CHAPTER 11

SEED AND SEED GERMINATION

11.1. Size, Weight and Moisture content of seeds

The general morphology of the seeds of R. humilis has been dealt with under 10.4 in Chapter 10. Plate 26. The size, weight and moisture content values of the seeds of R. humilis are given below :

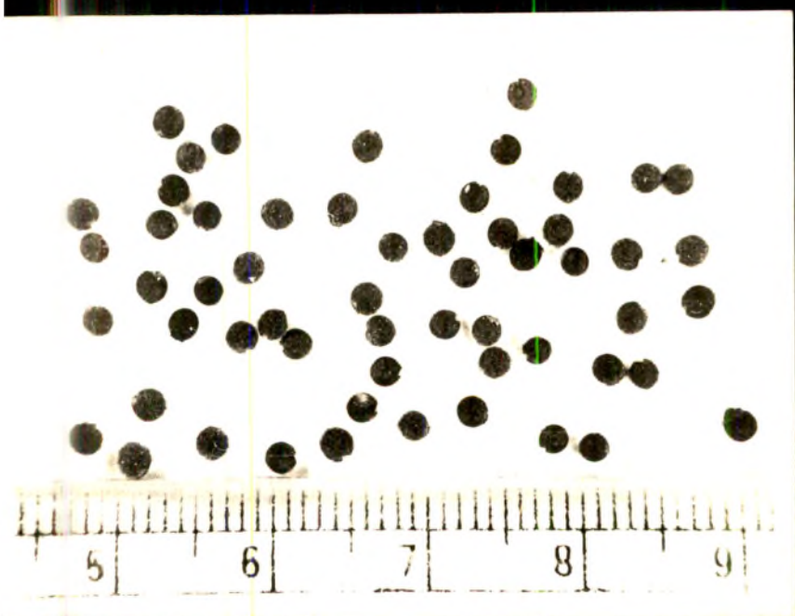
Size (Values based on 100 observations)

Diameter (mm)	2.092 ± 0.151
Thickness (mm)	1.453 ± 0.084

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)
L. V. Palace Compound	29.9.77	2.77 ± 0.03
- " -	13.12.77	2.99 ± 0.04
Botanical Garden (M. S University)	20.8.79	2.84 ± 0.03
- " -	27-1-79	2.78 ± 0.03
Private Orchard, Surat	26-12-78	3.13 ± 0.02
- " -	1-2-79	3.16 ± 0.04

a.



b.

PLATE No. 26.

Moisture Content	(Values based on 3 observations in lots of 100 seeds each).
(%)	8.38 ± 0.22

Note Values represent mean ± standard deviation.

11.2. Imbibition rate

The imbibition rate of seeds of R. humilis was studied under laboratory conditions, the procedure of which is given under 2.7 in Chapter 2. The data are given below :

I. Locality and date of seed collection - Surat Orchard dt. 1-2-79.

Duration of dry storage of seeds - 10 months.

Range of temperature during the imbibition experiment -

Maximum - 27.4 to 32.4°C

Minimum - 20.4 to 20.8°C

Duration of soaking (h)	Per cent Imbibition	Duration of soaking (h)	Per cent Imbibition
[illegible]	0.44	8	7.03
[illegible]	1.61	10	9.64
[illegible]	4.17	14	10.09
[illegible]	6.38	16	13.64
[illegible]	6.53	20	13.97
[illegible]	6.67	24	17.57

II. Locality and date of seed collection - Surat Orchard
Dt. 1-2-79.

Duration of dry storage of seeds - Ten and a half months.

Range of temperature during the entire period of the imbibition experiment -

Maximum - 29.2 to 34.3°C

Minimum - 14.2 to 18.9°C

Duration of soaking (h)	Per cent Imbibition	Duration of soaking (h)	Per cent Imbibition
16	12.42	4 X 24	25.65
1 X 24	13.51	5 X 24	24.38
2 X 24	20.59	6 X 24	30.77
3 X 24	24.38	7 X 24	27.96

It is evident from the data that seeds of R. humilis imbibe water at a very slow rate. After (6 X 24) h of imbibition the seeds imbibed only 30.77% water. A gradual increase in per cent imbibition was observed with the increase in duration of soaking.

11.3. Seed output

For the purpose of seed output study 40 mature plants of R. humilis randomly selected from the study sites were observed during their fruiting period. The number of

inflorescences per plant, the number of fruits per inflorescence and the number of seeds per fruit were noted, and the average seed output was calculated.

In R. humilis flowering and fruiting goes on simultaneously almost throughout the year in nearly monthly flushes, which are often overlapping. This situation makes the study of seed output of the plant very difficult. However, in the present study all the inflorescences in various stages of development - budding, blooming and fruiting - were considered as potential fruiting inflorescences and were included in the counts. The data are given below :-

	Range	Mean ± S D
Number of inflorescences per plant	33 to 99	72.85±18.65
Number of fruits per inflorescence	10 to 42	21.77± 6.89
Number of seeds per fruit	-	1 (one)
Average seed output	-	1585.94 i.e. 1586

11.4. Dispersal of seeds

The fruits or seeds of R. hunilis do not show any specialised mechanism for wide dispersal. The ripe fruits fall on the ground near the plant. The fruits being devoid

of any special device are not carried to any long distances even under the influence of strong winds.

The probable dispersing agencies appear to be - (i) the water current in the irrigation channel by the side of which the plants are growing, or the strong water current during the rainy season, and (ii) ants.

Fruits of R. humilis seem to attract ants, and have been observed in the field being carried by them, thus helping their dispersal. This observation has also been confirmed in the laboratory. Thus to use the terminology of Pijl (1972), R. humilis fruits are myrmecochorous.

11.5. Germination studies

Freshly collected seeds of R. humilis, 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 R. humilis, an extensive experimental work was carried out during the course of the present investigation so as 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.

11.5.1. Effect of type of soil

Experimental Procedure - Seeds of R. humilis collected

from [illegible]. V. Palace compound on dt. 29-9-77 and after three and a half 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 pre-treatment was not given. As already pointed out, seeds of R. humilis do not have any dormancy period, so acid pre-treatment as given to Abutilon ranosum seeds in the germination experiments is not necessary in case of these seeds (i.e. R. humilis seeds). This also applies to all the germination experiments that follow in the present chapter. The maximum and minimum temperatures ranged from 26.5 to 35.2°C and 6.8 to 20.0°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 11.1 and graph 9 (i).

Results and Discussion - Garden soil, clay and sand gave almost equal percentage germination (95.00 to 97.00%), while wasteland soil gave little less percentage germination (87.00%). The overall effect of different types of soil is significant at 5% level. However, LSD values reveal that there is no significant difference among the effects of clay, sand and garden soil.

The percentage germination obtained in different types of soil was fairly high, ranging from 87.00 to 95.00%. Thus, though the wasteland soil gave minimum percentage germination differing significantly from the remaining three types, the

Table 11.1 : Effect of type of soil on germination of seeds of R humilis.

Sr. No.	Type of soil	No. of seeds germinated/20	% Germination
1.	Clay	19.00 (0.71)	95.00
2.	Sand	19.40 (0.89)	97.00
3.	Wasteland soil	17.40 (0.89)	87.00
4.	Garden soil	19.00 (1.00)	95.00

L S I = 1.18 at 5% level

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

Analysis of Variance

Source of variation	SS	df	M S S	F
Between treatments	11.8	3	3.93	5.04 *
Within treatments	12.4	16	0.78	
Total	24.2	19		

Table value of F : F = 3.24 at 5% level
F = 5.29 at 1% level

resul obtained was fairly good. Thus as far as germination is co cerned, R. humilis seems to be well adapted to different types of soil.

11.5.1. Effect of depth of sowing

Experimental Procedure - Seeds of R. humilis collected from . V. Palace compound on dt. 29-9-77, and after four and a hal months of dry storage were used in this experiment. The same rocedure as that described under 5.5.9 in Chapter 5 was follo ed in this experiment. The maximum and minimum temperatures range from 26.9 to 39.0°C and 11.0 to 22.2°C respectively durin the course of the experiment. The experimental data were nalysed statistically and are presented in Table 11.2 and g aph 8.

esults and Discussion - A glance at the table clearly shows that maximum percentage germination (94.67%) was obtained at 1 depth, and a progressive decline in the percentage germi ation was observed, as the depth of sowing was increased. Howev r, fairly good results were obtained upto the depth of 6 cm, ermination percentage ranging from 76.00 to 94.67%, but beyon that depth there was a sudden and sharp decline in perce tage germination, so much so that at 10 cm depth the perce tage germination was almost negligible.

e statistical analysis reveals that the effect of varyi g depth of sowing is significant at 1% level. However,

Table 11.2 : Effect of depth of sowing on germination of seeds of R. humilis.

