CHAPTER 8

SEED AND SEED GERMINATION

8.1. Size, weight and moisture content of seeds

The general morphology of the seeds of E. geniculata has been dealt with under 7.4 in Chapter 7. (Plate 17). The size, weight and moisture content values of the seeds of E. geniculata are given below :

Size : (Values based on 100 observations)

Length (mm)	2.752±0.139
Breadth (mm)	2.414±0.118
Shape Index (Length/Breadth ratio)	1.144±0.082

Weight : (Values based on 3 to 10 observations of averages drawn from weight of seeds in lots of 100 each).

Locality	Date of seed Collection	Weight of one seed (mg)
University Library Area	3-11-1977	7.77±0.15
Arts Faculty Area	6-3-1978	7.11±0.86
Wire House Compound	26-9-1979	7.79±0.28
Cotton Farm, Surat	25-12-1978	7.37±0.18
Surat Orchard	12-9-1979	7.02±0.93

Moisture content : (Values based on 3 observations in lots of 100 seeds each).

(%)	8.03±0.05

Note Values represent mean ± standard deviation.

8.2. Imbibition rate

The imbibition rate of the seeds of E. geniculata (collected from Cotton Farm, Surat on dt. 25-12-78 and after 11 months of dry storage) was studied under laboratory conditions following the same procedure as given under 2.7 in Chapter 2. The maximum and minimum temperatures ranged from 27.4 to 32.4° and 20.4 to 20.8°C respectively during the course of the experiment. The data are given below :

Duration of soaking (h)	Per cent Imbibition	Duration of soaking (h)	Per cent Imbibition
	100.54	8	160.00
	128.59	10	165.58
	149.50	14	169.17
	154.54	16	179.15
	155.66	20	179.41
	156.02	24	178.95

The seed coat in E. geniculata seeds contains mucilaginous substances which form a sticky, swollen layer

around the seed immediately on coming in contact with water. The mucilaginous layer probably increases the imbibition capacity and also the imbibition rate of the seeds. The seeds of E. geniculata are thus able to imbibe considerably large amounts of water at a considerably high rate. As much as 100.54% water was imbibed within the first hour, and 179.15% within 16 h, beyond which the per cent imbibition remained almost steady upto 24 h.

8.3. Seed output

For the purpose of seed output study 20 mature plants of E. geniculata randomly selected from each of the three study sites were observed during their fruiting period, the number of fruits per plant and the number of seeds per fruit were recorded, and the average seed output was calculated. The data are given below :-

Study site	Number of fruits per plant	
	Range	Mean ± SD
Wire House Compound	14 to 82	40.90 ± 17.29
University Library Area	18 to 104	51.80 ± 24.54
Arts Faculty Area	24 to 149	71.70 ± 36.95

∴ Average number of fruits per plant = 54.80 i. e. 55

Number of seeds per fruit = 3

∴ Average seed output = 165.

8.4. Dispersal of seeds

The method of dispersal of seeds of E. geniculata is by an explosive dehiscence of the capsular fruits. Ridley (1930) describes the mechanism of dispersal in capsular fruits of Euphorbiaceae as follows :

"The outer layer of the pericarp is thin and soft and soon becomes dry, the inner endocarp is hard and woody, composed of transverse fibres which are straight when wet but recurve on themselves when dry, so suddenly as to cause an explosion and eject the seeds".

The effectiveness of this type of dispersal was studied inside the laboratory as follows :

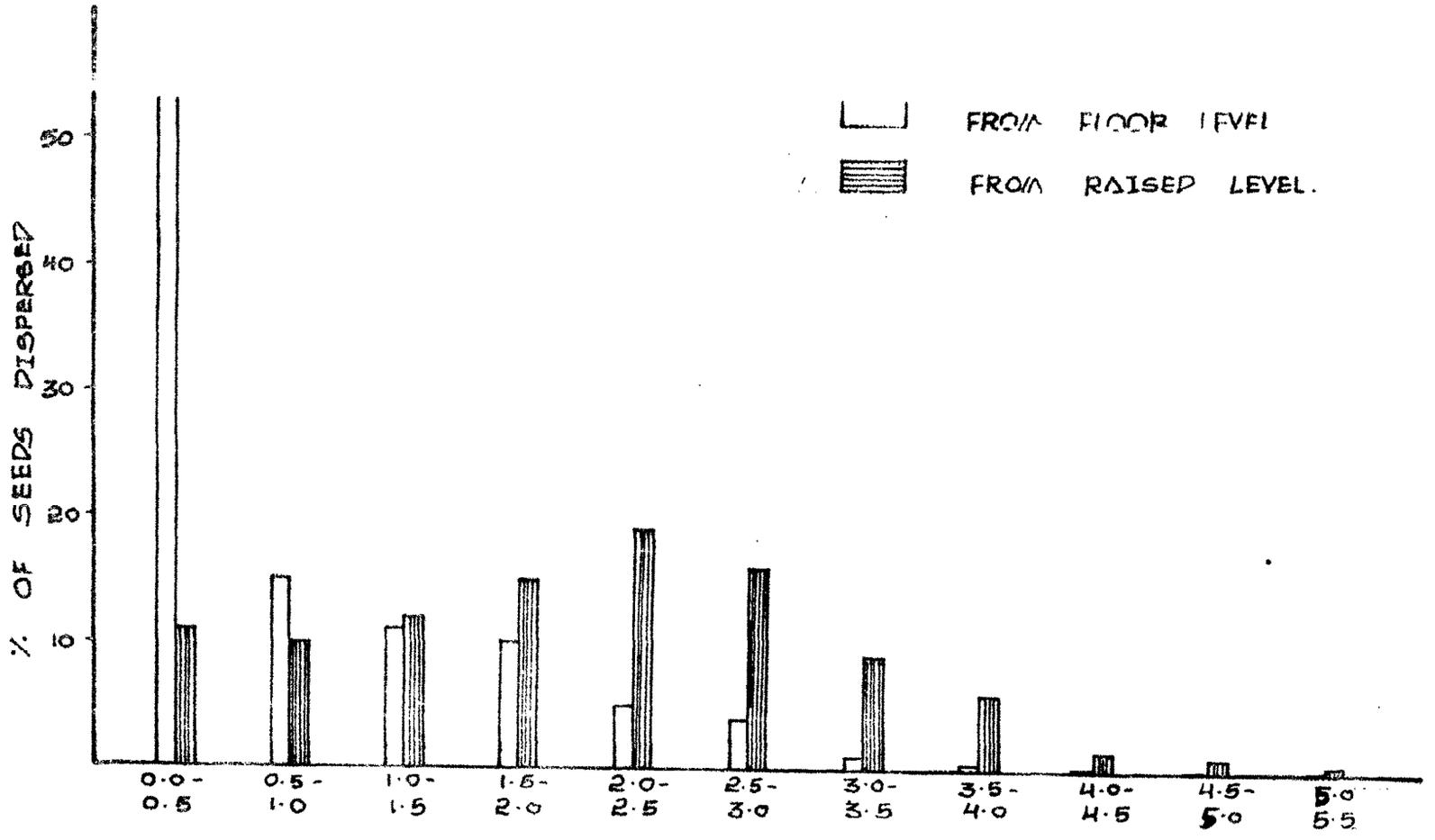
(i) Circles of radii 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 m were drawn on the floor of the laboratory. Freshly collected ripe capsules were put at the floor level in the centre and were allowed to dry and dehisce. The number of seeds dispersed at various distances were noted after two days

