CHAPTER 3

SEED GERMINATION AND CUTTING PROPAGATION OF *R. serpentina* IN ECOLOGICAL CONDITION OF DARJEELING DISTRICT

STUDIES ON SEED GERMINATION IN *R. serpentina*

INTRODUCTION

In the natural condition, *R. serpentina* is propagated by seeds. Owing to the hard sclerotic endocarp, the seeds require longer time to germinate as well as lower overall percentage of germination.

Santapau (1956) reported that germination of seeds of *R. serpentina* was poor and in general it was difficult to get more than 10% germination. Chandra (1956) found that more than 90% seeds of *R. serpentina* floated in water and among the heavy seeds, he reported a germination percentage of 43. Nayer (1956) also observed an irregular and sporadic germination of seeds and being 38% and 29% in case of Dehra-Dun and South India lot, respectively. Badhwar *et al.* (1956a) advocated propagation of *R. serpentina* by seed and reported a germination percentage of 25 to 50.

Breaking of dormancy and improvement of germination percentages have been done with various physical and chemical treatments in a number of wild and cultivated plants (Sinha, 1977; Singh and Kumar, 1984; Singh *et al.*, 1993; Padma *et al.*, 1994; Raina *el al.*, 1994; Devi and Selvaraj, 1994).

To hasten germination, the most common treatment practised is mechanical scarification, which was originally developed by Hughes (1915). A few chemicals have been used to eliminate dormancy and stimulate germination of seeds (Devi and Selvaraj, 1994).

The present investigation was taken to assess the effectiveness of different treatments for germination percentage of seeds of *R. serpentina*.

MATERIALS AND METHODS

Freshly collected seeds of *R. serpentina* were subjected to the following treatments :

(1) **Mechanical Scarification** : Individual seeds were rubbed against sand paper or grind stone or nicked with a needle.

(2) **Hot Water Soaking** : The seeds held in a netting wire were soaked in hot water at 80° ± 2°C for 5, 10, 15 and 20 minutes.

(3) **Sulphuric Acid Treatment** : The seeds were dipped in conc. sulphuric acid for 3, 5, 10, 15, 30, 45, 60 and 90 minutes, after which the seeds were thoroughly washed in running tap water and dried on paper towels.

(4) **Hydrochloric Acid Treatment** : As in sulphuric Acid Treatment.

(5) **Heat Treatment** : For dry heating, the seeds were exposed to temperatures of 70°, 80° and 90°C for 16, 24, 48, 72 and 96 hours duration in an oven.

(6) **Pre-sowing Seed Treatment with Chemicals** : Seeds were soaked for 24 hours in the following chemicals : 1% boric acid, 1% calcium hydroxide ($Ca(OH)_2$), 1% sodium dihydrogen phosphate (NaH_2PO_4), 1% potassium nitrate (KNO_3), 0.5% thiourea, 100 ppm GA_3 and 100 ppm NAA. Interactive effects of KNO_3 with GA_3 and NAA were also investigated.

Pre-soaked seeds were re-dried for 24 hours in a stream of air. Untreated seeds were used as control.

Germination tests were replicated three times and conducted in petri dishes of 9 cm diameter. Seeds were placed on two layers of blotting paper. A seed regarded as germinated when radicle was approximately 5 mm in length.

RESULTS

Among the various scarification treatments, seed scarification with sand paper was able to increase germination percentage to some extent (Table 4). On the other hand, grinding of seeds with stone or nicking with a needle were not effective in improving seed germination. The concentrated sulphuric acid and hydrochloric acid and hot water treatments could not prove to be effective in increasing germination percentage of seeds of *R. serpentina*.

Out of various treatments of the seed with conc. sulphuric acid, the treatments up to 30 minutes were able to increase germination percentage to some extent. Further increase in treatment period proved to be deleterious to seed germination. Similar results were obtained with conc. hydrochloric acid (Table 4).

Hot water treatment of *R. serpentina* seeds for different periods completely failed to improve seed germination.

Dry heating of the seeds for several hours also could not improve the germination percentage.