Sr. No.	Depth of sowing (cm)	No. of seeds germinated/15	% Germination
1.	0.5	12.00 (1.41)	80.00
2.	1	14.20 (1.30)	94.67
3.	2	13.80 (1.10)	92.00
4.	3	13.00 (1.87)	86.67
5.	4	12.20 (1.30)	81.33
6.	5	12.20 (1.92)	81.33
7.	6	11.40 (0.89)	76.00
8.	8	1.20 (0.84)	8.00
9.	10	0.40 (0.55)	2.67

L S D = 1.69 at 5% level; L S D = 2.26 at 1% level.

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

Analysis of Variance

Source of variation	S S	df	M S S	F
Between treatments	1131.51	8	141.44	81.76 * *
Within treatments	62.40	36	1.73	
Total	1193.91	44		

Table value of F : F = 2.21 at 5% level
F = 3.04 at 1% level.

on making independent comparisons, it was revealed that there is no significant difference among the effects of (i) 1 2 and 3 cm depths, and (ii) 0.5, 3, 4, 5 and 6 cm depths of sowing. It is clearly brought out that the percentage germination obtained at 1, 2 and 3 cm depths was significantly higher than that at any of the remaining depths. Thus R. humilis seeds seem to be well adapted to germinate at the depth of 0.5 to 6 cm, but still greater depths seem to be very unfavourable, so much so that germination is almost negligible at 10 cm depth.

Similar trend in germination of seeds in different species has been reported by several workers. Euphorbia caducifolia (Sen and Chatterji, 1966) seeds sown at depths of 2-5 cm germinated well but at lower depths, germination was very much delayed or did not take place at all. Rumex dentatus and R. nepalensis (Gupta, 1972) showed maximum per cent germination at the surface level, and a significant reduction in germination was observed in both the species with increasing depth and germination was completely suppressed at 10 cm depth.

11.5.3. Effect of soil moisture content

Experimental Procedure - Seeds of R. humilis collected from Botanical Garden, Baroda on dt. 18-1-79 and after six and a half months of dry storage were used in this experiment. The same procedure as that described under 5.5.10 in Chapter 5 was

followed in this experiment. The maximum and minimum temperatures ranged from 26.5 to 33.4°C and 22.4 to 25.4°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 11.3 and graph 9 (ii).

Results and Discussion - It is evident from the data that 30, 40 and 50% levels of soil moisture gave the best results (germination percentage ranging from 98.00 to 100.00%). A sharp decline in germination percentage was observed at 60% level of soil moisture which gave the minimum percentage germination (21.00%).

The statistical analysis reveals that the overall effect of varying soil moisture content is significant at 1% level. However, LSD values reveal that there is no significant difference among the effects of 30, 40 and 50% levels of soil moisture, and that the percentage germination obtained in each of them is significantly higher than that obtained in 20 and 60% soil moisture content.

Similar trend in germination results has also been reported by Gupta (1972) and Kaul (1974).

11.5.4. Effect of temperature

Experimental Procedure - Seeds of R. humilis collected from I. V. Palace compound on dt. 13-10-77 and after 2 months of dry storage were used in this experiment. The seeds were

Table 11.3 : Effect of soil moisture content on germination of seeds of R. humilis.

Sr. No.	Soil moisture content (%)	No. of seeds germinated/25	% Germination
1.	20	16.00 (1.63)	64.00
2.	30	25.00 (0.00)	100.00
3.	40	24.50 (0.58)	98.00
4.	50	24.50 (0.58)	98.00
5.	60	5.25 (0.50)	21.00

L S D = 1.28 at 5% level
L S D = 1.77 at 1% level

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

(2) Figures in parentheses are standard deviations.

Analysis of Variance

Source of variation	SS	df	MSS	F
Between treatments	1178.20	4	294.55	409.10**
Within treatments	10.75	15	0.72	
Total	1188.95	19		

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

kept for germination as usual at constant temperatures (low temp. 30°C, 35°C and 40°C) which were maintained in the incubators and refrigerator. The results are presented in Table 11.4.

Results and Discussion - The germination percentage at the constant temperatures tried was either zero or almost negligible. It appears that seeds of R. humilis do not germinate or show only negligible germination at constant temperatures. Alternating temperatures as are obtained in nature seem to be necessary for germination of R. humilis seeds.

Instances are known where a periodic alternation (most usually diurnal) of temperature is required for germination to occur, as in Oenothera biennis, Rumex crispus, Cynodon dactylon, Nicotiana tabacum, Holcus lanatus, Agrostis alba, Poa trivialis and many others (Mayer and Poljakoff-Mayber, 1975).

11.5.1. Effect of light

Experimental Procedure - Seeds of R. humilis collected from I. V. Palace compound on dt. 13-12-78 and after one month 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 22.6 to 35.8°C and 9.0 to 19.9°C

Table 7.4 : Effect of temperature on germination of seeds of R. humilis.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Constant low temp. in Fridge	0.00	0.00	-
2.	Constant 30°C	2.00 (1.00)	4.00	9
3.	" 35°C	0.33 (0.58)	0.67	18
4.	" 40°C	0.00	0.00	-

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

(2) Figures in parentheses are standard deviations.

respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 11.5 and graph 10 (if).

Results and Discussion - The per cent germination was maximum (99.33%) in alternate diffuse light and darkness, and that in continuous light was also equally high (98.00%), while that in continuous darkness declined to a great extent (being only 32.00%).

The statistical analysis reveals that the overall effect of light on germination is significant at 1% level. However, there is no significant difference between the effects of alternate diffuse light and darkness and continuous light, but both these light conditions gave significantly higher percentage germination than continuous darkness.

Different species may differ in responding to different light conditions. Bakshi (1952) found that Anisochilus eriocephalus seeds preferred to germinate in light. Bakshi and Kaul (1954) found that Mollugo cerviana seeds showed maximum (46%) germination in diffuse light, whereas in continuous darkness and continuous light per cent germination declined to 23 and 17% respectively. Light seemed to have no marked effect on germination of seeds of Chrozophora rottleri (Mall, 1956). Achyranthes aspera seeds are indifferent to light (Mall and Arzare, 1956). Echinochloa colonum (Ramkrishnan, 1960) seeds showed 78% germination in continuous light, 28%

Table 11.5 : Effect of light on germination of seeds of R. humilis.

Sr. No.	Light condition	No. of seeds germinated/50	% Germination
1.	Alternate diffuse light and darkness	49.67 (0.58)	99.33
2.	Continuous light	49.00 (1.00)	98.00
3.	Continuous darkness	16.00 (2.00)	32.00

L S D = 2.67 at 5% level

L S D = 4.04 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	MSS	F
Between treatments	2222.89	2	1111.45	624.41**
Within treatments	10.67	6	1.78	
Total	2233.56	8		

Table value of F = 5.14 at 5% level

F =10.92 at 1% level

in diffuse light and 6% in continuous darkness. In Aristida funiculata higher percentage germination was obtained in diffuse light while in complete darkness, the percentage was reduced to more than half (Varshney, 1966). Kaul, M.L.H. (1967) reported that Mecardonia dianthera seeds are light sensitive and do not germinate in darkness. Tribulus terrestris (Joshi, et al., 1967) seeds showed maximum percentage germination in diffuse light. Hemigraphis dura seeds (Kaul, R., 1974) are light sensitive and showed maximum percentage germination in diffuse light (83%), while in dark the seeds completely failed to germinate, and in continuous light the germination was 42%.

Findings in the present investigation indicate that though light favours germination of seeds of R. humilis, presence of light is not absolutely necessary for germination to occur. However, there is a highly significant reduction in per cent germination under continuous darkness.

11.5.6. Effect of colour (wavelength) of light

Experimental Procedure - Seeds of R. humilis collected from I. V. Palace compound on dt. 2-12-77 and after eight 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 24.9 to 34.9°C and 23.4 to 26.0°C respectively during the course of the experiment. The

experimental data were analysed statistically and are presented in Table 11.6 and graph 10 (ii).