(ii) The same method as described above was employed, but instead of putting the capsules at the floor level, they were put at a raised level at 40 cm height from the floor.

The results are presented in Table 8.1 and graph 7. It was observed that when the capsules were put at the floor

Table 8.1 : Dispersal of seeds of E. geniculata

Distance of dispersal (m)	% of seeds dispersed from the capsules put at the	
	Floor level	Raised level
0 - 0.5	52.8	11.3
0.5 - 1.0	15.2	9.5
1.0 - 1.5	11.4	11.6
1.5 - 2.0	9.8	14.9
2.0 - 2.5	5.1	19.2
2.5 - 3.0	4.3	15.6
3.0 - 3.5	1.0	9.2
3.5 - 4.0	0.5	5.9
4.0 - 4.5	-	1.5
4.5 - 5.0	-	1.2
5.0 - 5.5	-	0.2



GRAPH - 4

DISPERSAL OF SEEDS OF E- GENICULATA.

level, maximum (52.8%) dispersal occurred upto the distance of 0.5 m. There was a steep fall in the percentage of seeds dispersed at the distance of 0.5 to 1.0 m, with a gradual decrease upto the distance of 3.0 m. Very few seeds were dispersed beyond the distance of 3.0 m. However, when the capsules were put at the raised level (at 40 cm height from the floor), the dispersal of seeds was spread almost evenly upto the distance of 3.0 m. Further, the maximum dispersal was found at the distance of 2.0 to 2.5 m, with a gradual decrease in percentage of seeds dispersed on either side. Quite a good number of seeds were dispersed at the distance of 3.0 to 3.5 m and 3.5 to 4.0 m, while a few seeds were also found dispersed at the distance of 4.0 to 4.5 m and 4.5 to 5.0 m.

In comparing the dispersal of seeds from the floor level with that from the raised level it is seen that in the former case nearly 80% of the total seeds dispersed covered a distance upto 1.5 m, while in the latter case they covered a distance upto 3.0 m. It can be safely assumed that in nature, the seeds of E. geniculata are dispersed almost evenly upto the distance of 0 to 4 m, and that a few seeds might reach a little longer distance also depending upon the plant height.

Ramkrishnan (1960) studied the dispersal of seeds in Euphorbia hirta inside the laboratory. According to his

findings in that species, the dispersal was maximum at 45-50 cm radii, with a gradual decrease in the number of seeds dispersed on either side so that at 5 cm distance there were no seeds and at 80 cm distance there were only very few.

8.5. Germination studies

Freshly collected seeds of E. geniculata, when kept for germination, readily germinate thus showing that they do not have any dormancy period. In order to understand the ecology of seed germination in E. geniculata, experiments to study germination under different conditions of soil, temperature and light, and also to study the effect of some chemicals and growth regulators on germination were carried out extensively during the course of the present investigation.

8.5.1 Effect of type of soil

Experimental Procedure - Seeds of E. geniculata collected from Cotton Farm, Surat on dt. 25-12-78 and after 3 months of dry storage were used in this experiment. The same procedure as that described under 5.5.8 in Chapter 5 was followed in this experiment, except that the acid pretreatment was not given. As already pointed out, seeds of E. geniculata do not have any dormancy period, so acid pretreatment as given to Abutilon ramosum seeds in the germination experiments is not

necessary in case of these seeds (i.e. E. geniculata seeds). This also applies to all the germination experiments that follow in the present Chapter. The maximum and minimum temperatures ranged from 34.5 to 44.1°C and 18.4 to 24.9°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.2 and graph 9 (i).

