The unabraded seeds of *Cassia* and *Prosopis* showed irregular germination (Fig. 3b). On the other hand, abraded seeds showed 100% germination within 24 h irrespective of the duration of storage (Fig. 3c).

iii) *Effect of dense clustering on germination: Achyranthes* showed no significant difference in germination against aggregation of seeds except a non-significant negative trend on first day (Table 1). *P. bicalyculata* showed a significant negative trend to clustering on first day of incubation which, however, later diminished. *C. holosericea* was the only species which exhibited significant negative response ($p < 0.001$) at each time of observation. *Prosopis* also behaved like *Achyranthes.*

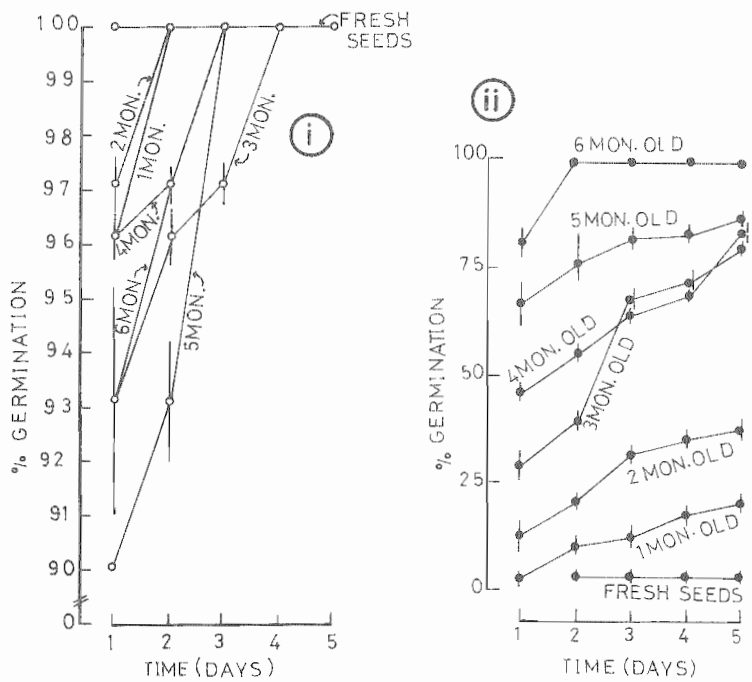

Fig. 3a. Effect of dry storage on germination of (i) *A. aspera* and (ii) *P. bicalyculata* seeds.

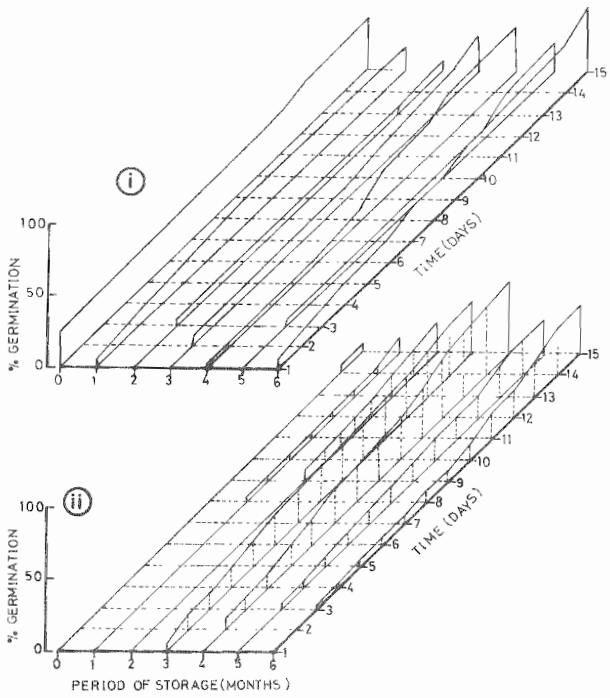

Fig. 3b. Germination response of unabraded seeds of (i) *C. holosericea* and (ii) *P. juliflora* to dry storage.

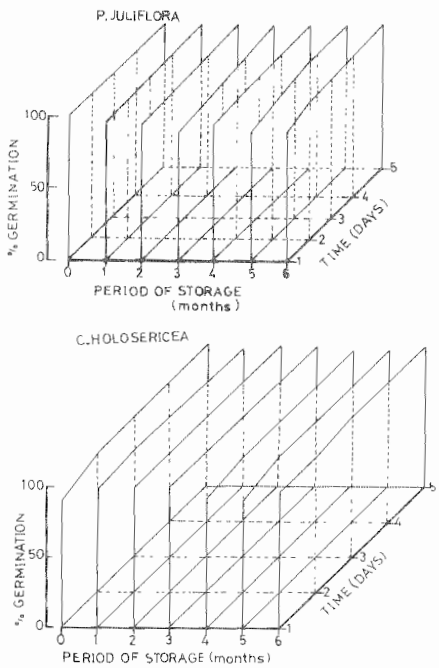

Fig. 3c. Germination response of slightly abraded seeds of *P. juliflora* and *C. holosericea* to dry storage.