Results and Discussion - It is evident from the table that white, red and yellow light showed favourable effect, whereas blue, green and far-red light showed more or less inhibitory effect. The inhibitory effect was maximum in far-red light, the per cent germination obtained under that light being minimum (22.00%). The percentage germination was maximum (72.00%) under white light, and red light also was almost equally effective and gave 69.33% germination.

The statistical analysis reveals that the overall effect of different colours (wavelengths) of light on germination is significant at 1% level. On making independent comparisons, however, it is revealed that there is no significant difference between the effects of - (i) white and red light, and (ii) Red and yellow light. The percentage germination obtained in white, red and yellow light is significantly higher than that obtained in blue, green and far-red light. It was surprising to observe that the per cent germination obtained in control (set without cellophane paper) was significantly lower than that in white light (set with white cellophane paper). The higher per cent germination under red light and considerable reduction in per cent germination under far-red light suggests the operation of phytochrome system in R. humilis seeds.

Table 4.6 : Effect of colour of light on germination of seeds of R. humilis.

Sr. No.	Colour of light	No. of seeds germinated/50	% Germination
1.	Control (without cellophane paper)	32.33 (2.08)	64.67
2.	White	36.00 (1.00)	72.00
3.	Red	34.67 (1.53)	69.33
4.	Yellow	32.00 (2.00)	64.00
5.	Blue	17.67 (1.53)	35.33
6.	Green	21.00 (1.00)	42.00
7.	Far-Red	11.00 (2.00)	22.00

L S D = 2.88 at 5% level; L S D = 4.00 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	MSS	F
Between treatments	1708.95	6	284.83	105.10**
Within treatments	38.00	14	2.71	
Total	1746.95	20		

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

Promotive effect of red light and inhibitory effect of far-red light have been reported with respect to germination of seeds of many species. Flint ('934) found that longer wavelengths of visible spectrum, i.e. red, orange and yellow wavelengths promote the germination of Lactuca seeds. Flint and McAlister (1935, 1937) determined the spectral ranges more accurately for lettuce seeds and showed that the most effective light in promoting germination is that having a wavelength of 670 nm and that a germination inhibiting zone of the spectrum has its maximum activity at 760 nm. Pandey (1965) reported that the seeds of Anagallis arvensis were light sensitive and phytochrome system participated in germination. Bhandari and Sen (1973) reported existence of phytochrome system in Citrullus colocynthis, and showed that the inhibition of germination induced by far-red light can be reversed by red light.

11.5.1. Effect of inorganic salts

Experimental Procedure - Experiment - I : Seeds of R. humilis collected from Surat Orchard on dt. 26-12-78 and after one month of dry storage were used in this experiment. The same procedure as that described for Experiment - I under 5.5.1. in Chapter 5 was followed in this experiment. The maximum and minimum temperatures ranged from 25.9 to 36.4°C and 9.0 to 20.0°C respectively during the course of the experiment. The experimental data were analysed statistically

and are presented in Table 11.7 and graph 11.

Experiment - II : Seeds of R. humilis collected from Surat Orchard on dt. 1-2-79 and after 10 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 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 11.8 and graph 12.

Results and Discussion - Experiment - I : It is clearly brought out from the data that the chlorides and nitrates of calcium, potassium and sodium at the concentrations used in the experiment inhibited germination either considerably or completely. Thus the percentage germination was considerably lower as compared to control in $CaCl_2$ - (0.5%), $Ca(NO_3)_2$ - (0.5 and 1.0%), KCl - (0.5%), KNO_3 - (0.5%) and $NaNO_3$ - (0.5%), while it was completely suppressed in 1.5 and 2.0% concentrations of $Ca(NO_3)_2$, and 1.0, 1.5 and 2.0% concentrations of $CaCl_2$, KCl, KNO_3 and $NaNO_3$, and all concentrations of NaCl.

The statistical analysis reveals that the overall effect of the various concentrations used is significant at 1% level. The per cent germination obtained in control was significantly higher than that in any of the concentrations of any of the salts.

Experiment - II : A perusal of Table 11.8 makes it clear that the percentage germination was lower as compared to control in all concentrations of all salts tried in the experiment,

Table ··.7 : Effect of inorganic salts on germination of seeds of R. humilis - I.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination
1.	Dist. water (Control)	25.67 (2.52)	51.33
2.	$CaCl_2$ 0.5%	13.67 (2.52)	27.33
3.	" 1.0%	0.00 (-)	0.00
4.	" 1.5%	0.00 (-)	0.00
5.	" 2.0%	0.00 (-)	0.00
6.	$Ca(NO_3)_2$ 0.5%	15.67 (2.52)	31.33
7.	" 1.0%	8.33 (2.08)	16.67
8.	" 1.5%	0.00 (-)	0.00
9.	" 2.0%	0.00 (-)	0.00
10.	KC. 0.5%	5.67 (2.52)	11.33
11.	" 1.0%	0.00 (-)	0.00
12.	" 1.5%	0.00 (-)	0.00
13.	" 2.0%	0.00 (-)	0.00
14.	KNO_3 0.5%	5.67 (0.58)	11.33
15.	" 1.0%	0.00 (-)	0.00
16.	" 1.5%	0.00 (-)	0.00

Contd...

Table 1.7 : contd.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination
17.	$ErCl_3$ 2.0%	0.00 (-)	0.00
18.	NaCl 0.5%	0.00 (-)	0.00
19.	" 1.0%	0.00 (-)	0.00
20.	" 1.5%	0.00 (-)	0.00
21.	" 2.0%	0.00 (-)	0.00
22.	$NaNO_3$ 0.5%	2.67 (1.53)	5.33
23.	" 1.0%	0.00 (-)	0.00
24.	" 1.5%	0.00 (-)	0.00
25.	" 2.0%	0.00 (-)	0.00

L S D = 1.86 at 5% level; L S D = 2.49 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	MSS	F
Between treatments	2977.68	24	124.07	96.18**
Within treatments	64.67	50	1.29	
Total	3042.35	74		

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

Table 11.8 : Effect of inorganic salts on germination of seeds of R. humilis - II.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
1.	Dist. water (Control)		45.33 (2.08)	90.67
2.	$CaCl_2$	0.1%	40.66 (0.58)	81.33
3.	"	0.2%	35.33 (1.15)	70.67
4.	"	0.3%	22.00 (1.00)	44.00
5.	"	0.5%	11.67 (2.52)	23.33
6.	$Ca(NO_3)_2$	0.1%	46.00 (1.00)	92.00
7.	"	0.2%	32.00 (1.00)	64.00
8.	"	0.3%	28.33 (2.08)	56.67
9.	"	0.5%	19.67 (2.52)	39.33
10.	KCl	0.1%	37.33 (2.08)	74.67
11.	"	0.2%	15.67 (0.58)	31.33
12.	"	0.3%	3.67 (1.53)	7.33
13.	"	0.5%	1.00 (0.00)	2.00
14.	KNO_3	0.1%	41.67 (1.53)	83.33
15.	"	0.2%	28.00 (1.00)	56.00
16.	"	0.3%	13.33 (1.15)	26.67

Contd.

Table 11.8 : contd.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
17.	KIO_3	0.5%	1.00 (1.00)	2.00
18.	KCl	0.1%	32.00 (2.00)	64.00
19.	"	0.2%	18.00 (2.00)	36.00
20.	"	0.3%	9.67 (2.08)	19.33
21.	"	0.5%	0.67 (0.58)	1.33
22.	$NaIO_3$	0.1%	33.33 (1.15)	66.67
23.	"	0.2%	20.67 (0.58)	41.33
24.	"	0.3%	13.67 (1.53)	27.33
25.	"	0.5%	0.67 (0.58)	1.33

L S D = 2.45 at 5% level; L S D = 3.27 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	MSS	F	
Between treatments	15804.46	24	658.52	295.30	**
Within treatments	111.33	50	2.23		
Total	15915.79	74			

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

except 0.1% $Ca(NO_3)_2$ wherein the percentage germination was slightly higher than that in control. Further, there was a progressive decline in percentage germination with the increase in concentration of the salts.

