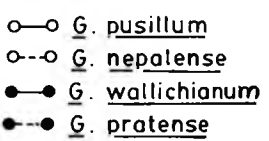
SEED GERMINATION EXPERIMENTS


G. pusillum
G. nepalense
G. wallichianum
G. pratense

Seed Germination under Controlled Conditions:

The seeds (30/Set) were kept on moist filter paper in sterilized petridishes with three replicates each. The dishes were subjected different temperature regimes to study the effect of temperature on germination.

Effect of Temperature

a) Laboratory Temperature (20°C) for different durations:

In *G. pratense* the %age germination was nil even after the lapse of 14 days. These seeds were then given a prick along the micropylar end and kept for germination. After 16 days 20% seeds germinated and after 18 days 30%. The maximum percentage germination was 50% after 24 days but in *G. wallichianum* it was 10% after 6 days, 36.6% after 10 days which finally increased to 50% only even after 18 days. In *G. nepalense* 16.6% germination was recorded in seeds after 4 days and 100% after 12 days but in *G. pusillum* 30% germination was recorded soon after 4 days and 100% after 14 days.

Thus 14 days interval seemed to be quite effective for the seeds of *G. pusillum* while in *G. wallichianum* only 50% germination was recorded in seeds within this period. In *G. nepalense* this percentage germination was achieved after 12 days only. However the seeds of *G. pratense* did not respond to this treatment, and could

Table 36. Per cent seed germination at laboratory temperature for different durations. Lab. temperature 20°C.

Species \ Days	2	4	6	8	10	12	14	16	18	24
G. pusillum	nil	30	43.3	43.3	56.6	63.3	100			
G. nepalense	nil	16.6	43.3	63.3	90	100				
G. wallichianum	nil	nil	10	26.6	36.6	50	50			
G. pratense	nil	nil	nil	nil	nil	nil	nil	20	30	50

Table 37. Per cent seed germination at constant temperature for different durations. Temperature: 2°C (Refrigerator)

Species \ Days	8	12	14	18	22	24	28	34
G. pusillum	nil	73.3	100					
G. nepalense	nil	nil	nil	nil	nil	nil	20	36.6
G. wallichianum	nil	nil	nil	nil	nil	nil	nil	nil
G. pratense	nil	nil	nil	nil	nil	nil	nil	nil

*Seeds were given a prick along micropylar end.

Fig. 1: Per cent seed germination at laboratory temperature for different durations

Lab temperature - 20°C

Fig. 2: Per cent seed germination at laboratory temperture for different durations

Lab temperature - 2°C

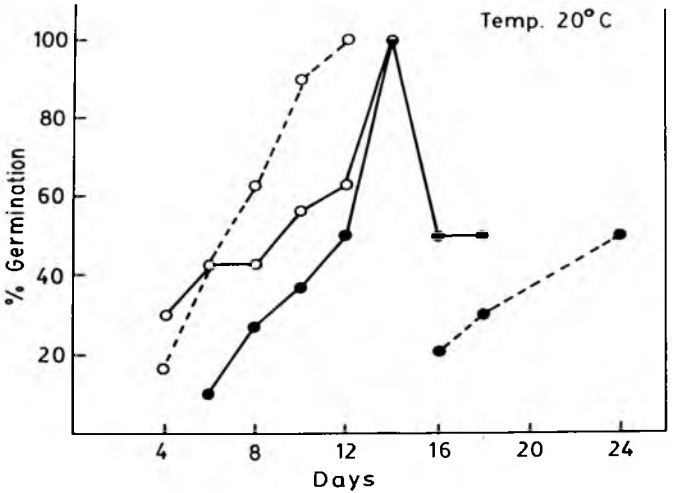

Temp. 20°C
% Germination
100
80
60
40
20
4
8
12
16
20
24
Days

FIG. 1

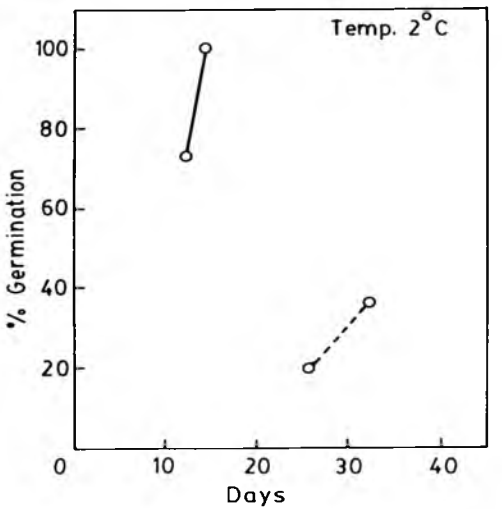

Temp. 2°C
% Germination
100
80
60
40
20
0
10
20
30
40
Days

FIG. 2

not germinate unless a routine pin prick was applied but only 50% seeds germinated (Table 36, Fig.1).

b) Constant temperature of 2°C (refrigerator for different durations:

In *G. pratense* and *G. wallichianum* the percentage germination was nil but in *G. pusillum* 20% germination was recorded after 28 days and 36.6% after 34 days. Maximum 73.3% germination in *G. pusillum* after 12 days and 100% after 14 days (Table 37, Fig.2).

c) Temperature 10°C: (Cooling Chamber of seed Germinator:

G. pratense and *G. wallichianum* did not germinate even after 34 days where as 93.3% germination occurred in *G. nepalense* within same period, but in *G. pusillum* 100% germination was achieved after 18 days only. However this temperature had no impact on the seeds of *G. nepalense* upto 18 days and later on 20% germination was recorded after 22 days and 93.3% germination was recorded within 34 days. *G. pusillum* seeds were in the state of dormancy upto 8 days and soon after 63.3% germination was registered after 12 days which finally increased to 100% after 18 days (Table 38, Fig.3).

d) Temperature: 5°C (Cooling Chamber of seed germinator

In *G. pratense* and *G. wallichianum* percentage germination

Table 38. Per cent germination at constant temperature for different durations.

Temperature: 10°C (cooling chamber of seed germination)

Species \ Days	8	12	14	18	22	24	28	34
G. pusillum	nil	63.3	86.6	100				
G. nepalense	nil	nil	nil	nil	20	50	80	93.3
G. dallichianum	nil	nil	nil	nil	nil	nil	nil	nil
G. pratense	nil	nil	nil	nil	nil	nil	nil	nil

Table 39. Per cent seed germination at constant temperature for different durations.