Primary seed treatment with different chemicals (Table 4) did not improve the germination percentage of *R. serpentina* seeds. Of the chemicals, potassium nitrate and thiourea appeared to improve germination of seeds to some extent. All other treatments were at par with each other and the control. As only one concentration of those chemicals were used in the present investigation, further research is needed with more concentrations.

Table 4 : Effect of presowing seed treatments on % of germination of *R. serpentina*.

Treatment	% of germination	Treatment	% of germination
Control	26	**Heat treatment**	
Scarification		70°C 16 h	28
Sand paper	48	24 h	28
Grind stone	32	48 h	32
Nicking	30	72 h	26
Hot water		96 h	28
5 min	26	80°C 16 h	28
10 min	24	24 h	30
15 min	28	48 h	32
20 min	28	72 h	30
Sulphuric acid		96 h	28
3 min	25	90°C 16 h	26
5 min	25	24 h	28
10 min	26	48 h	30
15 min	30	72 h	30
30 min	38	96 h	28
45 min	32	1% Boric acid	32
60 min	30	1% Calcium hydroxide	30
90 min	25	1% Sodium dihydrogen phosphate	30
		1.0% Potassium dihydrogen phosphate	30
Hydrochloric acid			
3 min	30	1.5% Potassium nitrate	40
5 min	28	0.5% Thiourea	30
10 min	32	100 ppm GA_3	32
15 min	26	100 ppm NAA	30
30 min	32		
45 min	28		
60 min	27		
90 min	27		

$LSD_{5\%}$ for comparing any two means = 7

In most of the treatments, seeds started germination at 12 days after sowing and continued upto 35 days. Speed of germination was not affected by the treatments.

DISCUSSION

Although *R. serpentina* can be propagated by both seeds and vegetative propagules, growth of the plants and root yield are better in those raised from seeds (Badhwar, 1956a). But germination of seeds is much lower (Dutta *et al.*, 1962; Nayar, 1956). Moreover, collection of seeds from wild sources is both laborious and costly, inasmuch as the plants grow sporadically and the seeds ripen a few at a time. If the ripe seeds are not collected in time, they drop off to the ground and are lost. For these reasons seeds are not easily available from wild sources. Therefore, in the present investigation attempts have been made to improve the germination percentage of seeds of *R. serpentina*.

As seed coat of *R. serpentina* is very hard, mechanical and chemical scarification methods were followed. Seed scarification with sand paper increased germination percentage to some extent, but grinding of seeds with stone or nicking with a needle were not effective. Sinha *et al.* (1993) also reported that scarification of seeds of *Trigonella corniculata* with sand paper was the most effective method for increase of germination. Singh *et al.* (1985) in lentil and Padma *et al.* (1994) in *Leucaena, Albizzia* and *Samanea* also observed similar result with sand paper. Contrary to the present results, Padma *et al.* (1994) reported increased percentage of germination with grind stone scarification and nicking.

In the present investigation, seed treatment with conc. sulphuric acid upto 30 min. increased germination percentage to some extent. This result corroborates the findings of Sinha *et al.* (1993), Padma *et al.* (1994) and Rao *et al.* (1985). However, the duration of soaking in sulphuric acid for better germination was different in different plant species.

The result of the present study revealed that hot water treatments of seeds for any duration and temperature did not improve germination percentage. These results are in agreement to the work of Jha and Sinha (1989) in *Vicia faba* and Sinha *et al.* (1993) in *Trigonella corniculata.* However, Padma *et al.* (1994) reported hot water (80°C) soaking for 5 minutes improved germination in *Leucaena leucocephala*, but not in *Albizzia lebbeck* and *Samanea saman.*

Presowing seed treatment with chemicals did not improve germination percentage. However, potassium nitrate and thiourea improve germination to some extent. Increased germination following treatment with potassium nitrate has been documented in several species like *Carica papaya* (Nagao & Furutani. 1986), *Citrus karna* (Singh *et al.*, 1979), *Glycine max* (Kalavathi, 1985) and *Momordica charantia* (Devi *et al.*, 1994). Increased germination following thiourea has been reported in marigold (Selvaraju, 1986) and bitter gourd (Devi *et al.*, 1994).