Results and Discussion - The percentage germination was maximum (99.00%) in garden soil and minimum (86.00%) in clay. The overall effect of different types of soil is significant at 1% level. However, LSD values reveal that there is no significant difference between the effects of - (i) clay and wasteland soil, (ii) sand and garden soil, and (iii) sand and wasteland soil.

The percentage germination obtained in different types of soil was fairly high, ranging from 86.00 to 99.00%. Thus, though the garden soil gave the best results, the other types of soil used in the experiment also gave fairly good results. Thus as far as germination is concerned, E. geniculata seems to be well adapted to different types of soil.

8.5.2. Effect of depth of sowing

Experimental Procedure - Seeds of E. geniculata collected from Cotton Farm, Surat on dt. 25-12-78 and after 3 months of dry storage were used in this experiment. The same procedure as that described under 5.5.9 in Chapter 5 was followed in

Table 8.2 : Effect of type of soil on germination of seeds of E. geniculata.

Sr. No.	Type of soil	No. of seeds germinated/20	% Germination
1.	Clay	17.20 (0.84)	86.00
2.	Sand	18.80 (0.84)	94.00
3.	Wasteland soil	18.00 (1.22)	90.00
4.	Garden soil	19.80 (0.45)	99.00

L S D = 1.18 at 5% level

L S D = 1.63 at 1%level.

Note : (1) Values are based on five observations.

(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	18.55	3	6.18	7.92 * *
Within treatments	12.40	16	0.78	
Total	30.95	19		

Table value of F : F = 3.24 at 5% level

F = 5.29 at 1% level

this experiment. The maximum and minimum temperatures ranged from 34.5 to 44.1°C and 18.4 to 24.9°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.3 and graph 8.

Results and Discussion - A glance at the table clearly shows that the percentage germination gradually decreases with the increase in depth of sowing beyond 2 cm. Maximum percentage germination (98.67%) was obtained at 1 and 2 cm depth, however, percentage germination obtained at 4 and 6 cm depth was also comparably high. Minimum percentage germination (52.00%) obtained at 10 cm depth is also quite noteworthy. It was noticed that germination was slightly delayed at the depths beyond 2 cm. The germination speed at 1 and 2 cm depths was 6 while that beyond 2 cm depth was 9.

The statistical analysis reveals that the overall effect of varying depths of sowing is significant at 1% level. However, on making independent comparisons it is revealed that there is no significant difference among the effects of 1, 2, 4 and 6 cm depths, while the percentage germination obtained at 8 and 10 cm depths is significantly lower than that at the lesser depths. Thus E. geniculata seeds seem to be well adapted to germinate at the depth of 1 to 6 cm. Fairly good number of seeds can germinate even on sowing at the depth of 8 or 10 cm. The capacity of the hypocotyl to elongate to a

Table 8.3 : Effect of depth of sowing on germination of seeds of E. geniculata.

Sr. No.	Depth of sowing (cm)	No. of seeds germinated/15	% Germination
1.	1	14.80 (0.45)	98.67
2.	2	14.80 (0.45)	98.67
3.	4	14.40 (0.89)	96.00
4.	6	14.00 (0.71)	93.33
5.	8	12.40 (0.89)	82.67
6.	10	7.80 (0.84)	52.00

L S D = 0.95 at 5% level
L S D = 1.29 at 1% level

Note : (1) Values are based on five observations.

(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	184.17	5	36.83	69.49 **
Within treatments	12.18	24	0.53	
Total	196.97	29		

Table value of F : F = 2.62 at 5% level
F = 3.90 at 1% level

great extent in E. geniculata probably makes the germination of such deeply sown seeds possible.

Hall (1956) obtained 60% germination in seeds of Chrozophora rottleri sown at the depth of 6 in (i.e. 15 cm) and 70% germination at the depth of 4 in (i.e. 10 cm). However, Gupta (1972) observed that germination of seeds of Rumex sp. was completely suppressed at 10 cm depth. Kaul (1974) observed that seeds of Hemigraphis dura failed to germinate when sown at the depth of 6 cm or more.

8.5.3. Effect of soil moisture content

Experimental Procedure - Seeds of E. geniculata collected from Cotton Farm, Surat on dt. 25-12-78 and after five and a half months of dry storage were used in this experiment. The same procedure as the one described under 5.5.10 in Chapter 5 was followed. The maximum and minimum temperatures ranged from 27.7 to 44.9°C and 20.5 to 30.6°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.4 and graph 9 (ii).

Results and Discussion - Maximum percentage germination (56.00%) was obtained in soil with 50% moisture content, and there was a gradual decline in percentage germination in either direction from that level of soil moisture. The soil with 10% moisture content gave only 13.00% germination,

Table 8.4 : Effect of soil moisture content on germination of seeds of E. geniculata.

Sr. No.	Soil moisture content (%)	No. of seeds germinated/25	% Germination
1.	20	3.25 (0.96)	13.00
2.	30	4.75 (0.50)	19.00
3.	40	8.00 (0.82)	32.00
4.	50	14.00 (0.82)	56.00
5.	60	11.50 (1.29)	46.00

L S D = 1.39 at 5% level
L S D = 1.90 at 1% level

Note : (1) Values are based on four observations.

(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	323.70	4	80.93	97.51**
Within treatments	12.50	15	0.83	
Total	336.20	19		

Table value of F = 3.06 at 5% level
F = 4.89 at 1% level

which was the minimum percentage germination obtained in the experiment.