Temperature: 5°C (cooling chamber of seed germination)

Species \ Days	8	12	14	18	22	24	28	34
G. pusillum	43.3	70	100					
G. nepalense	nil	nil	nil	nil	nil	16.6	43.3	50
G. wallichianum	nil	nil	nil	nil	nil	nil	nil	nil
G. pratense	nil	nil	nil	nil	nil	nil	nil	nil

Fig. 3: Per cent seed germination at constant temperature for different durations

Temperature - 10°C

Fig. 4: Per cent seed germination at constant temperature for different durations

Temperature - 5°C

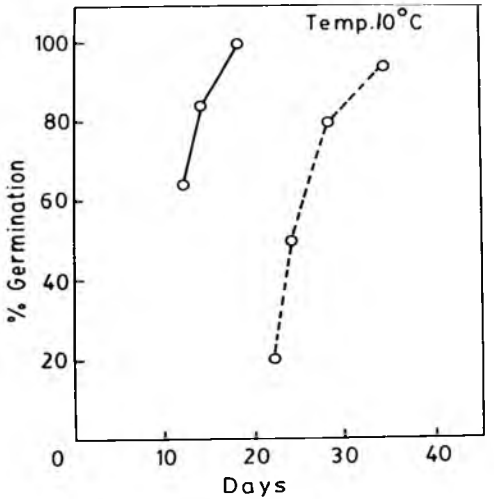

Temp.10°C
% Germination
100
80
60
40
20
0
10
20
30
40
Days

FIG. 3

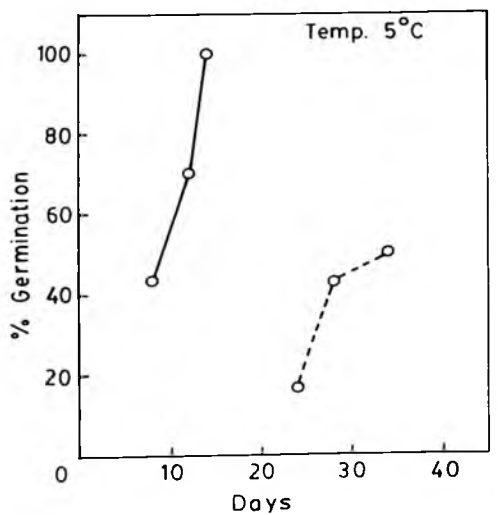

Temp. 5°C
% Germination
100
80
60
40
20
0
10
20
30
40
Days

FIG. 4

was nil at 5°C. In *G. nepalense* 16.6% germination was recorded after 24 days and only 50% even after 34 days, germination being maximum in *G. nepalense*.

However 5°C temperature seemed to have great impact on the seeds of *G. pusillum* (43.3%) after 8 days. Later on all the seeds did germinate (100%) within 14 days only. (Table 39, Fig. 4).

e) Temperature 20°C (heating chamber of Seed germinator:

G. pratense Seeds did not germinate even after 24 days whereas 10% germination was recorded in those of *G. wallichianum* after 12 days and maximum germination (30%) was soon achieved within 24 days.

However eight days interval seemed to be quite effective in reviving the seeds of *G. nepalense* and *G. pusillum* from dormancy. 20% germination was recorded in *G. nepalense* and 50% in *G. pusillum* within the same period. Whereas 93.3% germination in *G. nepalense* seeds within 18 days interval (some seeds turned to be abortive) and 100% germination was recorded in the seeds of *G. pusillum* within 12 days. (Table 40, Fig. 5).

f) Seed germination at alternating temperature for different durations (0°C and 20°C):

The seeds of *G. pratense* kept at 0°C for 2 hrs. later

Table 40. Per cent seed germination at constant temperature for different durations.

Temperature : 20°C (Heating chamber of seed germination)

Species \ Days	8	12	14	18	22	24	28	34
G. pusillum	50	100						
G. nepalense	20	43.3	60	93.3				
G. dallichianum	nil	10	23.3	23.3	25	30		
G. pratense	nil	nil	nil	nil	nil	nil		

Table 41. Per cent seed germination at alternating/constant temperature for different durations.

Temperature : 0°C and 20°C Seed germination(heating chamber)
Duration 0°C - 2 hrs. 20°C - till seeds germinate.

Species \ Days	2	4	6	8	12
G. pusillum	90	100			
G. nepalense	nil	nil	66.6	76.6	100
G. dallichianum	nil	nil	nil	16.6	26.6
G. pratense	nil	nil	nil	nil	nil

Fig. 5: Per cent seed germination at constant temperature for different durations

Temperature - 20°C

Fig. 6: Per cent seed germination at alternating/constant temperature for different durations

Temperature 0°C - Referigerator - 2 hrs

20°C - Seed germinator (heating chamber)

- till seeds germination

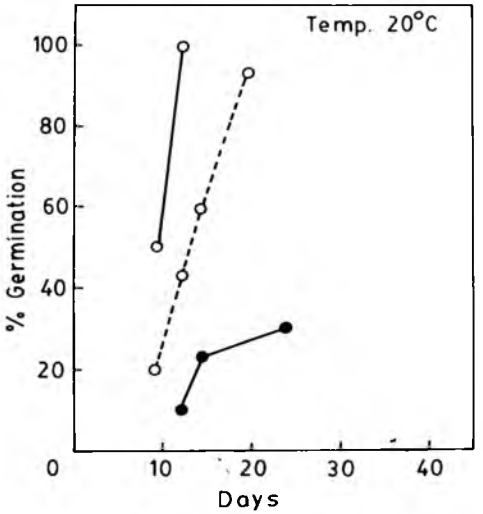
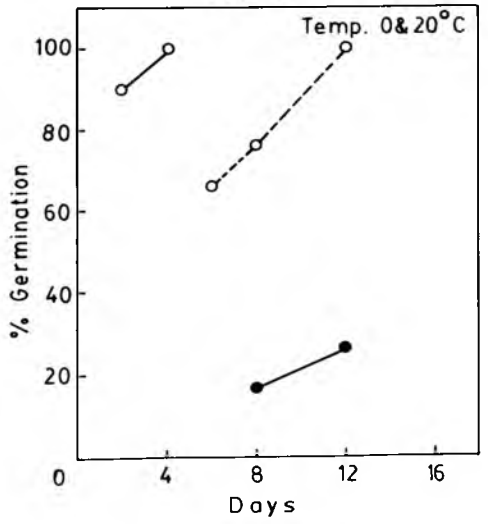

Temp. 20°C
% Germination
100
80
60
40
20
0
10
20
30
40
Days

FIG. 5


Temp. 0& 20°C
% Germination
100
80
60
40
20
0
4
8
12
16
Days

shifted to 20°C (for rest of the period) did not germinate at all where as percentage germination was very low in case of *G. wallichianum* (16.6%) within 8 days which finally got enhanced to 26.6% (maximum) after 12 days and 100% in *G. nepalense* within 12 days. The seeds of *G. pusillum* responded so well to this temperature and 100% germination was recorded within 4 days only (Table 41,Fig.6)

g) 20°C and 0°C, 20°C-2 hrs. 0°C- Till seeds germinate

Seeds of *G. pratense* and *G. wallichianum* kept at 20°C for 2 hrs. and then shifted to 0°C (till seeds germinate) did not germinate, and only 10% germination was recorded in *G. nepalense* where as 93.3% in *G. pusillum* seeds within 8 days only and finally all the seeds (100%) germinated at this temperature within 12 days only (Table 42, Fig.7).

h) 0°C and 20°

0°C - 4 hrs.