Basra *et al.* (1990) reported that seed soaking treatment with potassium nitrate, GA_3 and phthalimide increased seed germination in *Panicum maximum.* Devi *et al.* (1994) also observed that enhanced germination of bitter gourd due to seed soaking with a number of chemicals like bavistin, boric acid, calcium hydroxide, calcium oxychloride, sodium dihydrogen phosphate, potassium dihydrogen phosphate, succinic acid, NAA, cytozyme and mixtalol. But in the present study, some of these chemicals failed to elicit any positive effect on germination of *R. serpentina* seeds.

As mechanical and chemical scarification of seeds could not improve germination of *R. serpentina* seeds, it appears that germination inhibitors may be located inside the seeds. It is well known that presence of coumarins, phenolic and benzoic acid derivatives in seeds and plant parts inhibit their growth. Barton and Salt (1948) detected growth inhibitors in the aqueous extract of the seeds of *Sorbus* and *Berberis* and Siegel (1950) from the seeds of red kidney beans.

Sani and Datta (1969) examined air dry seeds of *R. serpentina* and *R. canescens* and found out that inhibition of germination may be ascribed largely to cinnamic acid derivatives and to a lesser extent to water soluble flavonoids, whereas in old seeds, the inhibition was largely due to hydroaromatic acids and to a lesser extent to cinnamic derivatives. The substituted coumarins, though present, appear to have negligible inhibitory effect.

The seeds of both the species of *Rauvolfia* accumulate more of hydrobenzoic acids on storage, probably synthesised from the breakdown processes of simple phenolics and aromatic compound 2,3- and 2, 5-dihydrobenzoic acids (0 – pyro catachuic and gentisic acids, respectively) in the old seeds of *R. serpentina*, inhibited lettuce seed germination markedly and inhibited root and shoot growth as well, to the same extent.

Out of the four substituted coumarins found in the extracts of fresh seeds of *R. serpentina* only imperatorin inhibited seed germination by 17%, but promoted root growth. Aesculetin, hernarin and umbelliferone had almost negligible effects on germination as well as on root growth.

Catechol was found in the fresh seeds of *R. canescens* but it had no inhibitory effect on germination.

Griffith (1958) has reported the presence of salicylic and genetisic acids in apocynaceous plants. But these two acids are not found in stored seeds of *R.*

serpentina and *R. canescens*. Probably there is a strong mechanism of converting these two acids as soon as they are formed so that the same remained absent in the seeds of *R. serpentina* or some different pathway is involved.

Torne (1964) subjected dry seeds of *R. serpentina* to irradiation with a series of gamma-ray doses ranging from 2,500 to 15,000 r. The irradiated seeds were immediately sown in pots along with untreated seeds as control. Results indicated that irradiation helped in increasing the percentage of germination from 20.5 in control to 74.5 and 73 in seeds with dosages 2,500 and 5,000 respectively. As the irradiation doses were increased further, germination percentage the gradually declined and it was 57.5% in seeds with 15,000 r dose.

From the above discussion it is clear that seed germination in *R. serpentina* is very complex and further work is necessary to understand the mechanism of germination.

DEVELOPMENT OF EASY PROPAGULES FOR CULTIVATION OF *R. serpentina* AND THEIR EFFECT ON ROOT PRODUCTION

INTRODUCTION

For obtaining roots for commercial purposes, cultivation of *R. serpentina* plants through seeds is the most economic method. But it is extremely difficult to obtain the required supply of seed from natural sources for raising commercial plantations immediately. Under the circumstances, there seems no other alternative than to undertake propagation by stumps, root cutting and stem cutting, which are more easily available. In fact, owing to the great demand for the drug, attempts are being made to raise *R. serpentina* plantation through vegetative propagation (Badhwar *et al.*, 1956b; Dutta *et al.*, 1963).

Moreover, germination of seeds of *R. serpentina* is very poor. In our experiment also, it was observed that germination percentage could not be increased substantially by physical and chemical scarification and with treatment with a number of chemicals.

Therefore, this study was undertaken to investigate the different methods of vegetative propagation of *R. serpentina* and the comparative performance of plants raised by different methods. Effect of different growth regulators on rooting behaviour of stem cuttings has also been studied.