The statistical analysis reveals that the overall effect of soil moisture content on germination is significant at 1% level. The LSD values further reveal that the differences among the effects of the different levels of soil moisture content are significant.

Patil (1974) reported similar results in Hemigraphic dura. Gupta (1972) reported maximum germination percentage at 30% soil moisture, and decrease in per cent germination in either direction from that level of soil moisture in case of Rumex sp.

8.5.4 Effect of temperature

Experimental Procedure - Seeds of E. geniculata collected from the House Compound on dt. 14-10-77, and after 2-4 months of dry storage were used in this experiment. The seeds were kept for germination as usual at constant temperatures (low temp. 25°C, 30°C, 35°C and 40°C) which were maintained in the incubators and refrigerator. The results are presented in Table 8.5.

Results and Discussion - The seeds failed to germinate at 40°C, that temperature may be probably harmful to the embryo. At 30°C maximum per cent germination (68.00%) was

Table 8.5 : Effect of temperature on germination of seeds of E. geniculata.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Constant low temp. in fridge	19.67 (2.52)	39.33	4
2.	Constant 25°C	26.33 (3.06)	52.67	4
3.	" 30°C	34.00 (2.65)	68.00	5
4.	" 35°C	22.67 (3.06)	45.33	6
5.	" 40°C	0.00	0.00	-

Note (1) Values are based on three observations.

(2) Figures in parentheses are standard deviations.

obtained, which declined with the change in temperature in either direction. Low temperature in fridge also gave 39.33% germination. Further, it was observed that germination was slightly delayed with the increase in temperature, as can be seen from the germination speed presented in the table. Thus E. geniculata seeds seem to be adapted to germinate under a wide range of temperature, but the per cent germination declines at temperatures higher or lower than 30°C which seems to be the optimum temperature, and at 40°C germination is completely suppressed.

8.5.5. Effect of light

Experimental Procedure - Seeds of E. geniculata collected from Cotton Farm, Surat on dt. 17-4-78 and after 3 months of dry storage were used in this experiment. The same procedure as that described under 5.5.12 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 31.3 to 33.9°C and 24.6 to 27.2°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.6 and graph 0 (i).

Results and Discussion - The germination percentage was maximum (72.00%) in alternate diffuse light and darkness, and minimum (40.00%) in continuous light. The statistical analysis revealed that the overall effect of light on germination is

Table 3.6 : Effect of light on germination of seeds of E. geniculata.

Sr. No.	Light condition	No. of seeds germinated/50	% Germination
1.	Alternate diffuse light and darkness	36.00 (1.00)	72.00
2.	Continuous light	20.00 (2.00)	40.00
3.	Continuous darkness	26.33 (2.08)	52.67

L S D = 3.52 at 5% level
= 5.34 at 1% level

Note : (1) Values are based on three observations.

(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	389.55	2	194.78	62.63 **
Within treatments	18.67	6	3.11	
Total	408.22	8		

Table value of F = 5.14 at 5% level
=10.92 at 1% level

significant at 1% level. Independent comparisons also reveal that the differences among the effects of different light conditions are highly significant.

The results obtained in the present experiment indicate that seeds of E. geniculata do not require presence of light for germination, however, per cent germination is significantly lower in continuous darkness than in alternate diffuse light and darkness. Further, continuous light seems to have adverse effect on germination as can be clearly seen from the minimum per cent germination obtained under that condition.

Gupta (1972) reported similar results in Rumex sp., maximum germination being obtained in diffuse day light and minimum in continuous light. Ramkrishnan (1960) working with Euphorbia hirta seeds reported maximum per cent germination (76%) in total darkness, and minimum (52%) in continuous light.

8.5.6. Effect of colour (wavelength) of light

Experimental Procedure - Seeds of E. geniculata collected from Cotton Farm, Surat on dt. 17.4.78 and after three and a half months of dry storage were used in this experiment. The same procedure as that described under 5.5.13 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 25.4 to 33.5°C and 23.2 and 26.0°C respectively during the course of the experiment. The experimental data were analysed statistically

and are presented in Table 8.7 and graph 10 (ii).

Results and Discussion - The data reveal that yellow light gave maximum (37.33%) and green light gave minimum (6.00%) germination. Strangely, however, germination percentage was comparatively less (24.00%) in control set without cellophane paper than that with white cellophane paper (35.33%).

The statistical analysis reveals that the overall effect of different colours of light is significant at 1% level. However, LSD values reveal that there is no significant difference between the effects of - (i) white and yellow light, (ii) blue and far-red light, (iii) blue and green light, and (iv) red and far-red light.

Thus germination of E. geniculata seeds seems to be inhibited by blue, green and far-red light. Different species respond differently with respect to seed germination under different wavelengths, as can be seen from the results reported by Singhal (1967), Kaul,A(1972), Chawan and Sen (1973) and Kaul, R. (1974).

8.5.7. Effect of inorganic salts

Experimental Procedure - Experiment - I : Seeds of E. geniculata collected from Cotton Farm, Surat on dt.25-12-78 and after one month of dry storage were used in this experiment. The same procedure as that described for Experiment - I

Table 8.7 : Effect of colour of light on germination of seeds of E. geniculata.