The statistical analysis reveals that the overall effect of the various concentrations of the inorganic salts used is significant at 1% level. On making independent comparisons it is revealed that the percentage germination obtained in 0.1% $Ca(NO_3)_2$ does not differ significantly from that in control, and that all concentrations of all salts tried in the experiment, except 0.1% $Ca(NO_3)_2$, gave significantly lower per cent germination as compared to control.

The inhibitory effect of chlorides and nitrates of calcium, potassium and sodium (at 0.5 to 2.0% concentrations) on germination of seeds of Acanthospermum australe has been observed by Jaychandra (1967).

11.5.8 Effect of nitrates on germination in darkness

Experimental Procedure - Seeds of R. humilis collected from Surat Orchard on dt. 1-2-79 and after ten and a half months of dry storage were used in this experiment, following the same procedure as that described under 5.5.15 in Chapter 5. The maximum and minimum temperatures ranged from 27.1 to 34.3°C and 10.8 to 18.9°C respectively during the course of the experiment. The experimental data were subjected to statistical analysis and are presented in Table 11.9 and graph 13.

Results and Discussion - A perusal of the table makes it

Table 11.9 : Effect of nitrates on germination of seeds of R. humilis in darkness.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
1.	Dist. water (Control)		20.33 (1.15)	40.67
2.	$Ca(NO_3)_2$	0.1%	19.00 (2.00)	38.00
3.	"	0.2%	24.33 (2.08)	48.67
4.	"	0.3%	19.67 (2.52)	39.33
5.	"	0.5%	11.67 (0.58)	23.33
6.	KNO_3	0.1%	22.67 (2.52)	45.33
7.	"	0.2%	23.00 (1.00)	46.00
8.	"	0.3%	22.33 (2.08)	44.67
9.	"	0.5%	4.00 (2.00)	8.00
10.	$NaNO_3$	0.1%	24.67 (0.58)	49.33
11.	"	0.2%	24.00 (1.00)	48.00
12.	"	0.3%	19.33 (1.15)	38.67
13.	"	0.5%	3.67 (0.58)	7.33
14.	NH_4NO_3	0.1%	18.67 (1.53)	37.33
15.	"	0.2%	19.00 (1.00)	38.00

Contd.

Table 11.9 : Contd.

Sr. No.	Treatment		No. of seeds germinated/50	% Germination
16.	NH_4NO_3	0.3%	21.67 (2.52)	43.33
17.	"	0.5%	7.67 (2.52)	15.33

L S D = 2.88 at 5% level

L S D = 3.86 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	MSS	F
Between treatments	2280.98	16	142.56	47.52**
Within treatments	102.00	34	3.00	
Total	2382.98	50		

Table value of F = 1.95 at 5% level

F = 2.58 at 1% level

clear that certain concentrations of all the four nitrates were effective in stimulating germination in darkness, while the remaining concentrations of them either inhibited germination or had no effect. Thus more or less increase in percentage germination as compared to control was observed in 0.2% $Ca(NO_3)_2$; 0.1, 0.2 and 0.3% KNO_3; 0.1 and 0.2% $NaNO_3$ and 0.3% NH_4NO_3. All the four nitrates at 0.5% concentration considerably inhibited germination.

The statistical analysis reveals that the overall effect of the various concentrations of the nitrates on germination in darkness is significant at 1% level. On making independent comparisons it is revealed that 0.2% $Ca(NO_3)_2$ and 0.1 and 0.2% $NaNO_3$ gave significantly higher percentage germination, while 0.5% concentration of all the four nitrates gave significantly lower percentage germination as compared to control. However, the per cent germination obtained in - (i) 0.1, 0.2 and 0.3% concentrations of KNO_3 and NH_4NO_3, (ii) 0.1 and 0.3% $Ca(NO_3)_2$ and (iii) 0.3% $NaNO_3$ does not differ significantly from that in control.

This nitrates of calcium, potassium and sodium at certain concentrations have promoting effect on germination of R.humilis seeds. The stimulating effect of KNO_3 on germination in darkness is known in case of many different species (Mayer and Poljakoff-Mayber, 1975).

11.5.9. Effect of thiourea

Experimental Procedure - Seeds of R. humilis collected

from urat Orchard on dt. 1-2-79 and after twelve and a half month of dry storage were used in this experiment, following the same procedure as the one described under 5.5.16 in Chapter 5. The maximum and minimum temperatures ranged from 29.6 to 41.3°C and 11.6 to 22.0°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 11.10 and graph 14.

Results and Discussion - It is evident from the data that thiourea at concentrations ranging from 50 to 1000 ppm had stimulating effect on germination. Further, the stimulating effect decreased gradually with the increase in concentration. Strangely, however, 500 ppm thiourea gave somewhat higher percentage germination as compared to that obtained in the lower concentrations of thiourea.

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 brought out that thiourea at all concentrations (ranging from 50 to 1000 ppm) gave significantly higher per cent germination as compared to control. However, there is no significant difference among the effects of - (i) 100, 200 and 1000 ppm, (ii) 50, 100 and 200 ppm, and (iii) 50, 100 and 500 ppm of thiourea.

The stimulating effect of thiourea on germination of seeds of many species has been reported (Shieri, 1941;

Table 11.10 : Effect of thiourea on germination of seeds of R. humilis.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist. water (Control)	33.00 (3.00)	66.00	11
2.	Thiourea 50 ppm	43.00 (1.00)	86.00	12
3.	" 100 "	41.33 (1.15)	82.67	11
4.	" 200 "	40.67 (2.52)	81.33	11
5.	" 500 "	44.33 (0.58)	88.67	12
6.	" 1000 "	38.33 (2.08)	76.67	11

L S D = 3.43 at 5% level

L S D = 4.81 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	MSS	F
Between treatments	245.11	5	49.02	13.18**
Within treatments	44.67	12	3.72	
Total	289.78	17		

Table value of F = 3.11 at 5% level

F = 5.06 at 1% level

Mayer and Poljakoff-Mayber, 1975; Agrawal, 1971; Kaul, 1974 and Pachpor, 1977).

11.5.10. Effect of GA_3

Experimental Procedure - Seeds of R. humilis collected from Surat Orchard on dt. 1-2-79 and after twelve and a half months of dry storage were used in this experiment, following the same procedure as the one described under 5.5.1 in Chapter 5. The maximum and minimum temperatures ranged from 29.6 to 41.3°C and 11.6 to 21.3°C respectively during the course of the experiment. The experimental data were subjected to statistical analysis and are presented in Table 11.11 and graph 15.

Results and Discussion - It is evident from the data that the per cent germination increased gradually with the increase in concentration of GA_3 from 50 to 1000 ppm, but beyond that a decline in per cent germination was observed which was more pronounced at 2000 ppm and onwards. Further, there was a noteworthy decrease in germination speed at 500 ppm and onwards. The percentage germination was slightly higher at 100 to 1000 ppm of GA_3 as compared to control.

The statistical analysis reveals that the overall effect of the various concentrations of GA_3 on germination is significant at 1% level. However on making independent comparisons, it is revealed that the increase in per cent

Table 11.11 : Effect of GA_3 on germination of seeds of *R. humilis*.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist.water (Control)	33.67 (1.53)	67.33	14
2.	GA_3 50 ppm	33.33 (1.53)	66.67	14
3.	" 100 "	34.33 (1.53)	68.67	14
4.	" 200 "	35.33 (1.15)	70.67	14
5.	" 500 "	34.67 (1.53)	69.33	19
6.	" 1000 "	36.00 (1.00)	72.00	21
7.	1500 "	31.67 (0.58)	63.33	19
8.	2000 "	16.67 (1.53)	33.33	17
9.	" 2500 "	14.33 (2.08)	28.67	21
10.	" 3000 "	14.00 (2.65)	28.00	19

L S D = 2.73 at 5% level; L S D = 3.72 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	MSS	F
Between treatments	2357.87	9	261.99	101.94**
Within treatments	51.33	20	2.57	
Total	2409.20	29		

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

germination at 100 to 1000 ppm of GA_3 is only apparent and not significant. Actually there is no significant difference among the results obtained in control and 50 to 1500 ppm of GA_3. The germination percentage obtained in 2000 to 3000 ppm of GA_3, was, however, significantly lower than that in control.

Thus GA_3 at concentrations ranging from 50 to 1500 ppm has no effect either stimulatory or inhibitory on germination in R. humilis, however, at concentrations beyond that there is a considerable inhibition of germination. Similar trend in results has been reported by Pandya (1971) in Celosia argentea seeds. Biswas (1967) reported inhibitory effect of GA_3 at concentrations higher than 250 ppm in Rauvolfia tetraphylla seeds, but lower concentrations had stimulating effect.