20°C - till seeds germinate

In *G. pratense* the percentage germination was nil but in *G. wallichianum* 20% within 14 days and 26.6% (maximum) within 18 days. However in *G. nepalense* 63.3% germination was recorded within 4 days period and 100% seeds germinate within 12 days whereas 100% germination was recorded very soon within 2 days only in the seeds of *G. pusillum* (Table 43, Fig.8).

Table 42. Per cent seed germination at alternating/constant temperature for different durations.

Temperature: 20°C and 0°C; 0°C - Referigerator; 20°C - seed germination (heating chamber)
Duration : 20°C - 2 hrs

Species \ Days	2	4	6	8	12	14	18
G. pusillum	nil	nil	nil	93.3	100		
G. nepalense	nil	nil	nil	nil	nil	10	10
G. wallichianum	nil	nil	nil	nil	nil	nil	nil
G. pratense	nil	nil	nil	nil	nil	nil	nil

Table 43. Per cent seed germination at alternating/constant temperature for different durations.

Duration: 0°C and 20°C; 0°C - 4 hrs; 20°C - till seed germinate.

Species \ Days	2	4	6	8	12	14	18
G. pusillum	100						
G. nepalense	nil	63.3	63.3	93.3	100		
G. wallichianum	nil	nil	nil	nil	nil	20	26.6
G. pratense	nil	nil	nil	nil	nil	nil	nil

Fig. 7: Per cent seed germination at alternating/constant temperature for different durations

Temperature 20°C - Seed germinator (heating chamber) - 2 hrs

0°C - referigerator - till seeds germinate

Fig. 8: Per cent seed germination at alternating/constant temperature for different durations.

Temperature 0°C - referigerator - 4 hrs

20°C - Seed germinator (heating chamber) - till seeds germinate

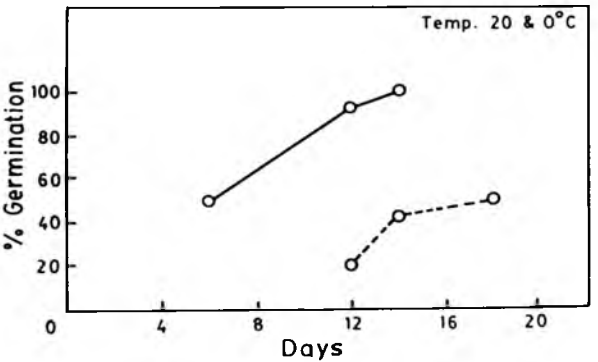

Temp. 20 & 0°C
% Germination
100
80
60
40
20
0
4
8
12
16
20
Days

FIG. 7

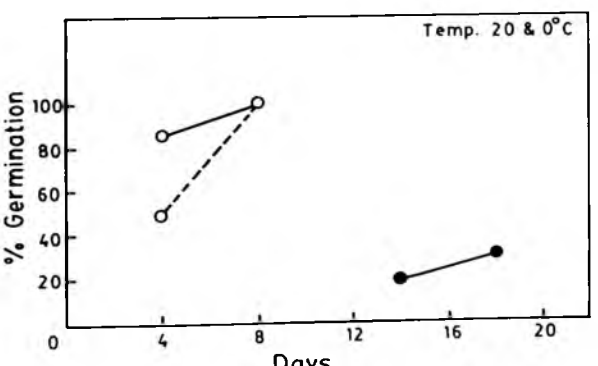

Temp. 20 & 0°C
% Germination
100
80
60
40
20
0
4
8
12
16
20
Days

FIG. 8

i) 20°C and/0°C

20°C - 4 hrs.

0°C - till seeds germinate

Seeds of *G. pratense* and *G. wallichianum* kept at 20°C for 4 hrs. and then shifted to 0°C for rest of the period did not germinate even after 24 days but 20% germination was recorded in *G. nepalense* seeds within 12 days which increased to 50% (maximum) within 18 days. *G. pusillum* recorded 50% germination within 8 days, 93.3% within 12 days and 100% within 14 days (Table 44, Fig.9).

j) 0°C and 20°C

0°C - 6 hrs.

20°C - till seeds germinate

G. pratense seeds did not germinate even after 18 days, but 30% (maximum) germination was recorded in *G. wallichianum* seeds. In *G. nepalense* 50% germination was recorded within 4 days and 100% within 8 days only In *G. pusillum* 86.6% germination was recorded within 4 days, and 100% within 8 days (Table 45, Fig.10).

k)20°C and 0°C

20°C - 6 hrs.

0°C - till seeds germinate

Temperature seemed to have no impact on the seeds of *G. pratense* and *G. wallichianum* and percentage germination

Table 44. Per cent seed germination at alternating/constant temperature for different durations.

Temperature: 20°C and 0°C; 0°C - Referigerator; 20°C - Seed germinator (heating chamber); Duration 20°C - 4 hrs.

Species \ Days	2	4	8	12	14	18
G. pusillum	nil	nil	50	93.3	100	
G. nepalense	nil	nil	nil	20	43.3	50
G. wallichianum	nil	nil	nil	nil	nil	nil
G. pratense	nil	nil	nil	nil	nil	nil

Table 45. Per cent seed germination at alternating/constant temperature for different durations.

Temperature: 0°C and 20°C; 0°C - Referigerator; 20°C - seed germinator heating chamber; Duration 0°C - 6 hrs; 20°C - till seeds germinate.

Species \ Days	2	4	8	12	14	18
G. pusillum	nil	86.6	100			
G. nepalense	nil	50	100			
G. wallichianum	nil	nil	nil	nil	20	30
G. pratense	nil	nil	nil	nil	nil	nil

Fig. 9: Per cent seed germination at alternating constant temperature for different durations.

Temperature 20°C - Seed germinator - 4 hrs (heating chamber)

0°C - Referigerator - till seeds germinate.

Fig. 10: Per cent seed germination at alternating/constant temperature for different durations.

Temperature 0°C - referigerator - 6 hrs

20°C - Seed germinator (heating chamber) - till seeds germinate

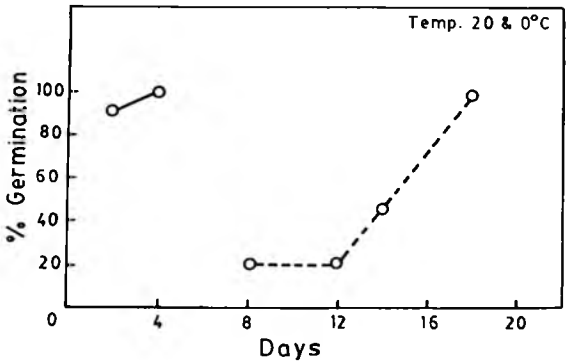

Temp. 20 & 0°C
% Germination
100
80
60
40
20
0
4
8
12
16
20
Days

FIG. 9

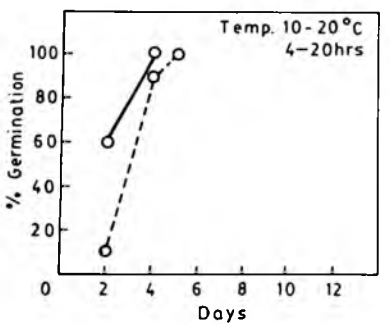

Temp. 10-20°C
4-20hrs
% Germination
100
80
60
40
20
0
2
4
6
8
10
12
Days

FIG. 10

was nill even after 18 days where as 20% occurred within 8 days and 100% after 18 days. However in *G. pusillum* 100% germination was recorded within 4 days only (Table 46).