Table 1. The cumulative percentage germination of seeds of four species aggregated to varying degrees

Species	Days	% germination in set of:				X^2	Response†
		1	5	10	25		
Achyranthes aspera	1	96	86	88	78	3.546	0(–)
	2	96	100	100	92	0.788	0
	3	96	100	100	92	0.788	0
Peristrophe bicalyculata	1	94	94	88	60	18.291***	(–)
	2	100	98	92	84	3.085	0(–)
	3	100	98	92	84	3.085	0(–)
Cassia holosericea	1	98	96	88	62	18.610***	(–)
	2	98	96	88	64	16.387***	(–)
	3	98	96	92	64	16.725***	(–)
Prosopis juliflora	1	96	96	92	84	1.917	0(–)
	2	100	100	96	86	2.549	0(–)
	3	100	100	96	86	2.549	0(–)

Significance level of X^2 with three degree of freedom:
***, $P < 0.001$.
† three types of responses are indicated:
0, no statistically significant difference between sets;
, response statistically significant (negative);
0(-), trend is suggestive but not statistically significant.

iv) *Effect of temperature:* The rate of germination of *A. aspera* declined at 20 and 30°C, however, the total germination remained unaffected (Fig. 4a). The rate as well as final germination percentage of *Peristrophe* was impeded at 20°C (Fig. 4b) and it remained unaffected at 35°C. Both the species failed to germinate at 40°C. The seeds of the species which failed to germinate at 40°C were dried at room temperature (30°C) for

three days which on remoistening, showed a germination of 100 and 33.33% respectively at room temperature.

The optimal temperature for germination of *C. holosericea* seeds was 30-35°C (Fig. 4c) below which the rate as well as the germination percentage declined. The seeds of *P. juliflora* failed to germinate until 48 h when kept at 20°C, however, after 3 days of incubation it gave 100% germination (Fig. 4d). The germination of its seeds remained unaffected at 25, 30 and 35°C as the seeds germinated readily (ca. 100%) within 24 h in this range of temperature. Both *Cassia* and *Prosopis* seeds germinated at 40°C.

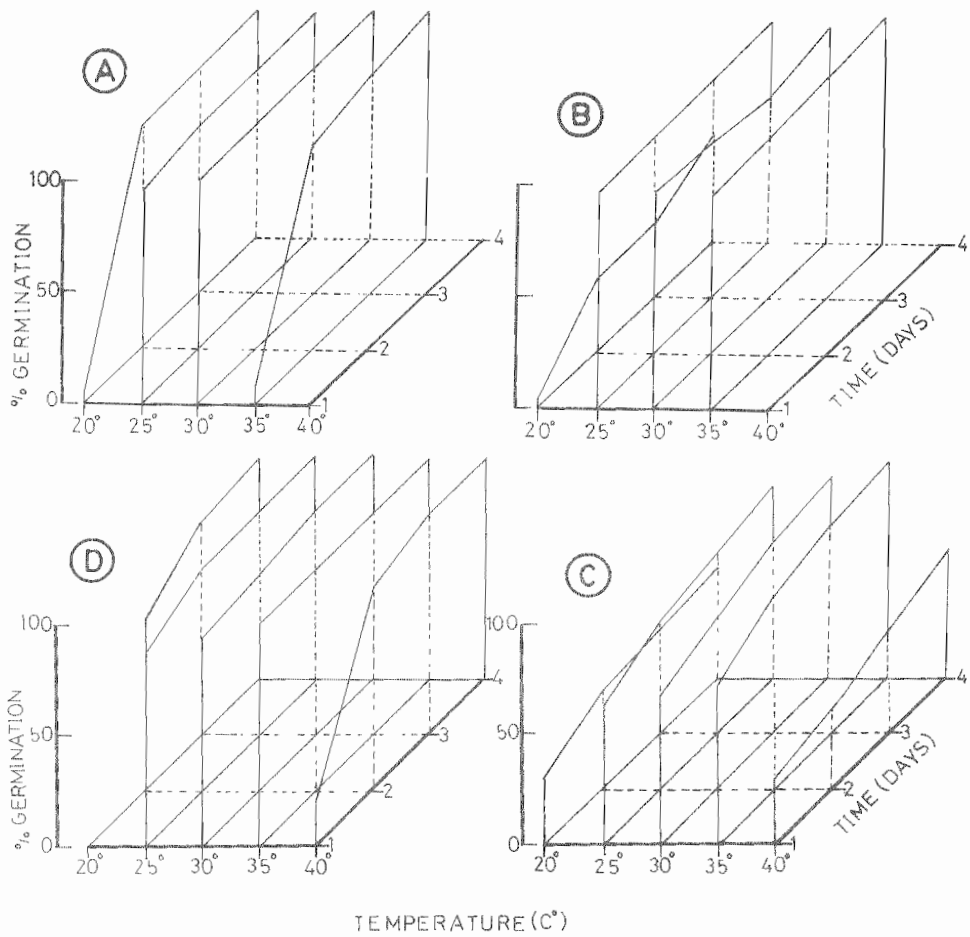

Fig. 4. Effect of temperature on seed germination of the selected species. Seeds of *Cassia* and *Prosopis* used were slightly abraded.