11.5. 1. Effect of kinetin

Experimental Procedure - Seeds of R. humilis collected from Surat Orchard on dt. 1-2-79 and after 12 months of dry storage were used in this experiment following the same procedure as that described under 5.5.18 in Chapter 5. The maximum and minimum temperatures ranged from 25.9 to 39.0°C and 9.0 to 19.6°C respectively during the course of the experiment. The experimental data were analysed statistically and are presented in Table 11.12 and graph 16.

Results and Discussion - Kinetin at 1 and 5 ppm concentrations gave higher per cent germination than control, but

Table 11.12 : Effect of kinetin on germination of seeds of R. humilis.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist. water (Control)	40.67 (2.52)	81.33	14
2.	Kinetin 1 ppm	46.33 (0.58)	92.67	13
3.	" 5 "	42.67 (2.52)	85.33	14
4.	" 10 "	34.67 (1.53)	69.33	15
5.	" 20 "	30.33 (3.06)	60.67	13
6.	" 50 "	28.67 (0.58)	57.33	21
7.	" 100 "	17.00 (3.00)	34.00	19
8.	" 200 "	15.67 (0.58)	31.33	19
9.	" 300 "	13.67 (2.52)	27.33	23
10.	" 500 "	12.67 (1.53)	25.33	23

L S D = 3.53 at 5% level; L S D = 4.82 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	MSS	F
Between treatments	4425.37	9	491.71	114.35**
Within treatments	86.00	20	4.30	
Total	4511.37	29		

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

at concentrations beyond 5 ppm, a progressive decline in per cent germination was observed with the increase in concentration. There was also a decrease in germination speed at concentrations from 50 ppm onwards.

The statistical analysis reveals that the overall effect of the various concentrations of kinetin on germination is significant at 1% level. However, LSD values reveal that - (i) 1 ppm kinetin gave significantly higher per cent germination than control, (ii) 5 ppm kinetin had no significant effect and (iii) concentrations from 10 ppm onwards gave significantly lower per cent germination.

The stimulating effect of kinetin (1 and 10 ppm) on seed germination in Lactuca sativa has been reported by Sankhla and Sankhla (1972).

11.5.2. Effect of 2,4-D

Experimental Procedure - Seeds of R. humilis collected from Surat Orchard and after twelve and a half months of dry storage were used in this experiment. The same procedure as the one described under 5.5.19 was followed. The maximum and minimum temperatures ranged from 29.6 to 41.3°C and 11.6 to 22.0°C respectively during the course of the experiment. The data obtained were subjected to statistical analysis and are presented in Table 11.13 and graph 17.

Results and Discussion - It is evident from the table

Table 11.13 : Effect of 2,4-D on germination of seeds of R. humilis.

Sr. No.	Treatment	No. of seeds germinated/50	% Germination	Germination speed
1.	Dist.water (Control)	33.00 (3.00)	66.00	11
2.	2,4-D 0.5 ppm	36.67 (2.52)	73.33	14
3.	" 1 "	32.67 (0.58)	65.33	12
4.	" 5 "	31.67 (2.08)	63.33	16
5.	" 10 "	31.33 (2.52)	62.67	16
6.	" 20 "	31.67 (1.53)	63.33	14
7.	" 50 "	31.33 (3.06)	62.67	16
8.	" 100 "	32.00 (1.00)	64.00	18
9.	" 200 "	31.67 (1.53)	63.33	19
10.	" 500 "	33.00 (1.00)	66.00	14
11.	" 1000 "	25.67 (0.58)	51.33	16
12.	" 2000 "	13.67 (0.58)	27.33	18

L S D = 3.19 at 5% level; L S D = 4.32 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	MSS	F
Between treatments	1108.31	11	100.76	28.15 **
Within treatments	86.00	24	3.58	
Total	1194.31	35		

Table value of F = 2.22 at 5% level

F = 3.09 at 1% level

that 0.5 ppm of 2,4-D had stimulating effect, but concentrations ranging from 1 to 500 ppm gave per cent germination which did not differ much from control. A decrease in per cent germination was, however, observed at 1000 and 2000 ppm of 2,4-D. Further, there was a more or less decrease in the germination speed at all concentrations of 2,4-D.

The statistical analysis reveals that the overall effect of the various concentrations of 2,4-D on germination is significant at 1% level. On making independent comparisons, however, it is revealed that only at 0.5 ppm of 2,4-D significantly higher percentage germination as compared to control was observed, while there is no significant difference among the effects of control and 1 to 500 ppm of 2,4-D. The per cent germination decreased significantly only at 1000 and 2000 ppm of 2,4-D.

A similar trend in results has also been reported by Dagar et al. (1977).

11.6. Reproductive capacity

Average seed output of R. hunilis as worked out under 11.3 in the present chapter is 1586. The average of the different values of maximum percentage germination obtained in the different experiments in R. humilis seeds works out to be 75 87% i.e. 76%. This value is taken as representing average percentage germination for the present purpose. The

reproductive capacity of R. humilis as calculated by the following formula works out to be -

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

$$= \frac{1586 \times 76}{100}$$

$$= 1205.36$$

i.e. 1205.

11.7. Seedling Morphology

The germination of seeds of R. humilis is epigeal. The radicle emerges from the seed by a split of the testa near the hilum. 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 cotyledons now unfold and become the first pair of foliage leaves. The true leaves now gradually appear in succession and the embryonic leaves persist until few of the true leaves are well developed. Plate 26.