Sr. No.	Colour of light	No. of seeds germinated/50	% Germination
1.	Control (Without cellophane paper)	12.00 (2.00)	24.00
2.	White	17.67 (1.53)	35.33
3.	Red	11.00 (2.00)	22.00
4.	Yellow	18.67 (1.53)	37.33
5.	Blue	6.00 (2.00)	12.00
6.	Green	3.00 (2.00)	6.00
7.	Far-Red	9.00 (2.00)	18.00

L S D = 3.29 at 5% level
= 4.56 at 1% level

Note : (1) Values are based on three observations.
(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	591.62	6	98.60	28.01 **
Within treatments	49.33	14	3.52	
Total	640.95	20		

Table value of F = 2.85 at 5% level
= 4.46 at 1% level

under 5.5.14 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 22.6 to 35.2°C and 9.0 to 19.9°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.8 and graph 11.

Experiment - II : Seeds of E. geniculata collected from Cotton Farm, Surat on dt. 25-12-78 and after 11 months of dry storage were used in this experiment. The same procedure as that described for Experiment - II under 5.5.14 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 29.2 to 34.1°C and 14.2 to 20.2°C respectively during the course of the experimental data were analysed statistically and are presented in Table 8.9 and graph 12.

Results and Discussion - Experiment - I : A perusal of Table 8.9 makes it very clear that in all the salt solutions, germination percentage decreased with the increase in the concentration of the salt solution. The higher concentrations of some salts, viz. KCl - 2.0%, NaCl - 1.5 and 2.0%, $NaNO_3$ - 2.0% proved to be highly toxic and inhibited germination completely or almost completely. $CaCl_2$ and KCl at 0.5% conc., and $Ca(NO_3)_2$ and KNO_3 at 0.5 and 1.0% conc. showed favourable effect on germination as compared to control. The percentage germination was markedly lower as compared to control in 1.5 and 2.0% conc. of $CaCl_2$, 2.0% conc. of $Ca(NO_3)_2$, 1.5%

Table 8.8: Effect of inorganic salts on germination of seeds of E. geniculata - I.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
1.	Dist. water (Control)		43.67 (1.53)	87.33
2.	$CaCl_2$	0.5%	47.00 (1.00)	94.00
3.	"	1.0%	43.67 (1.53)	87.33
4.	"	1.5%	28.67 (2.52)	57.33
5.	"	2.0%	10.67 (0.58)	21.33
6.	$Ca(NO_3)_2$	0.5%	47.33 (2.08)	94.67
7.	"	1.0%	46.33 (0.58)	92.67
8.	"	1.5%	41.67 (0.58)	83.33
9.	"	2.0%	33.67 (1.53)	67.33
10.	HCl	0.5%	47.67 (0.58)	95.33
11.	"	1.0%	39.67 (2.52)	79.33
12.	"	1.5%	13.67 (0.58)	27.33
13.	"	2.0%	1.00 (1.00)	2.00
14.	KIO_3	0.5%	48.33 (1.53)	96.67
15.	"	1.0%	46.67 (1.53)	93.33
16.	"	1.5%	28.33 (2.08)	56.67

Table 8.8 : contd.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
17.	KNO_3	2.0%	10.33 (0.58)	20.67
18.	NaCl	0.5%	37.33 (1.15)	74.67
19.	"	1.0%	7.33 (1.15)	14.67
20.	"	1.5%	0.00 (-)	0.00
21.	"	2.0%	0.00 (-)	0.00
22.	$NaNO_3$	0.5%	44.33 (1.15)	88.67
23.	"	1.0%	28.67 (0.58)	57.33
24.	"	1.5%	7.33 (0.58)	14.67
25.	"	2.0%	1.33 (1.53)	2.67

L S D = 2.17 at 5% level; L S D = 2.89 at 1% level.

Note : (1) Values are based on three observations.

(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	24299.39	24	1012.47	575.27 **
Within treatments	88.00	50	1.76	
Total	24387.39	74		

Table value of F = 1.74 at 5% level

F = 2.18 at 1% level

Table 8.9 : Effect of inorganic salts on germination of seeds of E. geniculata - II.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
1.	Dist. water (Control)		47.33 (2.08)	94.67
2.	$CaCl_2$	0.1%	46.67 (2.31)	93.33
3.	"	0.2%	47.33 (1.15)	94.67
4.	"	0.3%	44.33 (2.08)	88.67
5.	"	0.5%	44.67 (0.58)	89.33
6.	$Ca(NO_3)_2$	0.1%	47.33 (2.08)	94.67
7.	"	0.2%	46.67 (1.15)	93.33
8.	"	0.3%	46.33 (0.58)	92.67
9.	"	0.5%	46.33 (1.53)	92.67
10.	KCl	0.1%	45.67 (1.53)	91.33
11.	"	0.2%	45.00 (2.00)	90.00
12.	"	0.3%	43.67 (1.53)	87.33
13.	"	0.5%	29.67 (0.58)	59.33
14.	KIO_3	0.1%	47.67 (0.58)	95.33
15.	"	0.2%	47.67 (0.58)	95.33
16.	"	0.3%	44.67 (0.58)	89.33

Table 8.9 : Contd.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
17.	KNO_3	0.5%	40.67 (1.53)	81.33
18.	NaCl	0.1%	42.33 (0.58)	84.67
19.	"	0.2%	42.33 (2.08)	84.67
20.	"	0.3%	37.67 (1.53)	75.33
21.	"	0.5%	29.00 (1.73)	58.00
22.	$NaNO_3$	0.1%	47.67 (0.58)	95.33
23.	"	0.2%	47.00 (1.00)	94.00
24.	"	0.3%	42.33 (1.53)	84.67
25.	"	0.5%	37.33 (2.08)	74.67

L S D = 2.42 at 5% level; L S D = 3.22 at 1% level.