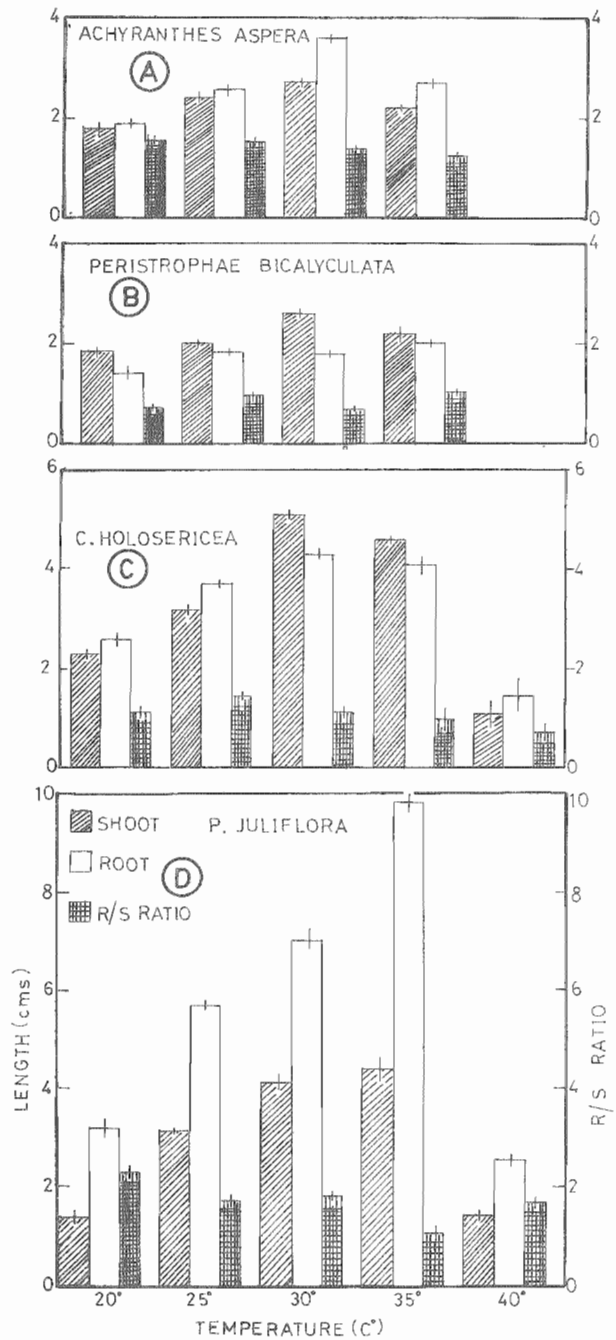

Fig. 5. Response of early seedling growth of the test species to various ambient temperatures.

The root as well as the shoot length of *A. aspera* (Fig. 5) declined with the increase in temperature upto 30°C and beyond. The increase in root length was comparatively faster than that of the shoot. Root/shoot ratio declined with the increase in temperature. The shoot growth of *P. bicalyculata* increased significantly with increase in temperature (Fig. 5) whereas the root growth did not. The root/shoot ratio showed fluctuation. The root and shoot growth of *C. holosericea* increased significantly with the temperature upto 30°C after which both started to decline. Root/shoot ratio declined regularly with the temperature except a slight irregularity at 25°C. Similar increase in root and shoot growth was exhibited by *Prosopis* upto 35°C. At this temperature the root and shoot growth of *Prosopis* were ca. three times greater than those at 20°C. This trend of increased growth abruptly fell at 40°C (Fig. 5).

v) *Effect of hydration and dehydration cycles:* The germination of *A. aspera* and *P. bicalyculata* to hydration and dehydration cycle is given in Table 2. Imbibition for 4 h period followed by drying did not alter the germination percentages of the seeds. Furthermore, the treated as well as untreated seeds required equal time period for germination i.e. 24 h, which suggested that these species require continuous moisture supply for germination. Germination was a bit more uniform and synchronous in treated seeds.

vi) *Effect of seed size on germination and seedling growth:* It is evident from Table 3 that seed size of the four species did not alter their final germination percentages, however, substantial effect on seedling growth was apparent. Root length of *A. aspera*

Table 2. Effect of hydration – dehydration – rehydration treatment on germination of *Achyranthes aspera* and *Peristrophe bicalyculata*.

Species	% final germination			
	Control	Time period (h) to which seeds were allowed to imbibe before drying for 24 hrs.		
		1 h	2 h	4 h
Achyranthes aspera	96.66 ± 3.333	100±0	100±0	100±0
Peristrophe bicalyculata	97.77 ± 2.222	100±0	100±0	100±0

Table 3. Germination percentage and seedling growth in relation to seed size of the four species.

Species	Larger seeds				Smaller seeds			
	% final germination	Root length (cm)	Shoot length (cm)	Seedlings dry wt. (mg)	% final germination	Root length (cm)	Shoot length (cm)	Seedlings dry wt. (mg)
Achyranthes aspera	98.333± 1.666	4.41 ± 0.752	1.34 ± 0.081	20.65 ± 0.985	100±0	$2.384 \pm 0.242^{***}$	$2.268 \pm 0.099^{**}$	$18.89 \pm 1.053_{ns}$
Peristrophe bicalyculata	96.666± 3.333	2.038 ± 0.235	2.375 ± 0.075	18.92 ± 0.531	100±0	$3.31 \pm 0.129_{ns}$	$1.69^{***} \pm 0\ 075$	$15.25^{*} \pm 0.368$
Cassia holosericea	96.666± 3.333	4.056 ± 0.5696	4.235 ± 0.483	144.83 ± 3.215	98.333± 1.666	$3.852 \pm 0.348_{ns}$	$3.008^{*} \pm 0.589$	$131\ 06^{*} \pm 2.993$
Prosopis juliflora	100±0	5.329 ± 0.2015	5.635 ± 0.305	159.66 ± 2.315	100±0	$4.562 \pm 0.369^{**}$	$3.346 \pm 0.269^{***}$	$144.82^{*} \pm 3.213$