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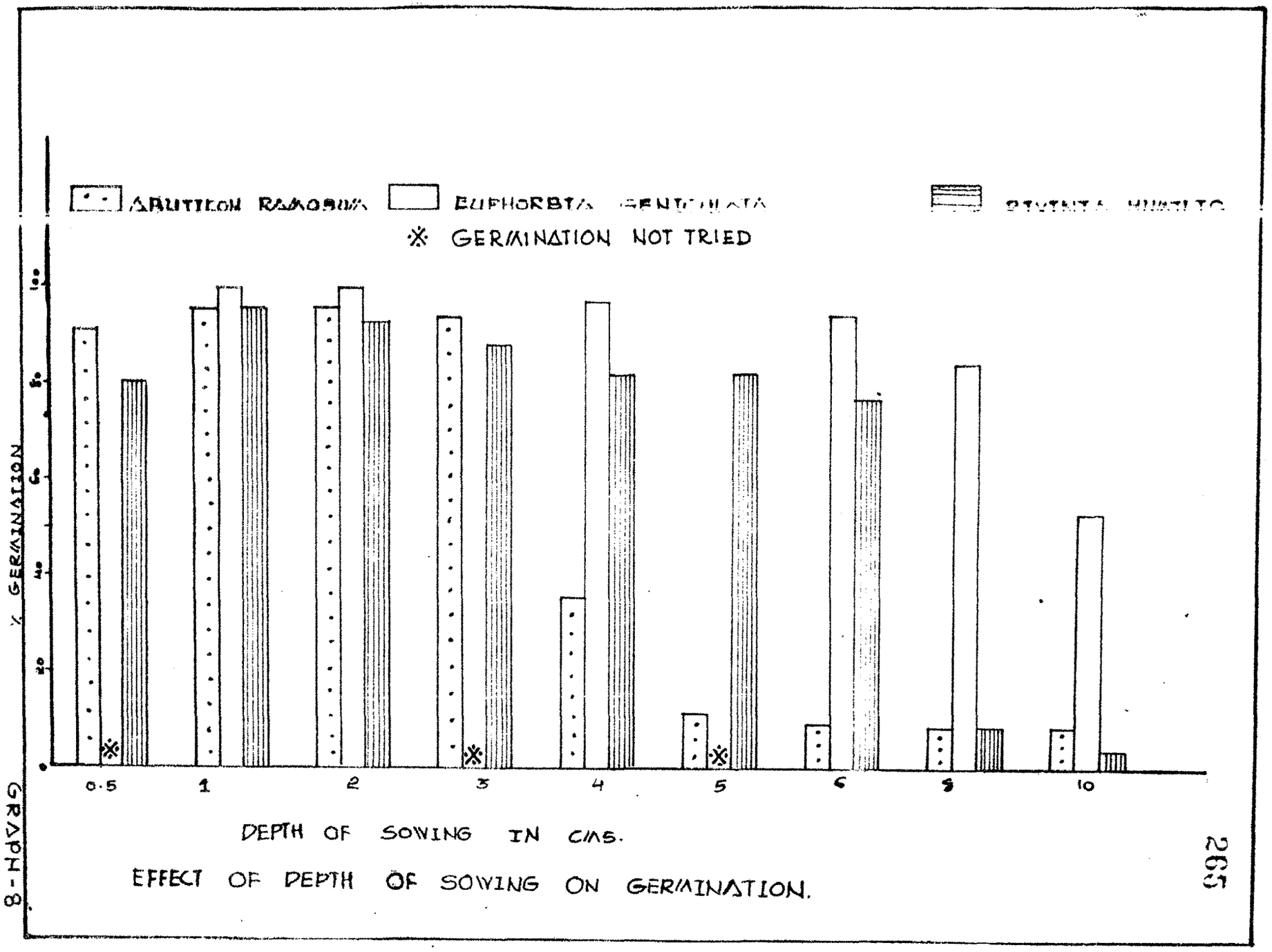
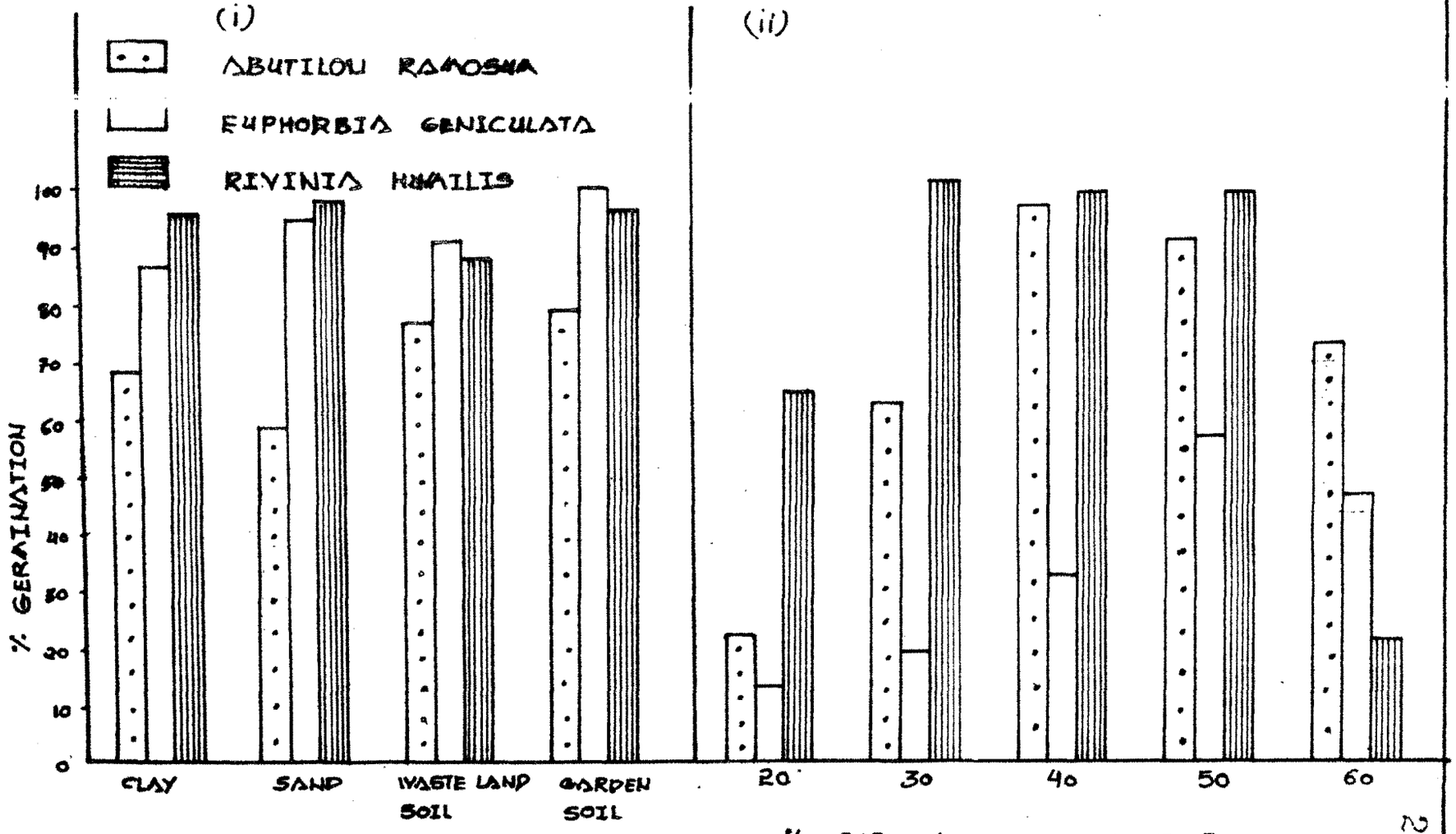


GRAPH-8

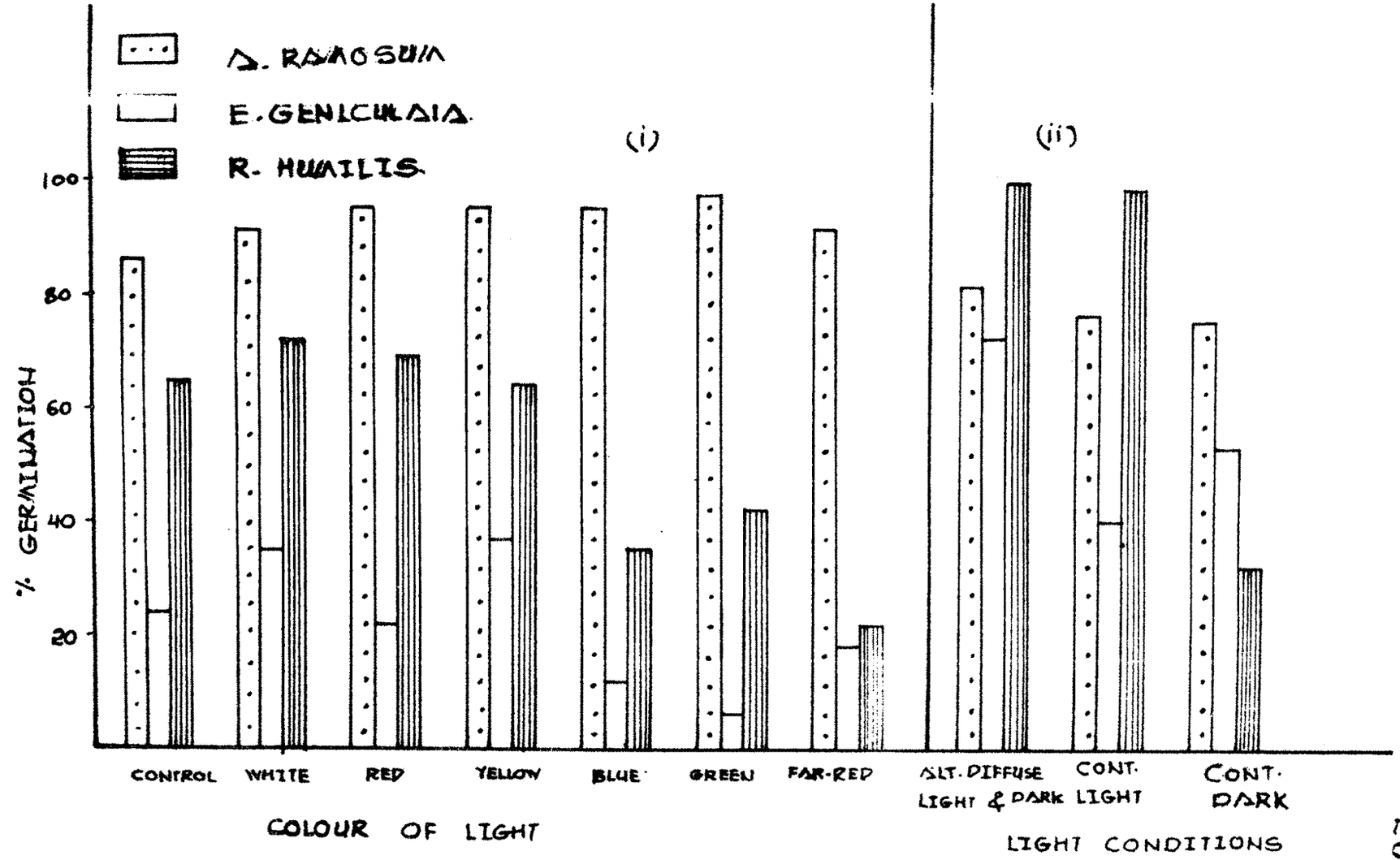
EFFECT OF DEPTH OF SOWING ON GERMINATION.