ROOT FORMATION POTENTIAL OF DIFFERENT CUTTINGS OF *R. serpentina*

The aim of this experiment was to study the effect of stem, stump (stem-root junction) and root cuttings of *R. serpentina* on root formation.

MATERIALS AND METHODS

From 1.5–2 years' old plants of *R. serpentina* 15 cm long cuttings were prepared from three places i.e., stem, stump (stem-root junction) and root. These cuttings were used in the experiment. Cuttings were planted in polythene bags by inserting basal end (5 cm) in the soil.

Polythene bags of 10 cm diameter and 20 cm height were used. Polythene bags were filled with fine and ground soil mixed with cowdung (2:1) leaving 2 cm at the top. For drainage of excess water, each bag was pierced at several places at the bottom.

RESULTS

Results given in Table 5 shows that cuttings from stump revealed the highest root formation activity (78.57%) and it was followed by root cuttings

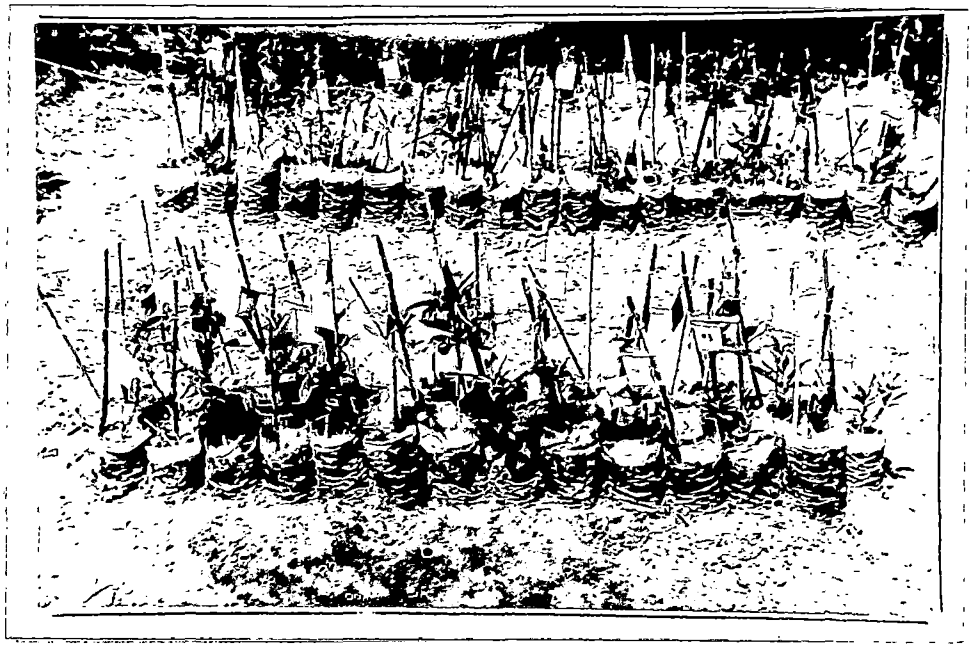
Table 5 : Root formation potential of different types of cuttings of *R. serpentina*.