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

A. aspera: wt. of smaller seeds ranged from 1.85 mg to 1.95 mg and wt. of larger seeds from 2.10 mg to 2.20 mg;
P. bicalyculata: wt. of smaller seeds ranged from 1.1 to 1.2 mg and that for larger seeds from 1.3 to 1.4 mg;
C. holosericea: wt. of smaller seeds ranged from 13.5 to 15.0 mg and that for larger seeds from 16-17.5 mg;
P. juliflora: wt. of smaller seeds ranged from 26.5 to 31.5 mg and that for larger seeds from 34.00 to 40 mg.

Table 4. Germination response of the four species to various sowing depths.

Species	Soil depth (cm)					
	0	0.5	1	2	4	6
Achyranthes aspera	76.666± 3.333	100±0	100±0	96.666± 3.333	—	—
Peristrophe bicalyculata	48.33 ± 1.68	68.33 ± 6.013	36.666± 3.333	0.0	—	—
Cassia holosericea	36.66 ± 3.333	63.666± 3.333	26.666± 6.666	10.0 ± 5.357	—	—
Prosopis juliflora	86.33 ± 3.33	98.33 ± 1.60	90.0±0	76.66 ± 6.666	66.666± 3.333	33.333± 3.333

seedlings emerging from smaller seeds was significantly ($P < 0.001$) smaller than that of larger seeds, however, reverse was true for shoot length and no significant difference was noted in dry matter production of the seedlings. Shoot length and dry matter of seedlings emerging from smaller seeds of *P. bicalyculata* were significantly low at $P < 0.001$ and $P < 0.05$ respectively as compared to that of larger seeds. *C. holosericea* also exhibited similar results. The root as well as shoot length of seedlings which appeared from smaller seeds of *P. juliflora* were significantly lower at $P < 0.01$ and $P < 0.001$ respectively than those appeared from larger seeds. Dry matter of seedlings was also low in case of smaller seeds.

vii) *Effect of sowing-depth on seedling emergence:* For all species the optimum sowing depth was 0.5 cm (Table 4). Seedling emergence of all species decreased with the increase in sowing depth. *P. juliflora* was the most successful species showing seedling emergence from 6 cm depth, however, the emergence was reduced to 33.33±3.33% which is ca. one-third of the emergence from 0.5 cm depth.

viii) *Effect of salt stress on germination and seedling growth:* NaCl upto 4 bar concentration showed almost no effect on germination of *A. aspera* seeds, beyond which rate as well as germination regularly declined (Fig. 6a(i)). Na_2SO_4 inhibited the germina-

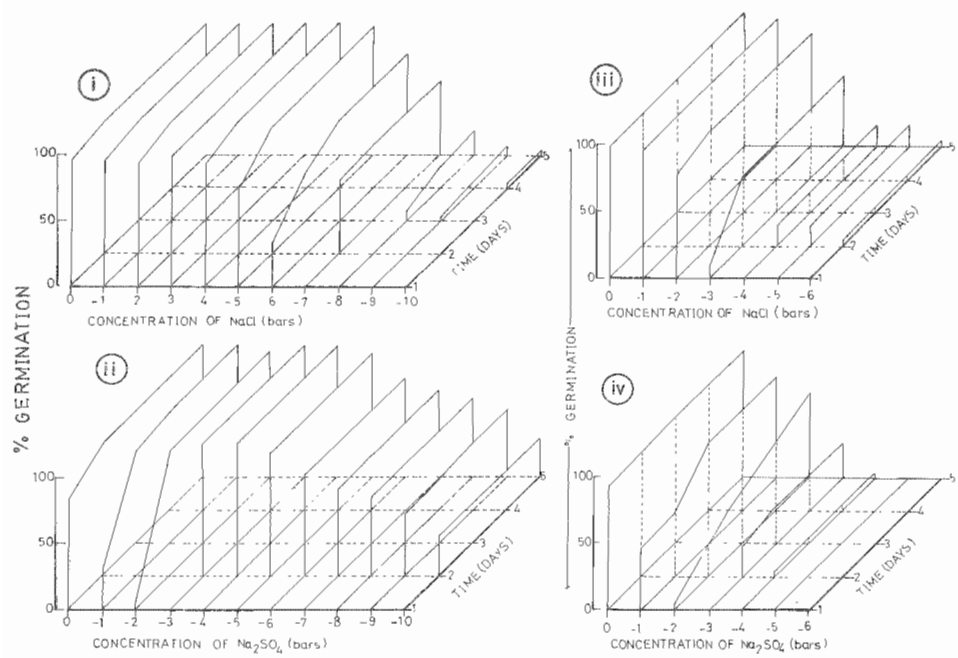

Fig. 6a. Osmotic and ionic effects of NaCl and Na_2SO_4 on germination of *A. aspera* (i & ii) and *P. bicalyculata* (iii & iv).

tion more drastically (Fig. 6a(ii)). *Peristrophe* and *Cassia* were comparatively more sensitive (Fig. 6a and b). The germination of *P. bicalyculata* was greatly reduced at 3 bar concentration of NaCl and Na_2SO_4. Similar response to salt stress were given by *Cassia.* No effect on final germination percentage of *P. juliflora* was observed when treated upto 8 bar NaCl. However, the rate of germination retarded (Fig. 6b). which was more pronounced in Na_2SO_4 than NaCl.