GRAPH - 5



EFFECT OF TYPE OF SOIL ON GERMINATION

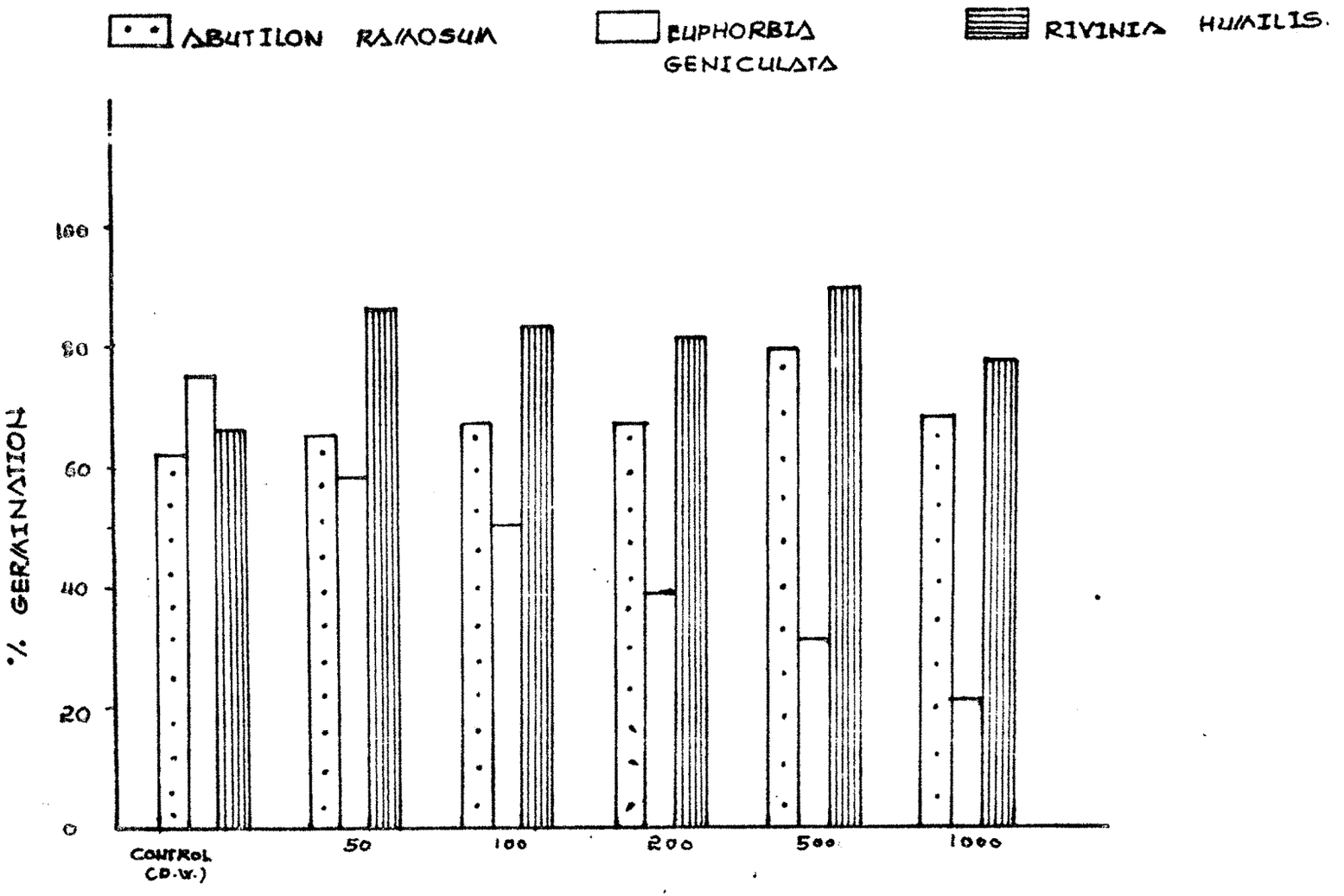
EFFECT OF SOIL MOISTURE CONTENT ON GERMINATION



EFFECT OF COLOUR OF LIGHT ON GERMINATION

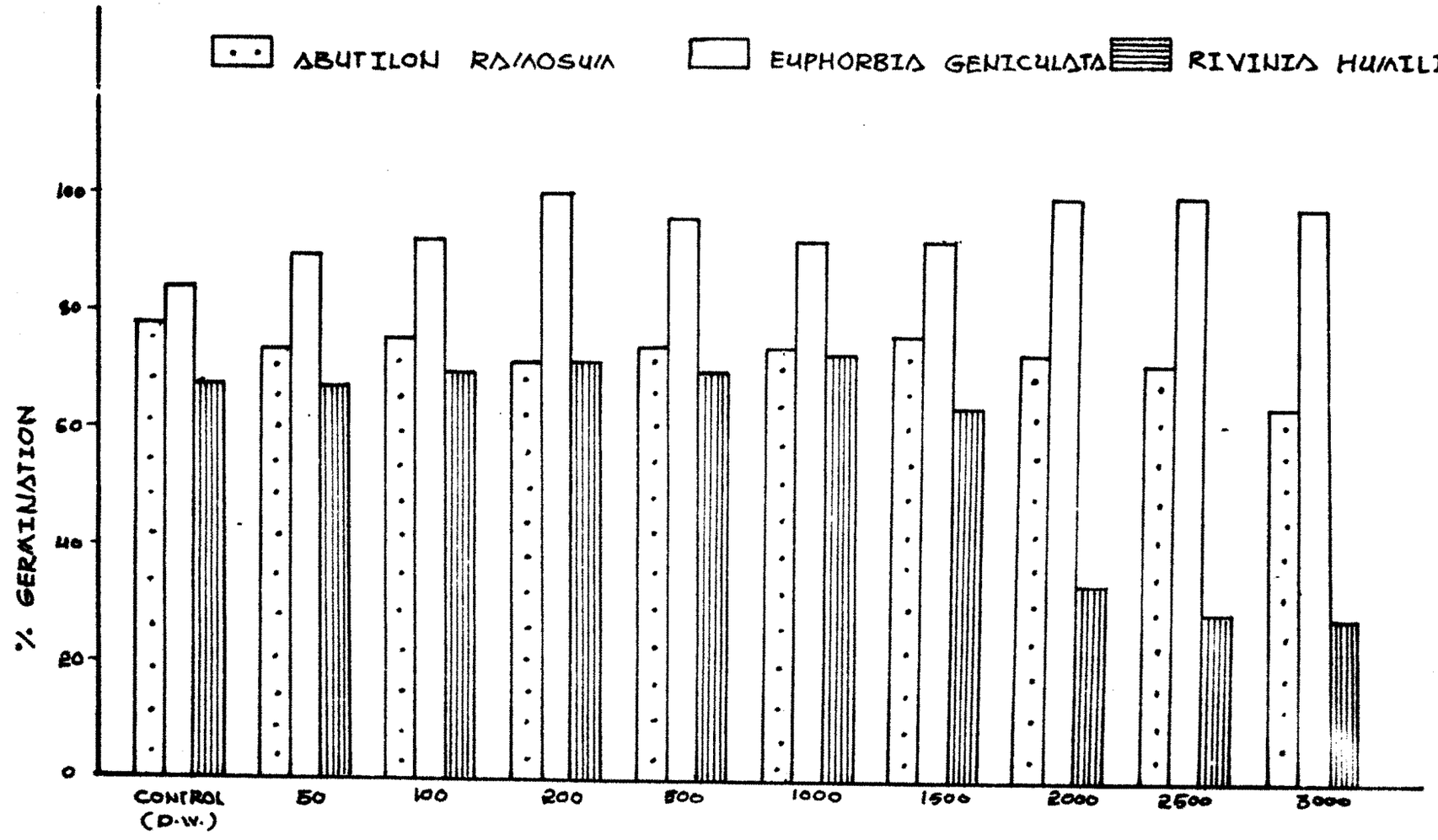
EFFECT OF LIGHT ON GERMINATION.