Type of cutting	**% of rooted cuttings**
Stem	43
Stem-root junction	79
Root	63

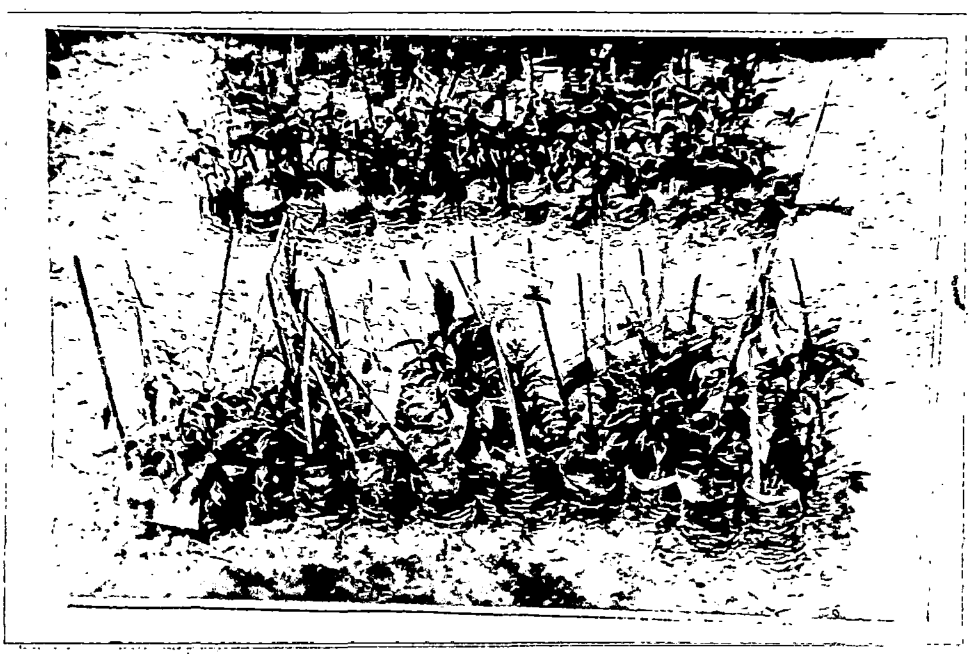
$LSD_{5\%}$ for comparing two means = 8

(62.82%) and stem cuttings (42.85%). This shows that, compared to others, stem cuttings had the lowest root formation activity. From stem cuttings, few plants

Photograph I. A view of *R. serpentina* in field condition



Photograph II. Propagules developed from stem cuttings.



Photograph III. Propagules developed from stem-root junction cuttings (upper) and root cuttings (lower).

were found to develop, whereas from others (stump and root cuttings), a good number of plants were found to develop.

EFFECT OF DIFFERENT GROWTH REGULATORS ON ROOTING BEHAVIOUR OF STEM CUTTINGS OF *R. serpentina.*

In the previous experiment, it was observed that stem cuttings of *R. serpentina* had the lowest root formation activity. Therefore, in this experiment, an attempt was made to improve root formation in stem cuttings of *R. serpentina* by applying different growth regulators.

MATERIALS AND METHODS

Stem cuttings (15 cm length) of *R. serpentina* were used for this purpose. Different growth regulators e.g., IBA, NAA and 2,4-D were used separately and IBA + NAA in combination in different concentrations (e.g., 1.5, 10, 50, 100, 200 and 500 ppm). Growth regulators were prepared in distilled water.

Initially the growth regulators were dissolved in ethanol or dilute NaOH, then the volume was made up to the mark with distilled water. For each treatment, equal number (6) of stem cuttings was taken and the basal part of the cuttings was dipped in the growth regulator solution till 48 hours, stem cuttings were transferred to prepared polythene bags (as in the previous experiment).

After treatment with growth regulator/ water, cuttings were inserted (5 cm) deep into the soil of polythene bags (2 cuttings/ bag). The polythene bags were kept out door under shade. Irrigation was done from time to time as per necessity.

RESULTS

Effect of IBA, NAA, their combinations and 2,4-D in different concentrations on the root formation in stem cuttings of *R. serpentina* is presented in Table 6. It is evident from the result that IBA at low concentration stimulated root formation. The highest stimulation (83%) was noted at 50 ppm IBA. With the

Table 6 : Effect of different growth regulators on root formation in stem cuttings of *R. serpentina*.

Growth regulators	Concentration (ppm)	Percentage of rooting	Growth regulators	Concentration (ppm)	Percentage of rooting
Control	-	43	IBA+ NAA	5+5	50
IBA	10	50		25+25	50
	50	83		50+50	50
	100	67		250+250	33
	200	50	2,4-D	1	50
	500	17		5	100
NAA	10	67		50	33
	50	33		100	00
	100	17			
	500	17			