1) % seed germination at alternating temperature (within 24 hour cycle):

10°C to 20°C
10°C - 2 hrs.
20°C - 22 hrs.

The seed lots of all the four species in three replicates kept at 10°C for 2 hrs. Later shifted to 20°C for 22 hrs (till seeds germinate) revealed that this treatment had no impact on seeds germination in *G. pratense* and *G. wallichianum* where as 50% seeds germinate in *G. nepalense* within five days and 100% in 6 days and in *G. pusillum* within 2 days only indicating that *G. nepalense* and *G. pusillum* seeds respond so well to this treatment (Table 47).

m) 10°C to 20°C
10°C - 4 hrs.
20°C - 20 hrs. (within 24 hours cycle)

This treatment also seemed to be quite ineffective for the germination of *G. pratense* and *G. wallichianum* seeds where as 90% germination was recorded in *G. nepalense* within 4 days only and 100% in *G. pusillum* within same period. Furthermore rest of the seeds of *G. nepalense* also germinated within one day and thus 100% seed germination was achieved

Table 46. Per cent seed germination at alternating/constant temperature for different durations.

Temperature: 0°C and 20°C; 0°C - Referigerator; 20°C - Seed germinator heating chamber; Duration 20°C - 6 hrs; 0°C - till seeds germinate.

Species	Days 2	4	8	12	14	18
G. *pusillum*	93.3	100				
G. *nepalense*	nil	nil	20	20	46.6	100
G. *wallichianum*	nil	nil	nil	nil	nil	nil
G. *pratense*	nil	nil	nil	nil	nil	nil

Table 47. Per cent seed germination at alternating temperature within 24 hour cycle.

Temperature: 10°C - seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration: 10°C - 2 hrs; 20°C - 22 hrs

Species	Days 2	4	5	6	8	10	12
G. *pusillum*	100						
G. *nepalense*	10	30	50	100			
G. *wallichianum*	nil	nil	nil	nil	nil	nil	nil
G. *pratense*	nil	nil	nil	nil	nil	nil	nil

within five days only (Table 48).

n) 10°C to 20°C

10°C - 6 hrs.

20°C - 18 hrs (within 24 hour cycle)

The percentage germination was nil in *G. pratense* and *G. wallichianum*. In *G. nepalense* 40% seeds germinated within 2 days only when 100% in *G. pusillum* within the same time (2 days) and 100% in *G. nepalense* within five days (Table 49).

o) 10°C to 20°C

10°C - 8 hrs.

20°C - 16 hrs.

The percentage germination was nil in *G. pratense* and *G. wallichianum* . In *G. nepalense* 40% seeds germinated within 2 days and 100% in *G. pusillum* within this short period. It seemed that in *G. nepalense* rest other seeds are also viable and all the seeds germinate (100%) within 5 days (Table 50).

p) 10°C to 20°C

10°C - 10 hrs.

20°C - 14 hrs. (within 24 hour cycle)

At this temperature also the results were same. The seeds of *G. pratense* and *G. wallichianum* did not germinate even after 12 days where as 100% seeds germinated within 5 days in *G. nepalense* and within 2 days in *G. pusillum* (Table 51).

Table 48. Per cent seed germination at alternating temperature within 24 hour cycle.

Temperature: 10°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration : 4 hrs and 20 hrs.

Species	Days	2	4	5	6	8	10	12
G. pusillum		60	100					
G. nepalense		10	90	100				
G. wallichianum		nil	nil	nil	nil	nil	nil	nil
G. pratense		nil	nil	nil	nil	nil	nil	nil

Table 49. Per cent seed germination at alternating temperature within 24 hour cycle.

Temperature: 10°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration : 6 hrs and 18 hrs.

Species	Days	2	4	5	6	8	10	12
G. pusillum		100						
G. nepalense		40	90	100				
G. wallichianum		nil	nil	nil	nil	nil	nil	nil
G. pratense		nil	nil	nil	nil	nil	nil	nil

Table 50. Per cent seed germination at alternating temperature within 24 hour cycle.

Temperature: 10°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration : 8 hrs and 16 hrs.

Species	Days	2	4	5	6	8	10	12
G. pusillum		100						
G. nepalense		40	90	100				
G. wallichianum		nil	nil	nil	nil			
G. pratense		nil	nil	nil	nil			

Table 51. Per cent seed germination at alternating temperature within 24 hour cycle.

Temperature: 10°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration: 8 hrs and 16 hrs. Duration: 10 hrs and 14 hrs.

Species	Days	2	4	5	6	8	10	12
G. pusillum		100						
G. nepalense		50	80	100				
G. wallichianum		nil	nil	nil	nil	nil		
G. pratense		nil	nil	nil	nil	nil		

q) 5°C to 20°C for 2 to 22 hrs

5°C - seed germinator cooling chamber

20°C - seed germinator heating chamber

The seeds were subjected to 5°C for 2 hrs and later shifted to 20°C for rest of the time (22 hrs) and process repeated till seeds germinated.

The seeds of *G. pratense* and *G. wallichianum* did not germinate at all where as 100% did in *G. nepalense* within 5 days and in *G. pusillum* within four days only (Table 52,Fig.11)

r) 5°C to 20°C for 4 to 20 hrs.

(within 24 hour cycle)

5°C - seed germinator cooling chamber

20°C - seed germinator heating chamber

The percentage germination was nil in *G. pratense* and *G. wallichianum* seeds whereas 100% germination occurred in *G. nepalense* within 5 days and in *G. pusillum* within 4 days only (Table 53, Fig. 12).

s) 5°C to 20°C for 6 to 18 hrs

(within 24 hour cycle)

5°C - seed germinator (cooling chamber)

20°C - seed germinator heating chamber

This treatment also seemed to be least effective for the seeds of *G. pratense* and *G. wallichianum* and percentage germination was nil in both the species where as 100%

Table 52. Per cent seed germination at alternating temperature within 24 hrs cycle. Temperature: 5°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration 2 hrs and 22 hrs.