GRAPH-10



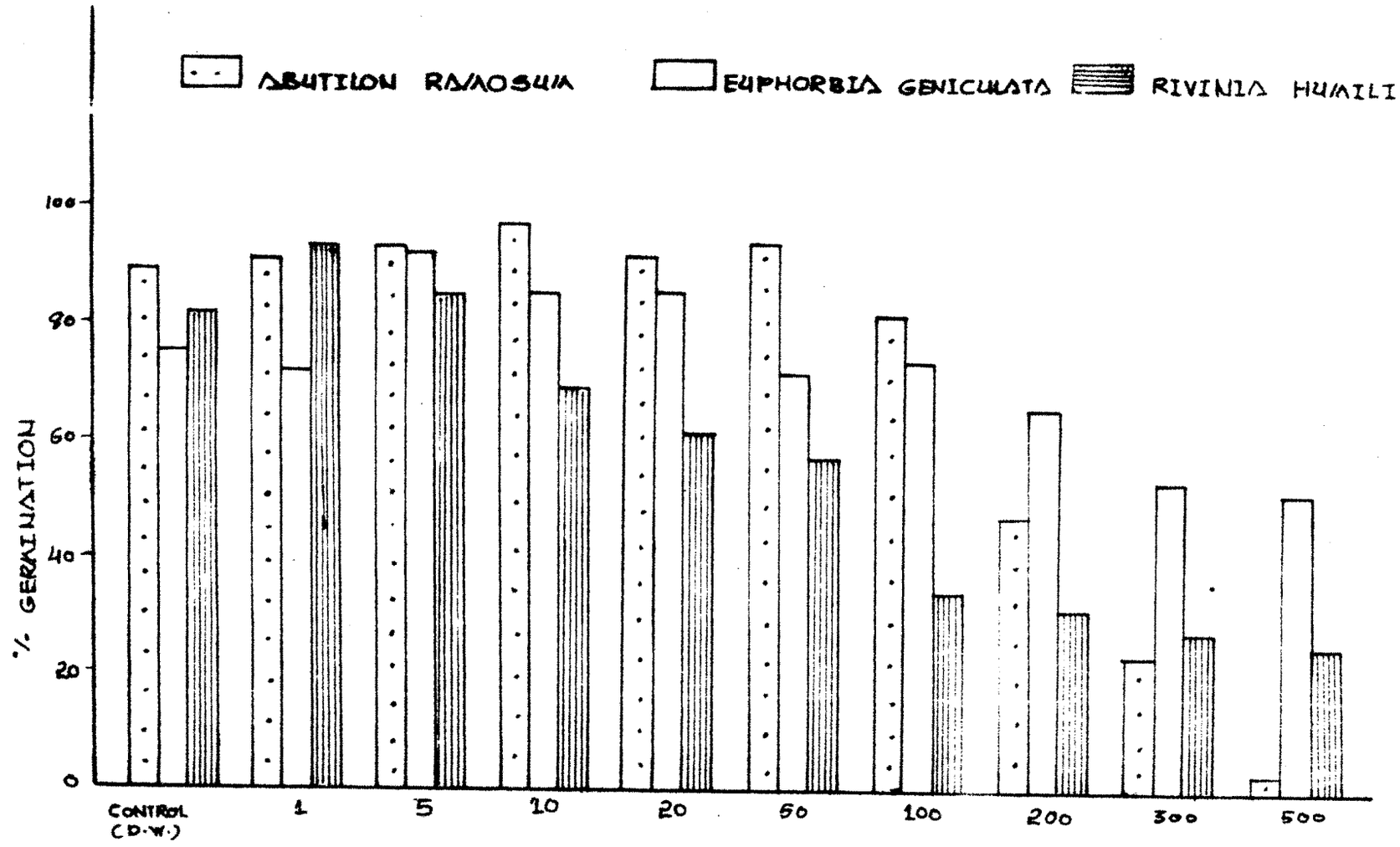
EFFECT OF THIOUREA ON GERMINATION.

GRAPH - 14.



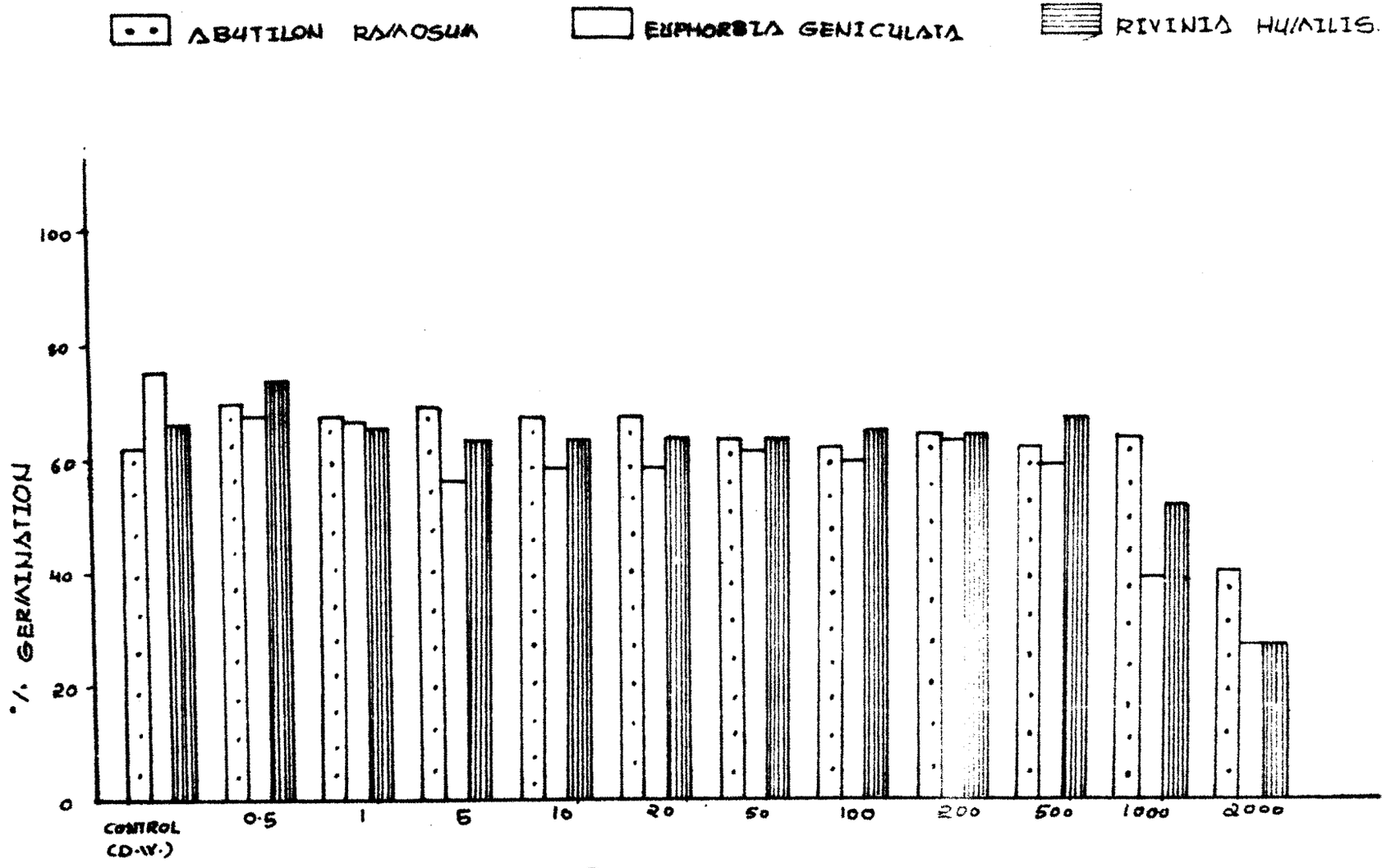
EFFECT OF GA3 ON GERMINATION

GRAPH - 15.



EFFECT OF KINETIN ON GERMINATION

GRAPH-16



EFFECT OF 2,4-D ON GERMINATION

GRAPH-17