Note : (1) Values are based on three observations.
(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	SS	df	M S S	F
Between treatments	1922.08	24	80.09	36.91**
Within treatments	108.67	50	2.17	
Total	2030.75	74		

Table value of F = 1.74 at 5% level
F = 2.18 at 1% level

conc. of KCl, 1.5 and 2.0% conc. of KNO_3, 0.5 and 1.0% conc. of NaCl, and 1.0 and 1.5% conc. of $NaNO_3$.

The statistical analysis reveals that the overall effect of the various concentrations of the inorganic salts used is significant at 1% level. $CaCl_2$ and KCl at 0.5% conc., and $Ca(NO_3)_2$ and KNO_3 at 0.5% and 1.0% conc. gave significantly higher percentage germination as compared to control. The germination percentage obtained in 1.0% $CaCl_2$, 1.5% $Ca(NO_3)_2$, and 0.5% $NaNO_3$ does not differ significantly from that in control, while 1.5 and 2.0% $CaCl_2$, 2.0% $Ca(NO_3)_2$, 1.0 and 1.5% KCl, 1.5 and 2.0% KNO_3, 0.5 and 1.0% NaCl, and 1.0 and 1.5% $NaNO_3$ gave significantly lower germination percentage as compared to control.

Experiment - II : A perusal of Table 8.9 makes it very clear that any of the salts at any of the concentrations tried did not give higher percentage germination than control. They either gave germination percentage nearly equal to control or less than control.

The statistical analysis reveals that the overall effect of the various concentrations of the inorganic salts used is significant at 1% level. However, the per cent germination obtained in 0.1 and 0.2% concentrations of $CaCl_2$, KCl, KNO_3 and $NaNO_3$; and in all the four concentrations of $Ca(NO_3)_2$ does not differ significantly from that in control. The per cent germination obtained in 0.3 and 0.5% concentrations of

$CaCl_2$, KCl, KNO_3 and $NaNO_3$; and in all the four concentrations of NaCl is significantly lower than that in control.

The inhibitory effect of inorganic salts at some higher concentrations and the promoting effect of some salts at some lower concentrations on germination as observed in E. geniculata have also been reported in different weed species by Datta (1965), Jaychandra (1967), Pandya (1971), Kaul (1972), and Dastar et al. (1977).

8.5.8. Effect of nitrates on germination in darkness

Experimental Procedure - Seeds of E. geniculata collected from Cotton Farm, Surat on dt. 25-12-78 and after eleven and a half months of dry storage were used in this experiment. The same procedure as that described under 5.5.15 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 27.1 to 34.3°C and 11.6 to 18.9°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.10 and graph 13.

Results and Discussion - The data reveal that all the four nitrates at all concentrations tried in the experiment, except 0.3 and 0.5% NH_4NO_3, gave slightly higher percentage germination as compared to control. The percentage germination obtained in 0.3 and 0.5% NH_4NO_3 was lower than that in control.

Table 8.10 : Effect of nitrates on germination of seeds of *E. geniculata* in darkness.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
1.	Dist. water (Control)		45.33 (1.15)	90.67
2.	$Ca(NO_3)_2$	0.1%	48.67 (C.58)	97.33
3.	"	0.2%	48.33 (0.58)	96.67
4.	"	0.3%	48.67 (1.53)	97.33
5.	"	0.5%	48.33 (0.58)	96.67
6.	KNO_3	0.1%	47.33 (0.58)	94.67
7.	"	0.2%	48.33 (1.15)	96.67
8.	"	0.3%	47.67 (0.58)	95.33
9.	"	0.5%	47.00 (2.00)	94.00
10.	$NaNO_3$	0.1%	49.33 (0.58)	98.67
11.	"	0.2%	48.33 (1.15)	96.67
12.	"	0.3%	49.00 (1.00)	98.00
13.	"	0.5%	46.67 (1.53)	93.33
14.	NH_4NO_3	0.1%	46.33 (0.58)	92.67
15.	"	0.2%	47.33 (0.58)	94.67

Table 8.10 : contd.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination
16.	NH_4NO_3 0.3%	42.33 (2.08)	84.67
17.	" 0.5%	33.33 (2.08)	66.67

L S D = 2.01 at 5% level,
= 2.70 at 1% level.

Note (1) Values are based on three observations.
(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	696.16	16	43.51	29.60 **
Within treatments	50.00	34	1.47	
Total	746.16	50		

Table value of F = 1.95 at 5% level
= 2.58 at 1% level.

The statistical analysis reveals that the overall effect of the treatments given is significant at 1% level. On making independent comparisons, it is revealed that $Ca(NO_3)_2$ at all concentrations tried gave significantly higher per cent germination than control. Similarly KNO_3 at 0.2 and 0.3% conc., and $NaNO_3$ at 0.1, 0.2 and 0.3% conc. gave significantly higher per cent germination than control, while NH_4NO_3 at 0.3 and 0.5% conc. gave significantly lower per cent germination than control. The per cent germination obtained in 0.1 and 0.5% KNO_3, 0.5% $NaNO_3$, and 0.1 and 0.2% NH_4NO_3 does not differ significantly from that in control.

Thus nitrates of calcium, potassium and sodium at certain concentrations have promoting effect on germination of E. geniculata seeds in darkness. Potassium nitrate promotes the germination of a number of seeds in the dark, e.g. Lepidium virginicum, Eragrostis curvula, Polypogon monspelliensis, various species of Agrostis, Sorghum halepense, Veronica longifolia, Hypericum perforatum, H. hirsutum, Epilobium hirsutum and E. montanum (Mayer and Poljakoff-Mayber, 1975).