Species \ Days	2	4	5	6	8	10	12
G. pusillum	60	100					
G. nepalense	nil	60	100				
G. wallichianum	nil	nil	nil	nil			
G. pratense	nil	nil	nil	nil			

Table 53. Per cent seed germination at alternating temperature within 24 hrs cycle. Temperature: 5°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration: 4 hrs to 20 hrs.

Species \ Days	2	4	5	6	8	10	12
G. pusillum	40	100					
G. nepalense	nil	60	100				
G. wallichianum	nil	nil	nil	nil	nil		
G. pratense	nil	nil	nil	nil	nil		

Fig. 11: Per cent seed germination at alternating temperature within 24 hour cycle
Temperature 5°C - Seed germinator (cooling chamber) - 2 hrs
20°C - Seed germinator (heating chamber) - 22 hrs

Fig. 12: Per cent seed germination at alternating temperature within 24 hour cycle
Temperature 5°C - Seed germinator (cooling chamber) - 4 hrs
20°C - Seed germinator (heating chamber) - 20 hrs

Fig. 13: Per cent seed germination at alternating temperature within 24 hour cycle
Temperature 5°C - Seed germinator (cooling chamber) - 6 hrs
20°C - Seed germinator (heating chamber) - 18 hrs

Fig. 14: Per cent seed germination at alternating temperature within 24 hour cycle
Temperature 5°C - Seed germinator (cooling chamber) - 8 hrs
20°C - Seed germinator (heating chamber) - 16 hrs

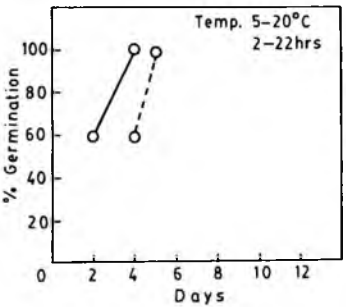


FIG. 11

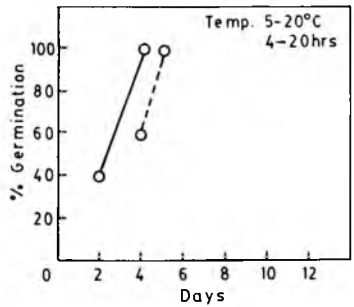


FIG. 12

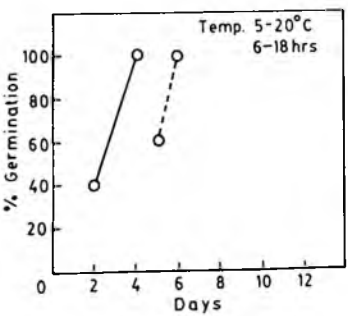


FIG. 13

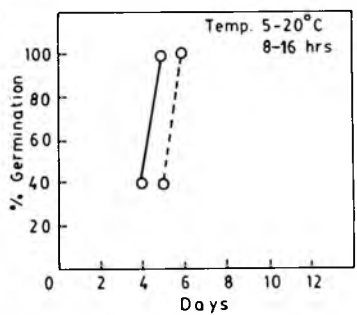


FIG. 14

germination was recorded in *G. nepalense* within 6 days and in *G. pusillum* within 4 days only (Table 54, Fig.13).

t) 5°C to 20°C for 8 to 16 hrs.
(within 24 hour cycle)

In *G. pratense* and *G. wallichianum* seeds percentage germination was nil but in *G. nepalense* seeds 40% germination was recorded within 5 days and 100% within 6 days only. However in *G. pusillum* seeds 40% germination was recorded within 4 days and finally within 5 days all the seeds (100%) had germinated (Table 55, Fig.14).

u) 5°C to 20°C for 10 to 14 hrs.
(within 24 hour cycle)

At this temperature also the percentage germination was nil in the seeds of *G. pratense* and *G. wallichianum* where as 100% germination was recorded in *G. nepalense* and *G. pusillum* seeds within 8 days in the former and 5 days in the latter (Table 56, Fig.15).

v) 0°C to 20°C for 2 to 22 hrs.
(within 24 hour cycle)
0°C - seed germinator cooling chamber
20°C - seed germinator heating chamber

The percentage germination was nil in *G. pratense* and *G. wallichianum* whereas 100% germination occurred in *G. nepalense* after 6 days and in *G. pusillum* within 4 days only (Table 57, Fig. 16).

Table 54. Per cent seed germination at alternating temperature within 24 hrs cycle.

Temperature: 5°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber. Duration: 6 hrs and 8 hrs.

Species \ Days	2	4	5	6	8	10	12
G. pusillum	40	100					
G. nepalense	nil	nil	60	100			
G. wallichianum	nil	nil	nil	nil	nil		
G. pratense	nil	nil	nil	nil	nil		

Table 55. Per cent seed germination at alternating temperature within 24 hrs cycle.

Temperature: 5°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration: 8 hrs and 16 hrs.

Species \ Days	2	4	5	6	8	10	12
G. pusillum	nil	40	100				
G. nepalense	nil	nil	40	100			
G. wallichianum	nil	nil	nil	nil	nil		
G. pratense	nil	nil	nil	nil	nil		

Table 56. Per cent seed germination at alternating temperature within 24 hrs cycle.

Temperature: 5°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration : 10 hrs and 14 hrs.

Species	Days 2	4	5	6	8	10	12
G. pusillum	nil	40	100				
G. nepalense	nil	nil	nil	40	100		
G. wallichianum	nil	nil	nil	nil	nil	nil	nil
G. pratense	nil	nil	nil	nil	nil	nil	nil

Table 57. Per cent seed germination at alternating temperature within 24 hrs cycle.

Temperature: 0°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration : 2 hrs and 22 hrs.

Species	Days 2	4	5	6	8	10	12
G. pusillum	40	100					
G. nepalense	nil	10	30	100			
G. wallichianum	nil	nil	nil	nil	nil	nil	
G. pratense	nil	nil	nil	nil	nil	nil	

Fig. 15: Per cent seed germination at alternating temperature within 24 hour cycle

Temperature 5°C - Seed germinator (cooling chamber) - 10 hrs

20°C - Seed germinator (heating chamber) - 14 hrs

Fig. 16: Per cent seed germination at alternating temperature for different durations

Temperature 0°C - Seed germinator (cooling chamber) - 2 hrs

20°C - Seed germinator (heating chamber) - 22 hrs

Fig. 17: Per cent seed germination at alternating temperature for different durations

Temperature 0°C - Seed germinator (cooling chamber) - 4 hrs

20°C - Seed germinator (heating chamber) - 20 hrs

Fig. 18. Per cent seed germination at alternating temperature for different durations.