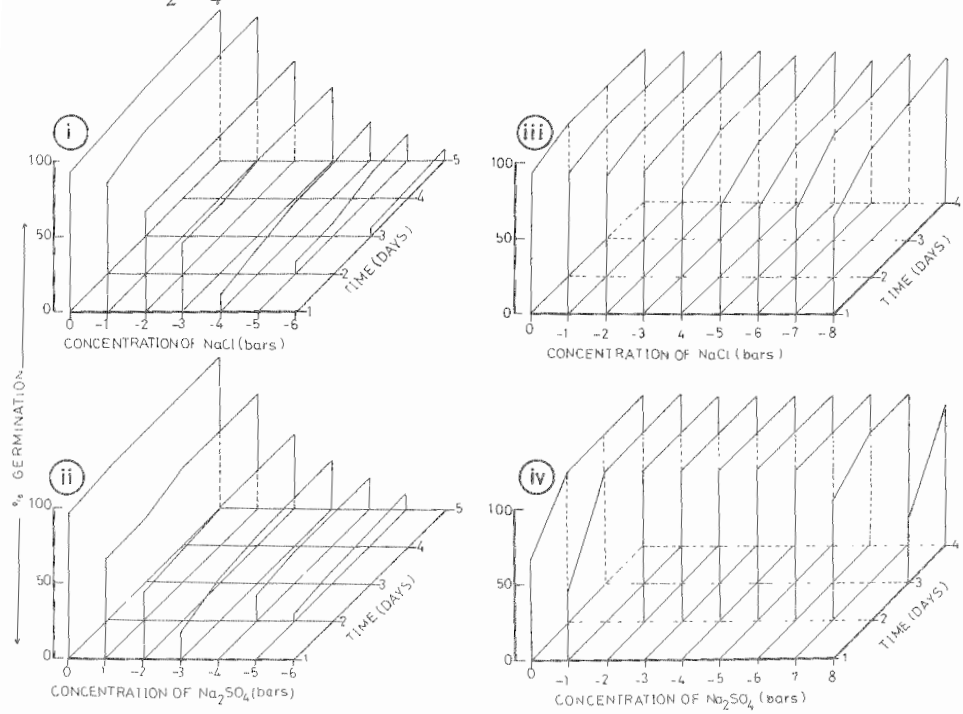

Fig. 6b. Osmotic and ionic effects of NaCl and Na_2SO_4 on germination of *C. holosericea* (i & ii) and *P. juliflora* (ii & iv). Abraded seeds of these species were employed.

Shoot length and its dry matter in *A. aspera* decreased regularly with the increase in concentration of NaCl and Na_2SO_4. The root length, however, increased upto 5 bar NaCl but sharply declined thereafter (Fig. 7). No promotory effect on radicle growth was observed in Na_2SO_4. *Cassia* and *Peristrophe* responded more or less in a similar fashion and reduction in dry matter of root and shoot was more pronounced by Na_2SO_4 salinity than NaCl salinity (Fig. 8 and 9). A pattern of decrease in shoot length of *P. juliflora* was exhibited against increasing stress of NaCl and Na_2SO_4. The response of root length to NaCl and Na_2SO_4 were contrary. NaCl was promotory to radicle growth upto at least 5 bar NaCl whereas Na_2SO_4 was inhibitory (Fig. 10). The dry weight of shoot was also significantly high over the control in NaCl-treated seedlings. Root dry weight represented a fluctuating-decreasing trend to NaCl and Na_2SO_4 however, it was more susceptible to Sodium sulphate than Sodium chloride.

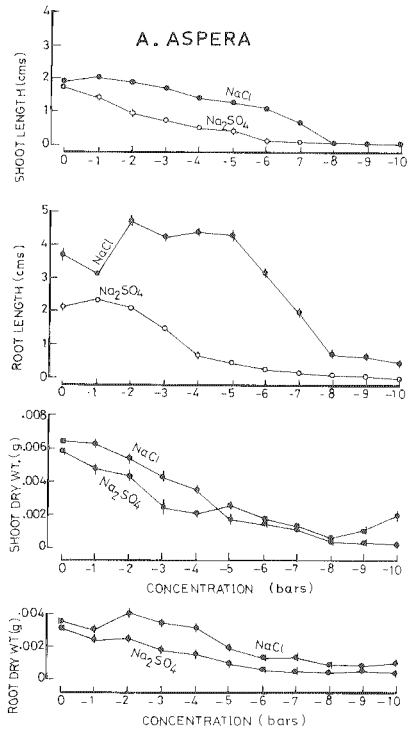

Fig. 7. Response of early seedling growth of *Achyranthes* to NaCl– and Na_2SO_4-salinity.