$LSD_{5\%}$ for comparing two means = 12

further increase of concentration (100, 200 ppm), root formation was found to decrease gradually and at 500 ppm an inhibitory effect, compared to control was noted. At this concentration, the percentage of root formation was 17%. Only at low concentration (10 ppm) NAA stimulated root formation (67%). At higher concentrations (50, 100 and 500 ppm) NAA inhibited the rooting activity of the cuttings. When used individually, both IBA and NAA at low concentration stimulated rooting activity. However, when they were used in combination and at low concentration, no synergistic effect was observed. IBA and NAA (5+5, 25+25, and 50+50 ppm) revealed 50% root formation activity. Only at more higher concentrations (250+250 ppm), IBA and NAA induced inhibitory effect. 2,4-D at very low concentration stimulated root formation on the stem cuttings. The highest activity (100%) was observed at 5 ppm of 2, 4-D. At 50 ppm it inhibited root formation and at 100 ppm it totally inhibited (100%) rooting activity of the stem cuttings.

DISCUSSION

Propagation of *R. serpentina*, particularly through seed is yet to some extent difficult. Cuttings from stem and other parts were tested for the development of propagules. Different growth regulators were also applied. All these growth regulators (IBA, NAA and 2,4-D) at low concentration increased root formation activity of the stem cuttings. But different combinations of IBA and NAA did not produce any synergistic effect on root formation activity of the cuttings, rather inhibitory effect was noted at high concentration. Chandra (1956) used different concentrations of IAA and NAA solutions on stem cuttings (12–15 cm long and 0.4–1 cm diameter) of *R. canescens* and did not observe stimulatory effect of these growth regulators on propagule development from those stem cuttings. Besides, cutting from stem-root junction without any growth regulators pretreatment may be effectively used for propagules development. In the present work, it was observed that stem cuttings developed 43%, stem-root junction cuttings developed 79% and root cuttings developed 63% of propagules of *R. serpentina* (Table 5). So, cuttings from stem-root junction may be considered very effective for development of propagules.

EFFECT OF TIME OF PLANTING AND TYPE OF CUTTING ON THE SUCCESS AND GROWTH OF *R. serpentina*

The aim of this experiment was to study the effect of time of planting and type of cutting on the success of cutting and subsequent growth of *R. serpentina.*

MATERIALS AND METHODS

From 1.5–2 years' old plants of *R. serpentina* 3–5 cm long root cutting (C_1) and about 15 cm long stem cutting (C_2) were planted in the experimental field of North Bengal University at 5 dates, i.e., 15 March (T_1), 15 April (T_2), 15 May (T_3), 15 June(T_4) and 15 July (T_5), 1998. The experiment was laid out in a randomized complete block design with a factorial arrangement of 5 times of planting and 2 types of cuttings. There were three replications. The cuttings were spaced at 30 x 20 cm. Weeding and watering were done as and when necessary.

Percentage of successful cuttings were recorded and growth and yield characters were noted after 1.5 years of planting. Data were analysed statistically.

RESULTS AND DISCUSSION

Mean squares from analysis of variance for some characters of *R. serpentina* are presented in Table 7. The results revealed that the effects of both time of planting and type of cutting were significant for percentage of success, plant height, no. of roots/ plant, length of longest root and air-dried root weight. Interaction between time of planting and type of cutting was also significant for all the characters except no. of roots/ plant and length of largest root.

Table 7 : Mean squares from analysis of variance for some characters of *R. serpentina*.

Sources of variation	df	% of success	Plant height (cm)	No. roots/ plant	Length of longest root (cm)	Air-dried root wt./ plant (g)
Replication	3	42	10	2.9	4	12
Time of planting (T)	4	4415**	1255**	34**	270**	1120**
Type of cutting (C)	1	1673**	434**	29**	89**	520**
T x C	4	210**	67**	5	3	160**
Error	27	35	12	3.1	6	16

** indicates significant at 1% level.

Main effects of time of planting and type of cutting are given in Table 8 and their interaction in Table 9. The results indicate that there was variation regarding % of success of cutting due to difference in planting time. The % of success of cutting varied from 18.4 to 59.7, being highest in 15 June planting and lowest in 15 March. The second highest value of 42.4% was recorded in 15 May. There was no statistical difference among 15 March, 15 April and 15 July plantings. Badhwar *et al.* (1956b) reported that the best month for raising rooted cuttings of *R. serpentina* under Dehra Dun condition to be June. Hartmann and Kester (1968) also reported similar results and they mentioned that broad-leaved evergreens usually initiate root most readily if the cuttings were taken after a flush of growth has been completed and the wood was partially matured.