Temperature 0°C - Seed germinator (cooling chamber) - 6 hrs

20°C - Seed germinator (heating chamber) - 18 hrs

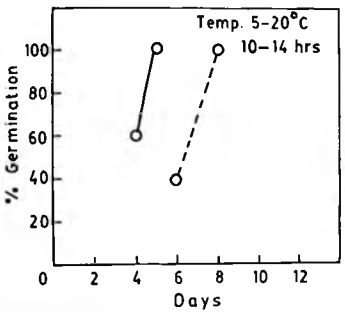


FIG. 15

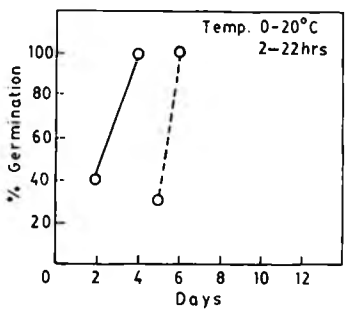


FIG. 16

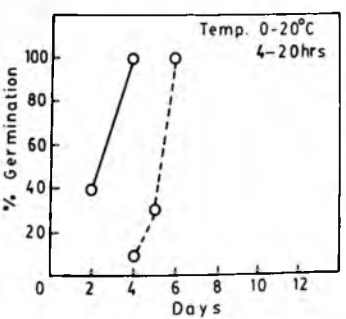


FIG. 17

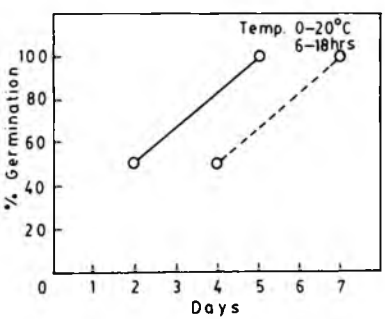


FIG. 18

w) 0°C to 20°C for 4 to 20 hrs.

(within 24 hour cycle)

This temperature also seemed to be least effective in inducing germination in *G.pratense* and *G.wallichianum* and percentage germination was nil after 6 days and in *G. pusillum* 100% within 4 days only (Table 58, Fig.17).

x) 0°C to 20°C for 6 to 18 hrs.

(within 24 hour cycle)

The seeds of *G. pratense* and *G. wallichianum* did not germinate. In *G. nepalense* 50% did germinate after 6 days and 100% (maximum) after 7 days where as in *G. pusillum* 100% after 3 days (Table 59; Fig.18).

y) 0°C to 20°C for 8 to 16 hrs.

(within 24 hour cycle)

0°C - seed germinator cooling chamber

20°C - seed germinator heating chamber

This temperature also was ineffective in breaking the dormancy of *G.pratense* and *G. wallichianum* seeds where as in *G. nepalense* 100% germination was recorded after 7 days and in *G. pusillum* after 5 days only (Table 60, Fig.19).

z) 0°C to 20°C for 10 to 14 hrs.

0°C - seed germinator cooling chamber

20°C - seed germinator heating chamber

Table 58. Per cent seed germination at alternating temperature within 24 hrs cycle. Temperature: 0°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration: 4 hrs and 20 hrs.

Species	Days 2	4	5	6	8	10	12
G. pusillum	40	100					
G. nepalense	nil	10	30	100			
G. wallichianum	nil	nil	nil	nil			
G. pratense	nil	nil	nil	nil			

Table 59. Per cent seed germination at alternating temperature within 24 hrs cycle. Temperature: 0°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration: 6 hrs and 18 hrs.

Species	Days 2	4	5	6	7	8	10
G. pusillum	50	100					
G. nepalense	nil	nil	nil	50	100		
G. wallichianum	nil	nil	nil	nil	nil	nil	nil
G. pratense	nil	nil	nil	nil	nil	nil	nil

Table 60. Per cent seed germination at alternating temperature within 24 hrs cycle. Temperature: 0°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration: 8 hrs and 16 hrs.

Species	Days	2	4	5	6	7	8	10	12
G. pusillum		50	70	100					
G. nepalense		nil	nil	50	60	100			
G. wallichianum		nil	nil	nil	nil	nil	nil	nil	nil
G. pratense		nil	nil	nil	nil	nil	nil	nil	nil

Table 61. Per cent seed germination at alternating temperature within 24 hrs cycle. Temperature: 0°C - Seed germinator cooling chamber; 20°C - Seed germinator heating chamber; Duration 10 hrs and 14 hrs.

Species	Days	1	2	4	5	6	8	10	12
G. pusillum		46.6	90	90	100				
G. nepalense		nil	50	80	100				
G. wallichianum		nil	nil	nil	nil	nil	nil	nil	
G. pratense		nil	nil	nil	nil	nil	nil	nil	

Fig. 19: Per cent seed germination at alternating temperature for different durations.

Temperature 0°C - Seed germinator (cooling chamber) - 8 hrs

20°C - Seed germinator (heating chamber) - 16 hrs

Fig. 20: Per cent seed germinator at alternating temperature for different durations.

Temperature 0°C - Seed germinator (cooling chamber) - 10 hrs

20°C - Seed germinator (heating chamber) - 14 hrs

Fig. 21: Per cent seed germination in medium shade for different durations.

Fig. 22: Per cent seed germination in deep shade for different durtions.

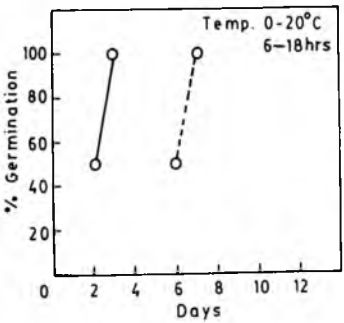


FIG. 19

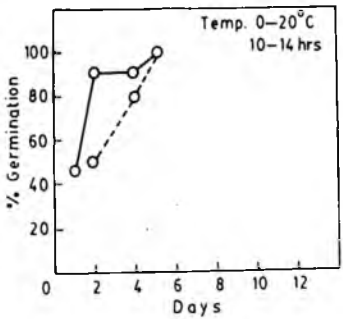


FIG. 20

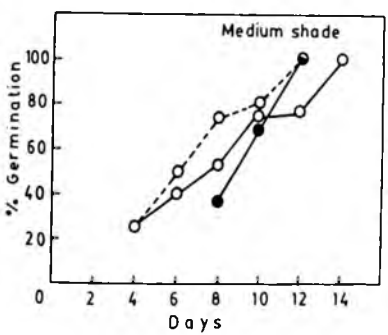


FIG. 21

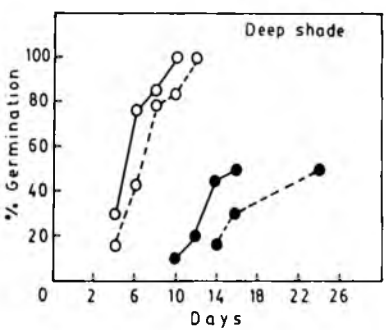


FIG. 22

In *G. pratense* and *G. wallichianum* seeds the percentage germination was nil but in *G. nepalense* and *G. pusillum* 100% germination was recorded within 5 days (Table 61, Fig.20).

Seed Germination in bright sun for different duration: (to study the effect of light)

The seeds of different species of *Geranium* kept for germination in bright sun did not show any germination even after 16 days as bright sun light was not effective in reviving the seeds from dormancy.