8.5.9. Effect of thiourea

Experimental Procedure - Seeds of E. geniculata collected from a private orchard at Surat on dt. 12-9-79 and after five and a half months of dry storage were used in this experiment. The same procedure as that described under 5.5.16 in Chapter 5 was followed in this experiment. The maximum and minimum

temperatures ranged from 29.6 and 39.0°C and 11.6 and 19.9°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 3.11 and graph 14.

Results and Discussion - A glance at the table brings out clearly that thiourea at all concentrations (ranging from 50 to 100 ppm) tried in the experiment showed inhibitory effect on germination. Further, the effect increased progressively with the increase in concentration.

The statistical analysis reveals that the overall effect of the various concentrations of thiourea is significant at 1% level. On making independent comparisons, it is revealed that the percentage germination in each of the concentrations tried is significantly lower than that in control.

Thiourea has been shown to stimulate the germination of seeds of Cichorium and Gladiolus (Shieri, 1941). The dark germination of many seeds is stimulated by thiourea (Mayer and Poljakoff-Mayber, 1975). Strangely, however, in the present experiment thiourea showed inhibitory effect on germination of E. peniculata seeds. It may be probably due to some complex interaction between the effect of thiourea and that of other factors affecting germination, such as light and temperature. Or, it may be probably due to the continued treatment of the seed with thiourea as in the present experiment. An interaction between the effects of light and

Table 8.11 : Effect of thiourea on germination of seeds of E. geniculata.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist. water (Control)	37.33 (0.58)	74.67	3
2.	Thiourea 50 ppm	29.00 (3.00)	58.00	3
3.	" 100 "	25.00 (1.00)	50.00	3
4.	" 200 "	19.33 (0.58)	38.67	3
5.	" 500 "	15.67 (2.52)	31.33	3
6.	" 1000 "	10.33 (2.08)	20.67	2

L S D = 3.36 at 5% level
= 4.71 at 1% level

Note (1) Values are based on three observations.

(2) Figures in parentheses are standard deviations.

Analysis of variance

Source of variation	S S	df	M S S	F
Between treatments	1418.44	5	283.69	79.69 **
Within treatments	42.67	12	3.56	
Total	1461.11	17		

Table value of F = 3.11 at 5% level
= 5.06 at 1% level

thiourea has been shown by Evenari et al. (1954) and that between the effects of temperature and thiourea by Poljakoff-Mayber et al. (1958).

8.5.16 Effect of GA_3

Experimental Procedure - Seeds of E. geniculata collected from a private orchard at Surat on dt. 12-9-79 and after 5 months of dry storage were used in this experiment. The same procedure as that described under 5.5.17 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 30.9 to 39.0°C and 11.9 to 19.2°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.12 and graph 15.

Results and Discussion - It is evident from the table that GA_3 at all concentrations (ranging from 50 to 3000 ppm) showed stimulating effect on germination. Maximum germination (99.33%) was obtained at 200 ppm concentration. GA_3 at 2000, 2500 and 3000 ppm concentrations also gave equally good per cent germination (ranging from 96.67 to 98.67%). There was, however, no effect of GA_3 on germination speed.

The statistical analysis reveals that the overall effect of various concentrations of GA_3 is significant at 1% level. On making independent comparisons, it is brought out clearly that the per cent germination obtained in each of the

Table 8.12 : Effect of GA_3 on germination of seeds of *E. geniculata*.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist. water (Control)	41.67 (1.53)	83.33	2
2.	GA_3 50 ppm	44.67 (1.53)	89.33	2
3.	" 100 "	46.00 (2.00)	92.00	2
4.	" 200 "	49.67 (0.58)	99.33	2
5.	" 500 "	47.67 (1.53)	95.33	2
6.	" 1000 "	45.67 (1.53)	91.33	2
7.	" 1500 "	45.67 (0.58)	91.33	2
8.	" 2000 "	49.00 (1.00)	98.00	2
9.	" 2500 "	49.33 (1.15)	98.67	2
10.	3000 "	48.33 (2.08)	96.67	2

LSD = 2.45 at 5% level;
= 3.34 at 1% level.

Note (1) Values are based on three observations.
(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	170.04	9	18.89	9.13 **
Within treatments	41.33	20	2.07	
Total	211.37	29		

Table value of F = 2.40 at 5% level
= 3.45 at 1% level

concentrations of GA_3 is significantly higher than that in control. However, there are no significant differences among the effects of - (i) 50, 100, 100C and 1500 ppm concentrations, (ii) 100, 500 and 3000 ppm concentrations and (iii) 200, 500, 2000, 2500 and 3000 ppm concentrations of GA_3.

The stimulating effect of GA_3 on germination has also been reported in different species by Lona (1956), Kallio and Piirainen (1959), Biswas (1967), Kaul (1974) and Dagar et al., (1977).

8.5.11. Effect of kinetin

Experimental Procedure - Seeds of E. geniculata collected from a private orchard at Surat on dt. 12-9-79 and after four and a half months of dry storage were used in this experiment. The procedure as that described under 5.5.18 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 25.9 to 38.3°C and 9.0 to 17.8°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.13 and graph 16.