Table 8 : Mean effect of time of planting and type of cutting on some characters of *R. serpentina*.

Treatment	% of success	Plant height (cm)	No. of roots/ plant	Length of longest root (cm)	Air-dried root weight/ plant (g)
Time of planting					
T_1	18.4	19.5	6.0	14.1	14.4
T_2	21.5	25.5	6.1	18.5	21.7
T_3	42.4	37.1	9.6	22.9	23.4
T_4	59.7	40.4	11.2	29.8	30.0
T_5	26.7	29.0	8.2	20.8	18.3
LSD 5%	6.1	3.6	1.8	2.5	4.1
Type of cutting					
C_1	38.2	33.5	8.9	22.7	24.3
C_2	29.3	27.1	7.5	19.7	18.7
LSD 5%	4.3	2.5	1.3	1.8	2.9

There was significant effect due to types of cutting on the % of success. The highest % of success of 38.2% was achieved from root while it was lowest (29.3%) from stem cuttings (Table 7). % of success of *R. serpentina* due to types indicated the superiority of root cuttings over stem cuttings. This is in agreement with the findings of Dutta *et al.* (1963). Stem cuttings are best prepared from woody twigs, tender green twigs have not been successful (Badhwar *et al.*, 1956b).

It has been noticed that although stem cuttings started aprouting 3–4 days after planting, they actually produced root after 60–65 days, producing 4 to 5 thin rootlets. Most of the root cuttings started sprouting about 20–25 days after planting which corroborates the statement of Dutta and Chopra (1963) and Badhwar *et al.* (1956b). Chandra (1954) through his trial opined that root cuttings rooted within 10–15 days, produced healthy roots and shoots and that root cuttings of 1.2 cm diameter gave the best results.

Table 9 : Interacting effect of time of planting and type of cutting on some characters of *R. serpentina*.

Treatment		% of success	Plant height (cm)	No. of roots/ plant	Length of longest root (cm)	Air-dried root weight/ plant (g)
T_1	C_1	22.4	24.7	6.4	14.8	16.2
	C_2	14.4	14.3	5.6	13.3	12.5
T_2	C_1	26.8	26.7	6.3	19.5	23.6
	C_2	16.3	24.2	5.9	17.4	19.7
T_3	C_1	46.5	41.1	10.0	25.0	27.4
	C_2	38.3	33.0	9.1	20.8	19.3
T_4	C_1	65.2	45.2	12.4	31.9	34.2
	C_2	54.1	35.5	9.9	27.7	25.8
T_5	C_1	30.1	29.6	9.2	23.3	20.3
	C_2	23.3	28.3	7.2	19.3	16.3
LSD 5%		2.7	1.6	0.8	1.1	1.8

The combined effect of both factors namely time of planting and type of cutting showed no synchronized trend of significance regarding % of success

(Table 9). The highest % of success was noticed in 15 June planting in combination with root cutting.

Plant height due to different times of planting was found to be significant. The highest plant height was noticed when the cuttings were planted on 15 June and the lowest in 15 March planting. The difference between 15 April and 15 July plantings was not significant. Higher growth of plants of 15 June planting may be due to proper maturity of the cuttings. Because in *R. serpentina* it was observed by Gupta (1956) in India that both over-matured and immatured cuttings did not root easily with subsequent slow growth of the cuttings corroborating the present findings.

The results revealed that types of cuttings had significant effect on plant height. Root cuttings had higher height than stem cuttings. This is in agreement with the findings of Nayar (1956). Analysis of variance indicated the significant effect of interaction between the time of planting and type of cutting. Root cuttings when planted on 15 June produced the highest plant height (41.1 cm) (Table 9), but it was lowest in cuttings from stem planted on 15 March (14.3 cm).

The variation in total number of roots/ plant due to different times of planting was significant. Maximum number of roots (11.2) was recorded in 15 June planting, which was statistically identical to that of 15 May planting. The minimum number of roots (6.0) was achieved from 15 March, statistically similar to that of the 15 April planting.