Another similar seed lot kept for germination in medium shade revealed that in medium shade seeds germinate immediately and in *G. pusillum* and *G. nepalense* 26.6% germination was recorded after 4 days which enhanced to 100% after 12 days in *G.nepalense* and 14 days in *G. pusillum* In *G. wallichianum* though seed germination was quite slow in the initial stage and 36.6% germination was recorded after 8 days but 100% germination was achieved after 12 days. In *G. pratense* medium shade had no impact on seed germination and seeds did not germinate even after 14 days (Table 62, Fig.21).

Third similar lot (in three replicates) was kept for germination in deep shade. *G. pratense* seeds did not germinate even after 12 days but after applying a soft prick along micropylor end and kept for germination

Table 62. Per cent seed germination in Medium shade for different durations.

Species	Days	2	4	6	8	10	12	14	16
G. *pusillum*		nil	26.6	40	53.3	96	76.6	100	
G. *nepalense*		nil	26.6	50	73.3	80	100		
G. *wallichianum*		nil	nil	nil	36.6	70	100		
G. *pratense*		nil	nil	nil	nil	nil	nil	nil	

Table 63. Per cent seed germination in Deep shade for different durations.

Species	Days	2	4	6	8	10	12	14	16	24
G. *pusillum*		nil	30	77	86.6	100				
G. *nepalense*		nil	16.6	43.3	80	83.3	100			
G. *wallichianum*		nil	nil	nil	nil	10	20	43.3	50	
G. *pratense*		nil	nil	nil	nil	nil	nil	16.6	30	50

Table 64. Per cent seed germination at alternating light (light to darkness) within 24 hrs cycle.
Duration: 2 hrs and 22 hrs.

Species	Days	2	4	8	12	14	18	24	48
G. pusillum		nil	40	50	100				
G. nepalense		nil	50	100					
G. wallichianum		nil	nil	nil	nil	nil	nil	nil	20
G. pratense		nil	nil	nil	nil	nil	nil	nil	40

Table 65. Per cent seed germination at alternating light (light to darkness) within 24 hrs cycle.
Duration: 4 hrs and 20 hrs.

Species	Days	2	4	8	12	24	48
G. pusillum		nil	nil	nil	100		
G. nepalense		nil	40	50	100		
G. wallichianum		nil	10	20	20		
G. pratense		nil	nil	nil	nil		

Fig. 23: Per cent seed germination in alternating light (light to dark) within 24 hour cycle

Light - 2 hrs

Dark - 22 hrs

Fig. 24: Per cent seed germination in alternating light (light to dark) within 24 hour cycle

Light - 4 hrs

Dark - 20 hrs

Fig. 25: Per cent seed germination in alternating light (light to dark) within 24 hour cycle

Light - 8 hrs

Dark - 16 hrs.

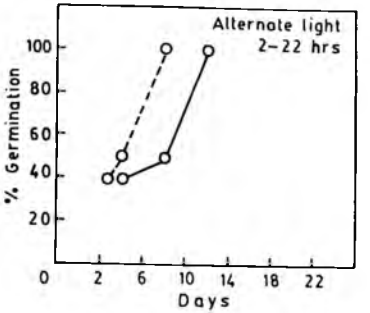


FIG. 23

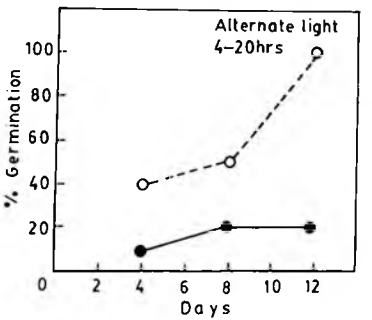


FIG. 24

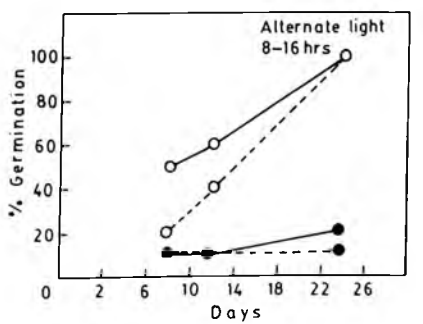


FIG. 25

showed 16.6% germination after 14 days and maximum germination 50% was recorded after 24 days. In *G. wallichianum* 10% seeds germinate after 10 days and 50% after 16 days whereas in *G.nepalense* 100% after 12 days and in *G. pusillum* 100% after 10 days (Table 63, Fig.22).

% seed germination in alternating light (light to darkness) within 24 hour cycle:

1. 2 hrs. (light) to 22 hrs (darkness) (within 24 hour cycle).

The *G. pratense* and *G. wallichianum* seeds did not germinate at all when exposed to light for 2 hrs. subsequently kept in darkness for 22 hrs. (within 24 hour cycle) even after 14 days. The seeds when given a prick (softly) along micropylar end and kept for germination under same conditions 40% germinated in *G. pratense* and 20% in *G. wallichianum* after 48 days. In *G. nepalense* 100% germinated after 8 days and in *G. pusillum* 100% after 12 days under the same conditions (Table 64, Fig.23).

2. 4 hrs. (light) ro 20 hrs. (darkness)
(within 24 hour cycle)

In *G. pratense* the percentage germination was nil under such conditions however *G. wallichianum* seeds recorded 20% (maximum) germination after 12 days

Table 66. Per cent seed germination at alternating light (light to drakness) within 24 hrs cycle.
Duration: 6 hrs and 18 hrs.

Species	Days 2	4	8	12	24
G. pusillum	nil	nil	nil	100	
G. nepalense	nil	nil	nil	100	
G. wallichianum	nil	nil	nil	10	
G. pratense	nil	nil	nil	nil	10

Table 67. Per cent seed germination at alternating light (light to darkness) within 24 hrs cycle.
Duration: 8 hrs and 16 hrs.

Species	Days 2	4	8	12	24	48
G. pusillum	nil	nil	50	60	100	
G. nepalense	nil	nil	20	40	100	
G. wallichianum	nil	nil	10	10	20	
G. pratense	nil	nil	10	10	10	

Fig. 26: Per cent seed germination in alternating light (light to dark) within 24 hour cycle
Light - 10 hrs
Dark - 14 hrs

Fig. 27: Per cent seed germination after mechanical scarification.