Results and Discussion - It is evident from the table that certain concentrations (10 and 20 ppm) of kinetin showed stimulating effect on germination, while concentrations below 10 ppm (1 and 5 ppm) and those above 20 ppm had inhibitory effect on germination. Further, the inhibitory effect

Table 8.13 : Effect of kinetin on germination of seeds of *E. geniculata*.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist. water (Control)	37.67 (2.52)	75.33	3
2.	Kinetin 1 ppm	35.67 (2.52)	71.33	3
3.	" 5 "	35.33 (1.15)	70.67	3
4.	" 10 "	42.33 (2.08)	84.67	3
5.	" 20 "	42.67 (0.58)	85.33	3
6.	" 50 "	35.67 (0.58)	71.33	3
7.	" 100 "	36.67 (0.58)	73.33	4
8.	" 200 "	32.33 (3.06)	64.67	4
9.	" 300 "	26.67 (2.52)	53.33	4
10.	" 500 "	25.33 (2.08)	50.67	4

L S D = 3.38 at 5% level
= 4.61 at 1% level

Note : (1) Values are based on three observations.
(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	880.30	9	97.81	24.89 **
Within treatments	78.67	20	3.93	
Total	958.97	29		

Table value of F = 2.40 at 5% level
= 3.45 at 1% level

increased in magnitude with the increase in concentration of kinetin. The higher concentrations (100 to 500 ppm) of kinetin slightly decreased the germination speed.

The statistical analysis reveals that the overall effect of various concentrations of kinetin is significant at 1% level. On making independent comparisons, it is revealed that (i) 10 and 20 ppm concentrations of kinetin gave significantly higher per cent germination than control, (ii) 200, 300 and 500 ppm concentrations gave significantly lower per cent germination than control, and (iii) 1, 5, 50 and 100 ppm concentrations had no significant effect either stimulatory or inhibitory.

Miller (1958) showed that kinetin promotes the germination of seeds. Sankhla and Sankhla (1972) also reported stimulating effect of kinetin on germination of Lactuca sativa seeds.

8.5.12 Effect of 2,4-D.

Experimental Procedure - Seeds of E. geniculata collected from a private orchard at Surat on dt. 12-9-79 were used in this experiment. The same procedure as that described under 5.5.19 in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 29.6 to 39.0°C and 11.6 to 19.9°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 8.14 and graph. 17.

Table 8.14 : Effect of 2,4-D on germination of seeds of *E. geniculata*.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist. water (Control)	37.33 (0.58)	74.67	3
2.	2,4-D 0.5 ppm	33.67 (1.53)	67.33	4
3.	" 1 "	33.00 (2.00)	66.00	4
4.	" 5 "	28.00 (1.73)	56.00	7
5.	" 10 "	29.00 (1.00)	58.00	6
6.	" 20 "	29.67 (2.52)	59.33	5
7.	" 50 "	30.33 (1.15)	60.67	5
8.	" 100 "	29.67 (1.53)	59.33	7
9.	" 200 "	31.00 (1.00)	62.00	7
10.	" 500 "	29.00 (1.00)	58.00	6
11.	" 1000 "	19.33 (3.06)	38.67	5
12.	" 2000 "	13.67 (2.52)	27.33	5

L S D = 3.01 at 5% level
= 4.08 at 1% level

Note (1) Values are based on three observations.
(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	1325.64	11	120.51	37.78 **
Within treatments	76.67	24	3.19	
Total	1402.31	35		

Table value of F = 2.22 at 5% level
= 3.09 at 1% level

Results and Discussion - It is evident from the table that 2,4-D at all concentrations (ranging from 0.5 to 2000 ppm) showed inhibitory effect on germination. The inhibitory effect was more pronounced at 1000 and 2000 ppm concentrations. Further, it was also noticed that 2,4-D decreased the germination speed.

The statistical analysis reveals that the overall effect of the various concentrations of 2,4-D is significant at 1% level. LSD values reveal that the per cent germination obtained in each of the concentrations of 2,4-D is significantly lower than that in control. However, there are no significant differences among the effects of - (i) 5, 10, 20, 50, 100, 200 and 500 ppm concentrations, and (ii) 0.5, 1 and 200 ppm concentrations of 2,4-D.

The inhibitory effect of 2,4-D on germination in different species has also been reported by Jaychandra (1967), Chawan and Sen (1970), Dubey and Mall (1975), Dagar et al. (1977)

8.6. Reproductive Capacity

Average seed output of E. geniculata as worked out under 8.3 in the present Chapter is 165. The average of the different values of maximum percentage germination obtained in the different experiments in E. geniculata seeds works out to be 81.21% i.e. 81%. This value is taken as representing average

percentage germination for the present purpose. The reproductive capacity of E. geniculata as calculated by the following formula works out to be -

$$\text{Reproductive capacity} = \frac{\text{Av. seed output X av. \% germination}}{100}$$

$$= \frac{165 \times 81}{100}$$

$$= \frac{13365}{100}$$

$$= 133.65 \quad \text{i. e. } \underline{134}.$$

8.7. Seedling Morphology

The germination of seeds of E. geniculata is epigeal. The radicle appears as a protruberance from the pointed end of the seed, by a split of the testa. When the radicle is a few mm long, the hypocotyl forms a hook and comes above the soil surface along with the cotyledons in the folded condition. The hypocotyl hook straightens and the cotyledons are raised. The hypocotyl elongates to a great extend, the cotyledons now unfold, turn green and become the first pair of leaves. The next pair of leaves is also very much like the embryonic leaves and those developing after the 4-leaf stage are true leaves The first four leaves persist until several of the true leaves are well developed. Plate 17.

*****