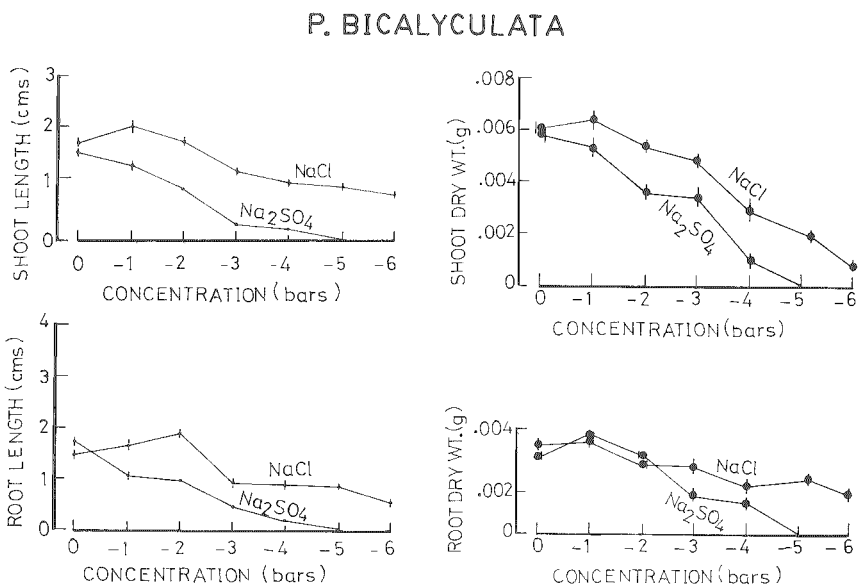

Fig. 8. Effect of NaCl and Na_2SO_4– salinity on seedling growth of *Peristrophe.*

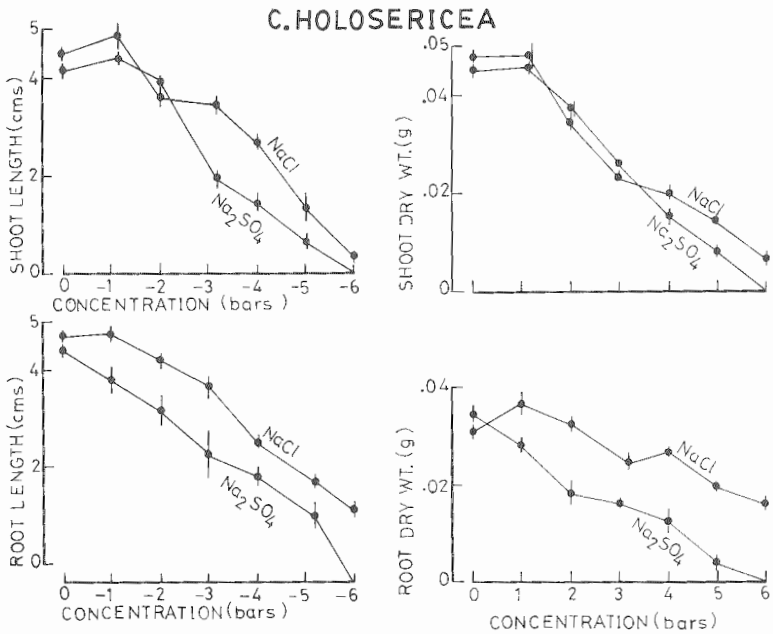

Fig. 9. Effect of Sodium Chloride and Sodium Sulphate salinity on early seedling growth of *C. holosericea*.

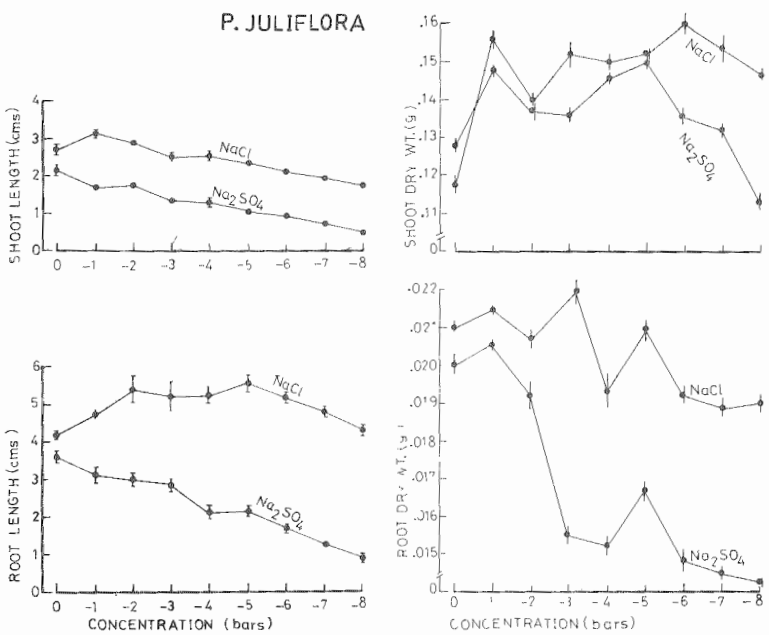

Fig. 10. Response of seedling growth of *P. juliflora* to NaCl and Na_2SO_4–salinity.