Different types of cuttings had significant influence on the production of root. As usual the root cuttings produced the highest numbers of roots than the stem cuttings. There was no significant interaction between types of cuttings and times of planting in respect of root number.

Analysis of variance showed that the highest root length was significant by different types of planting. Maximum root length (19.8 cm) was recorded from 15 June planting which was statistically different from the remaining planting times and the minimum (14.1 cm) by 15 March planting. Gupta (1956) reported that both over-matured and the immatured cuttings could not root easily with subsequent slow growth of cuttings.

The differences in the length of the longest roots as influenced by different types of cuttings were significant. The highest root length was obtained from root cuttings and the lowest from the stem cuttings (Table 8). The interaction between times of planting and types of cuttings was non-significant.

Significant difference in respect of air-dried root weight/ plant was recorded due to different times of planting. Planting on 15 June resulted in maximum root weight (30.0 g) which differed significantly from the rest of the treatments. 15 April, 15 May and 15 July plantings produced statistically identical and 15 March planting produced the lowest root yield (14.4 g). Like other characters, root cuttings produced significantly higher root weight than the stem cuttings.

Analysis of variance indicated significant interaction between planting time and type of cuttings. The maximum root yield was obtained from the treatment combination of root cuttings and 15 July planting, while the minimum by 15 March x stem cuttings.

The results of the present study indicate that though *R. serpentina* could be propagated by both stem and root cuttings, better growth and root yield were obtained when propagation was done by root cuttings. These results also revealed that better growth and root yield could be achieved if root cuttings are planted on 15 June.

SUMMARY

R. serpentina is propagated by seeds. Owing to the hard sclerotic endocarp, the seeds require longer time to germinate and the overall germination percentage is low. Experiment was undertaken to assess the effectiveness of different treatments for germination percentage of seeds of *R. serpentina*.

Seed scarification with sand paper was able to increase germination to some extent. But grinding of seeds with stone or nicking with a needle were not effective in germination. The concentrated sulphuric and nitric acids and hot water treatments could not prove to be effective in increasing germination.

Presowing seed treatment with chemicals did not improve germination. However, potassium nitrate and thiourea improved germination to some extent.

As mechanical and chemical scarification of seeds could not improve germination of *R. serpentina* seeds, it appears that germination inhibitors may be located inside the seeds.

Although cultivation of *R. serpentina* through seeds is the most economic method, but it is extremely difficult to obtain the required supply of seed from natural sources. Therefore, there seems no other alternative than to undertake propagation by stumps, root and stem cuttings, which are more easily available. Study was undertaken to investigate the different methods of vegetative propagation of *R. serpentina* and the effect of different growth regulators on rooting of stem cuttings.

Stump cuttings had the highest root formation activity and it was followed by root cuttings and stem cuttings.

IBA at low concentration stimulated root formation of stem cuttings. The highest stimulation was noted at 50 ppm IBA. With the further increase of

concentration, root formation was decreased gradually. NAA also stimulated root formation in stem cuttings at low concentration only. 2,4-D at very low concentration stimulated root formation on the stem cuttings. The highest activity (100%) was observed at 5 ppm of 2,4-D and at 100 ppm it totally inhibited rooting activity of the stem cutting.

Experiment was undertaken to study the effect of time of planting and type of cutting on the success of cutting and subsequent growth of *R. serpentina.*

Both type of planting and type of cutting had significant effect on percentage of success, plant height, no. of roots/ plant, length of longest root and air-dried root weight.

The percentage of success of cutting varied from 18.4 to 59.7, being highest in 15th June planting and lowest in 15th March. There was no statistical difference among 15th March, 15th April and 15th July plantings. The highest percentage of success of 38.2% was achieved from root while it was lowest (29.3%) from stem cuttings.

Planting on 15 June produced the highest plant weight, maximum number of roots and highest root weight/ plant. 15 March planting produced the lowest root yield. Like other characters, root cuttings produced significantly higher root weight than the stem cuttings. Better growth and root yield of *R. serpentina* could be achieved if root cuttings were planted on 15 June.