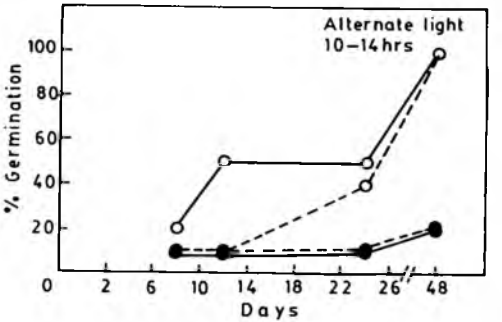

Alternate light
10–14hrs
% Germination
100
80
60
40
20
0
2
6
10
14
18
22
26
48
Days

FIG. 26

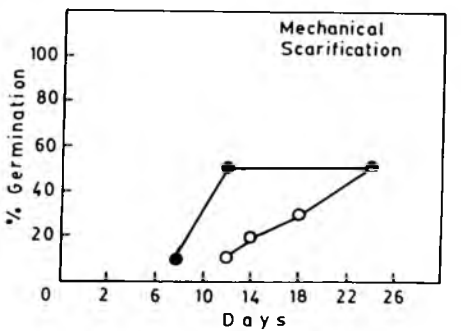

Mechanical
Scarification
% Germination
100
80
60
40
20
0
2
6
10
14
18
22
26
Days

FIG. 27

whereas in *G.nepalense* and *G. pusillum* 100% was recorded after 12 days under the same conditions (Table 65, Fig.24).

3. 6 hrs. (light) to 18 hrs. (darkness)
(within 24 hour cycle)

In *G. pratense* 10% germination was recorded after 24 days. The percentage germination was same in *G.wallichianum* but only after 12 days, where as 100% in both *G.nepalense* and *G. pusillum* within the same period (12 days) (Table 66).

4. 8 hrs. (light) to 16 hrs. (darkness)
(within 24 hour cycle)

In *G. pratense* 10% germination was recorded after 24 days and in *G. wallichianum* 20% within same time but in *G.nepalense* and *G. pusillum* it was 100% (within the same time) (Table 67; Fig.25).

5. 10 hrs. (light) to 14 hrs. (darkness)
(within 24 hour cycle)

In *G.pratense* and *G.wallichianum* 20% germination was recorded after 48 days when seed lots (in three replicates) where kept in light for 10 hrs and subsequently kept in darkness for 14 hrs, and process repeated till seeds germinate. In *G. nepalense* and *G. pusillum* 100% germination was recorded after 48 days under the same conditions (Table 68, Fig.26).

Table 68. Per cent seed germination at alternating light (light to darkness) within 24 hrs cycle.
Duration: 10 hrs and 14 hrs.

Species	Days	2	4	8	12	24	48
G. pusillum		nil	nil	20	15	50	100
G. nepalense		nil	nil	10	10	40	100
G. wallichianum		nil	nil	10	10	10	20
G. pratense		nil	nil	nil	10	10	20

Table 69. Per cent seed germination after mechanical scarification (freshly harvested seeds).

Species	Days	2	4	8	12	14	18	24
G. pusillum		nil	nil	nil	10	20	30	50
G. nepalense		nil	nil	nil	nil	nil	nil	nil
G. wallichianum		nil	nil	nil	nil	nil	nil	nil
G. pratense		nil	nil	20	50	50	50	50

% seed germination after mechanical scarification: (freshly harvested seeds)

The freshly harvested seeds of *Geranium* species where mechanically scarified (methodology) and then kept for germination at laboratory temperature (22°C). In *G. pratense* 20% germination was recorded after 8 days and 50% (being the maximum) after 24 days. The *G. wallichianum* and *G. nepalense* seeds did not germinate at all. In *G. pusillum* 10% germination was recorded after 12 days and the percentage increased to 50% after 24 days (being the maximum) (Table 69, Fig.27).

Effect of burial on seed germination:

The seeds of all the four species of *Geranium* were tied separately in muslin bags and buried under soil at different depths (2 cm, 5 cm, 10 cm, 15 cm) and were taken out periodically (2 days, 4 days, 8 days, 12 days, 24 days, 48 days) and kept for germination at laboratory temperature (20°C). It was observed that seeds from all the lots did not respond to this effect and percentage germination was nil in every seed lot. However 20% germination was recorded in *G.wallichianum*, 50% in *G. nepalense* and 100% in *G. pusillum* after 12 days in control.

Effect of Acid scarification on seed germination:

The seeds of *Geranium* species were soaked in different concentrations of H_2SO_4 (30%, 50% and 70%) for 5 mts, and then kept for germination for different durations.

Table 70. Effect of acid scarification on seed germination.

Species	Days	2	4	8	12	14
G. pusillum		nil	nil	16.6	50	
G. nepalense		nil	nil	13.3	26.6	50
G. wallichianum		nil	nil	nil	nil	nil
G. pratense		nil	nil	nil	nil	nil

Table 71. Percentage viability of seeds at laboratory temperature (one year old seeds).

Species	Days	2	4	8	12	14	18	24
G. pusillum		26.6	46.6	70	100			
G. nepalense		13.3	20	50	70	100		
G. wallichianum		10	10	13.3	23.3	40	50	50
G. pratense		nil	nil	nil	nil	nil	nil	23.3

Fig. 28: Per cent seed germination after acid scarification.

Fig. 29: Percentage viability of seeds at labortory temperature (one year old seed).

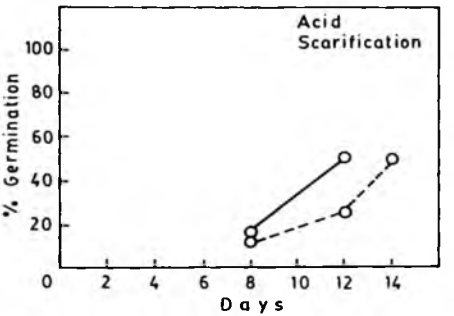

Acid
Scarification
% Germination
100
80
60
40
20
0
2
4
6
8
10
12
14
Days

FIG. 28

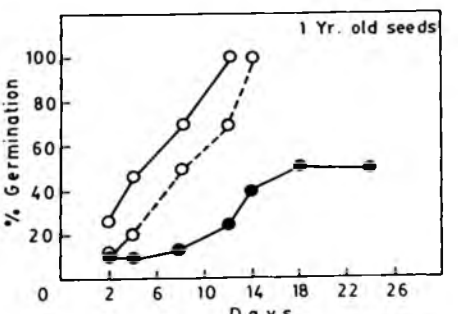

1 Yr. old seeds
% Germination
100
80
60
40
20
0
2
6
10
14
18
22
26
Days

FIG. 29

In *G. pratense* and *G. wallichianum* seeds did not germinate even after 14 days whereas in *G. nepalense* 50% (soaked in 30% H_2SO_4) did so after 14 days, in *G. pusillum* 50% (soaked in 30% H_2SO_4) after 12 days. In other seed lots percentage germination was nil (Table 70, Fig.28).

<u>% viability of seeds at laboratory temperature</u>:

(one year old seeds) lab. temp. (20°C).

In case of *G. pratense* the seeds did not germinate even after 18 days when given a prick along micropylar end to break the dormancy and kept for germination, however 23.3% germination was recorded after 24 days.

In *G.wallichianum* the seeds registered 10% germination after 2 days and 50% after 24 days (maximum). However *G. nepalense* and *G. pusillum* seeds were quite viable (after one year storage) and 100% germination was recorded after 14 days in former and after 12 days in later (Table 71,Fig.29).