Discussion

The distribition of seed weight of the four selected species was homogeneous as the coefficients of variability were low, particularly in case of *A. aspera.* This contrasts with the findings of Harper *et al.*, (1970) who found high degree of variability in the seed weight of several species. However, Labouriau & Pacheco (1979) found that a lot of *Dolichos lablab* L. (*D. biflorus* L.) was relatively uniform and dispersed randomly. As the shoot and root growth of a seedling is faster in case of larger seeds, such a difference in seedling growth may be a significant factor in interaspecific competition (Black, 1957). The implication of low variability of seed weight may be a significant factor in the population dynamics of the species under study.

Fresh seeds of *A. aspera* germinated readily (within 24 h) and did not exhibit any form of dormancy. On the other hand, fresh seeds of *Peristrophe* did not germinate well unless the seed coat was scarified which indicated that smooth membranous black seed coat was some how impervious to water and imposed an external dormancy. Hard-coated fresh seeds of *Cassia* and *Prosopis* also behaved similarly and did not germinate unless scarified physically or chemically. Several families of plant bear hard-coated seeds (Crocker & Barton, 1957) and several methods of chemical and physical scarification have been successfully used to break dormancy imposed by hard seed coat (Hussain & Qadir, 1970; Fawusi, 1979). The improvement of the rate of germination of *P. bicalyculata* and to some extent of *Cassia* and *Prosopis* on dry storage may be due to appearance of some micro-cracking in the seed coat during desiccation and not due to immature embryo since freshly harvested seeds of these species germinated well on scarification and in the soil. Storage upto six months, in any case, does not effect the viability of the seeds. Similarly, increase in germination percentage of spring collected seeds of *Senecio vulgaris* L. on dry storage has been reported by Poppay & Roberts (1970). Dormancy in freshly harvested seeds similar to *P. bicalyculata* was also reported by Barton (1945) in *Amaranthus retroflexus* and *Rumex obtusifolius* where the fresh seeds did not germinate well, but gradually improved on dry storage, over a wide range of temperature.

The impact of seed density upon germination rates is interesting in the context of physiology and adaptation. The physiological mechanisms responsible for negative responses to density are likely to involve germination inhibitors which are known to be released from seeds (Evenari, 1949; Boerner, 1960; Qadir & Abbassi, 1970; Mubarak & Hussain, 1978). The delay in germination of *P. bicalcylata* and *A. aspera* seeds in response to dense clustering may be due to release of some phyto-toxins which may eventually get oxidized under moist conditions and thereby inducing the seeds to germinate. Exudation of phyto-toxins from germinating seeds of all the selected species is known (Khan, 1980). Come (1967) reported that phenolic components of apple seeds (mainly phloridzin, chlorogenic acid and para-coumaryl-quinic acid) can easily be oxidized when seed coat that contains them is moistened. While phenolic substances oxidize, the concentra-

tion of oxygen available to the embryo depletes. At high temperatures like those in arid or semi-arid zones, the oxygen availability to seeds may further be decreased because oxygen becomes less soluble in water of the seed coat and phenolic toxins may fix more oxygen with the result that germination is inhibited (Come & Tissaoui, 1973). Since *A. aspera* and to some extent *P. bicalyculata* appeared to require relatively low oxygen concentrations to germinate than *C. holosericea* and *P. juliflora* (Khan, 1980) the seeds of the former two species showed delayed germination and exhibited non-significant negative trend to dense clustering. On the other hand, *C. holosericea* showed negative response to clustering which may be due to occurrence of toxins in greater amount or number in the seedcoat of this species and leaching of these toxins from germinating seeds (Khan, 1980). Exudation of toxins from germinating seeds *Cassia tora* L. and *C. auriculata* L. has also been reported by Bhattia & Chawan (1976). However, the adaptive aspects of the response to density need explanation. The negative response of *C. holosericea* to density may provide a population-regulation mechanism. Colonizing and weedy species often grow poorly under competition (Baker, 1965) and reduced germination at higher densities decrease the likelihood of having dense populations. Similar explanations to negative response to density is given by Linhart (1976). Indeed *C. holosericea* populations are almost pure but the individuals are sparsely dispersed and are not so close as those of *A. aspera* and *P. bicalyculata* populations (Khan, 1980).

Germination of *A. aspera* and *P. bicalyculata* was not affected by hydration-dehydration-rehydration treatment in comparison to the seeds continuously hydrated. The germination in treated seeds was more uniform and synchronous than that of untreated seeds. Similarly germination response to hydration-dehydration-rehydration treatment has been reported by Heydecker (1974) and Salter & Derby (1976). Furthermore, treated and untreated seeds required more or less equal duration of imbibition (24 h) for maximum germination ($\geq$ 95%) which suggests that these species require a continuous moisture supply for a certain duration (15-24 h) in order to germinate. Successive cycles of wetting and drying are frequent in arid environment and seedling adaptation to such conditions are extremely important since adaptations to these cycles tend to minimize post-germination seedling loss. Under low rainfall the germination of seeds in arid regions is generally endangered with subsequent drought. To minimize this environmental hazard, seeds of these species probably obtain benefit by germinating in moderate rains while the chances of immediate subsequent drought are extremely reduced.

The cumulative percentage germination of the larger seeds of the selected species was not significantly different from the smaller seeds. However, Strauss *et al.*, (1979) reported that germination of heavy seeds is always greater in all eight cultivars of *Colocasia esculenta* tested.

The experiment related to the comparative growth of seedlings emerging from larger and smaller seeds, indicated that the root and shoot growth was proportional to the

seed weight. Similar relationship for *Lotus corniculatus* L. is reported by Henson & Layman (1961). Practically, foresters have a natural interest in possible correlations between the seed weight and rate of seedling growth. However, literature for trees in this connection is confusing. Hough (1942) concluded that seed weight and seedling growth of *Pinus resinosa* Ait., were directly correlated while Nienstadt & Olson (1961) working on *Tsuga canadensis* (L.) Carriere, felt that some differences that have been attributed to seed weight belong in smaller or larger proportion to other genetic factors which evolved in this species through an adaptation to the length of frost free season. Probably the most generalized conclusion is that of Mirov & Baker (1942) who stated that "seed size is effective only in determining the size of the seedling for a very short time". However, this short period of time may be critical for the seedling survival. In an extensive study of the relationship between seed weight and seedling growth in *Trifolium subterraneum*, L., Black (1957, 1958) showed that the difference in shoot growth may be significant in interaspecific competition as the seed weight affect the mean leaf area of the seedling which has considerable effect on the subsequent seedling performance. Mean area (mm^2) of the fully expanded cotyledons of the seedlings grown from twenty randomly selected seeds of each of *A. aspera, P. bicalyculata, C. holosericea* and *P. juliflora* was 44.20 ± 2.16, 28.26 ± 1.53, 60.05 ± 3.13 and 100.10 ± 5.24 respectively. Interestingly, the errors associated are of low magnitude and perhaps it may be attributed to the low seed weight variation of these species. The above results lead to the conclusion in accordance with Black (1958), Harper & Clatworthy (1963) and Baker (1972) that seed weight is one of the important factors that regulates the population balance.

Comparatively low germinability of all the four species at the soil surface may be partly due to evaporation from the seed and soil surface. The optimum sowing depth for all the species was found to be 0.5 cm and *P. juliflora* was the most successful species, the seedling of which were capable of emerging from 6 cm depth. Baker (1960) also reported that for optimum germination of *Circium arvense* the sowing depth should not exceed 0.5 cm. *Euphorbia caducifolia* Haines also exhibited its highest germinability when sown at 0.5 cm soil depth (Hussain & Qadir, 1970). However, the optimum germination percentage of *Tussilago farfara* was recorded when sown at the soil surface (Bakker, 1960). The results of seedling emergence suggest that probably the potential of a seedling to emerge from deeper soil levels correlates with the seed weight of the species.

A. aspera and *P. bicalyculata* showed a wide range of temperature tolerance (20-35°C) within which the germination percentages of both species were quite high. The optimal temperature for germination and growth of these species is nearly 30°C and both germinate simultaneously during the monsoon in the field. Both species did not germinate at 40°C. Maintenance of *A. aspera* seeds at 40°C for four days, however, do not alter the viability of the seeds. On the other hand, viability of *P. bicalyculata* seeds once exposed to 40°C while moist for four days is reduced to one-third. Temperature

tolerane similar to *A. aspera* seeds is also reported by Labouriau (1970) for *Vicia graminea* the seeds of which do not germinate at 33°C but as soon as they are transferred to optimal temperature (19°C), high germination percentage is recorded. The capacity of *Achyranthes* and *Peristrophe* seeds to tolerate such a high temperature is of great ecological significance. The seeds of these species pass the summer season in the soil when they have to tolerate a long dry and hot period of summer before the rainy season of June and July. These species germinate after rains in dense clusters and by the time the winter begins, their seeds are shed on the soil. These species do not germinate in winter rains as the temperature remains unfavourable for their germination. Similarly the seeds of the annuals such as *Ambrosia artimisifolia* and *Chenopodium album* also show a wide range of temperature tolerance and germinate in March and April whereas after-ripened seeds of *Amarathes retroflexus* requires high temperature for germination and do not germinate in the field until May and June (Baskin & Baskin, 1977). Similarly, Baskin & Baskin (1979) reported that the temperature requirement of *Aster pilosus* correspond with that of the spring period.

C. holosericea and *P. juliflora* appeared better adapted to high temperature as they can even germinate at 40°C. At low temperature (20°C) their rate of germination is greatly affected. The optimal temperature of these species is 30-35°C and both species germinate simultaneously in the monsoon. High temperature requirement for germination of these species is probably a result of the fact that they evolved in regions with summer rainfall.

The results indicate all the species tested are more sulphate sensitive, however, among the four species, *P. bicalyculata* and *Cassia holosericea* are more salinity susceptible than *A. aspera* or *P. juliflora.* Amongst the latter two species, *Prosopis* appeared more resistant to salinity; particularly the NaCl salinity. Indeed most of the plants are found relatively resistant to NaCl than Na_2SO_4 and many plants have been reported more sensitive to SO_4^{--} ion, than Cl^- ion e.g. White lupin, wheat, sorghum and cotton (Strogonov, 1964).

Relatively greater tolerance to NaCl salinity by *P. juliflora* further substantiates the field observations of Ahmad & Khan (1983) and its prevalence in saline habitats. It is leading dominant of many salt free to monderately saline (NaCl-affected) habitats of Karachi and adjacent Las Bella coast. The soil salinity (EC) of these habitats ranges from 2.3 to 11.8 m mhos/cm and total sodicity from 110 to 3300 ppm. On the other hand, other three species are generally observed growing in relatively salt free productive situations (Khan, 1980).

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