EFFECT OF SEED PRODUCTION, DISTRIBUTION, VIABILITY, LOSSES AND GERMINATION ON THE NATURAL REGENERATION OF SILVER FIR (*ABIES PINDROW*) IN MOIST TEMPERATE FORESTS OF PAKISTAN

Raza-ul-Haq, Central Silviculturist, Pakistan Forest Institute, Peshawar.

ABSTRACT

A number of experiments were laid out at Kund and Sharan to study seed production, distribution, viability and losses of seed affecting natural regeneration of *Abies pindrow* in the moist temperate forests of Pakistan. Seed production from mature and over-mature tree crops (150-200 years old) is numerically adequate (upto 136 seeds/m^2) in some years. However, the amount of viable seeds does not exceed 15% (20 seeds per m^2). Seed production in 1987 at Kund was seven times higher than in 1988. No seed was produced in 1989, indicating that a 2 or more years seeding cycle is likely to be occurring in natural stands. Data for Kund (136 seeds/m^2) and Sharan (320 seeds/m^2) for the 1987 indicated that large variation in seed production exists between the localities. Field observations also revealed that *Abies pindrow* does not have a persistent seed bank and seed remains viable for less than a year in natural stands. 97% of seeds are lost due to rodents, birds and microbial attacks. The results indicated that low seed viability with seed losses must have been a major factor in the poor regeneration in fir forest, even if other soil and microclimatic conditions were favourable.

INTRODUCTION

The definition of the regeneration niche of a plant population includes various aspects, such as spatial and temporal variations in seed rain and the seed bank, seed losses due to different factors (e.g., predation, microbial attack, and depletion of seed reserves) and seed longevity (Cavers, 1983; Sullivan *et al.* 1983; Simpson *et al.* 1989). Whether sown naturally or by artificial means, pine seed is subject to enormous losses, primarily to seed-eating animals and fungal pathogens, before the seedling stage is reached. Serious wastage also results when seeds fail to germinate, due to weather conditions or to the immediate environment in which they fall (Ferguson and Stephenson, 1955). Smith and Aldous (1947) listed 40 small mammals that are found to eat coniferous seed in the USA, but pointed out that the species vary with the part of the country and the habitat involved. Keyes and Smith (1943) reported that birds consume pine seeds and are a major obstacle to successful establishment of pine seedlings in the USA. In order to study the factors responsible for the failure of natural regeneration in fir forests, a number of studies were conducted at Kund and Sharan in the moist temperate forests of Pakistan. The seed crops at both sites originated from mature and over-mature trees of 150 to 200 years of age. This paper discusses the role of seed production, distribution, viability and losses on the natural regeneration of *Abies pindrow*.

MATERIALS AND METHODS

Study Areas

Experiments were carried out in almost pure stands of *Abies pindrow* at two sites, Kund (elevation: 2475 m), and Sharan (elevation: 2440 m), separated by 50 km distance. These stands of mature trees typically have little natural regeneration. Both sites have similar climates. The annual rainfall is in excess of 1700 mm and is concentrated during the monsoon from July to September. The coldest months are December to April when the areas are under snow. June is the hottest month with a maximum mean temperature of 22°C. The growing season is from May to September.

Kund site: The experimental area is below a ridge on a steep slope facing north-west. The gradient varies from 21° to 46°. The trees are mature and over mature with a mean diameter of 76 cm (standard deviation = $\pm$ 26.5 cm) and a mean height 36 m (SD = $\pm$ 12.1 m). Out of 122 trees, 80 percent are *Abies pindrow* and the remaining 20 percent are *Picea smithiana*, *Pinus wallichiana*, *Cedrus deodara* and *Juglans regia*. The main shrub is *Viburnum nervosum*.

Sharan site: The experimental area is on a moderate slope of 32° to 37° facing west. The trees are mature and over-mature with a mean diameter of 72 cm (SD = $\pm$ 24.07 cm) and mean height 42 m (SD = $\pm$ 13.8 m). Out of a total of 89 trees, 90 percent are *Abies pindrow* while the remaining 10 percent consist of *Pinus wallichiana*, *Pieca smithiana* and *Aesculus indica*. The main undergrowth is *Viburnum nervosum* which is rather more vigorous than that of the Kund site.

Seed Production

Seed production and distribution for 1987 was investigated at Kund, using a network of 52 locally designed bird and rodent proof seed collectors of 45 cm x 45 cm (Fig. 1), placed 4.7 m from each other down the slope and 10 m apart across the slope in both the fenced and unfenced plots. In 1988, the sampling intensity was increased by adding 52 smaller seed collectors (22 cm x 22 cm). These were located on four transect lines on the same spacing (Fig. 2). In both years the seed collectors were installed in July; well in advance of seed production. In 1987, they were examined from September to November and in 1988 from August to October.

At Sharan seed production and distribution data for 1987 and 1988 was also collected in the same manner.

Seed Viability

The viability of *Abies pindrow* seeds from Kund was tested using standard germination test procedures used by Leadem (1986) for the germination test of *Abies amabilis* seeds and also the procedure followed by Gosling (personal communication from Mr. P. G. Gosling - Seed Testing Laboratory Alice Holt, UK) for testing *Abies* seeds.

Seed Losses

To study seed losses, the area was stratified into three major ground conditions: (i) bare ground - paths; (ii) areas covered by ground vegetation; and (iii) areas covered by shrub growth. To determine the losses from these areas due to rodents and birds, an experiment with six replicates was laid out in a split plot design with cover conditions as the main plot treatment. The three sub-plot treatments using 0.5 m x 0.5 m plots were: (a) control - no enclosure only demarcation with pegs; (b) enclosures 75 cm high with open tops and netting at the sides of fine mesh (size 0.4 inches) - open for birds but not rodents; (c) enclosure with overhead netting with fine mesh (size 0.4 inches) - no access for rodents or birds.

All the plots were covered with plastic sheeting from September to November 1988 to prevent seedfall from the surrounding trees, 40 seeds marked with ultra violet fluorescent dye were sown in each plot in October 1988. Monthly counts of seed and seed germinations were made from May to August 1989 using a portable ultra violet lamp.

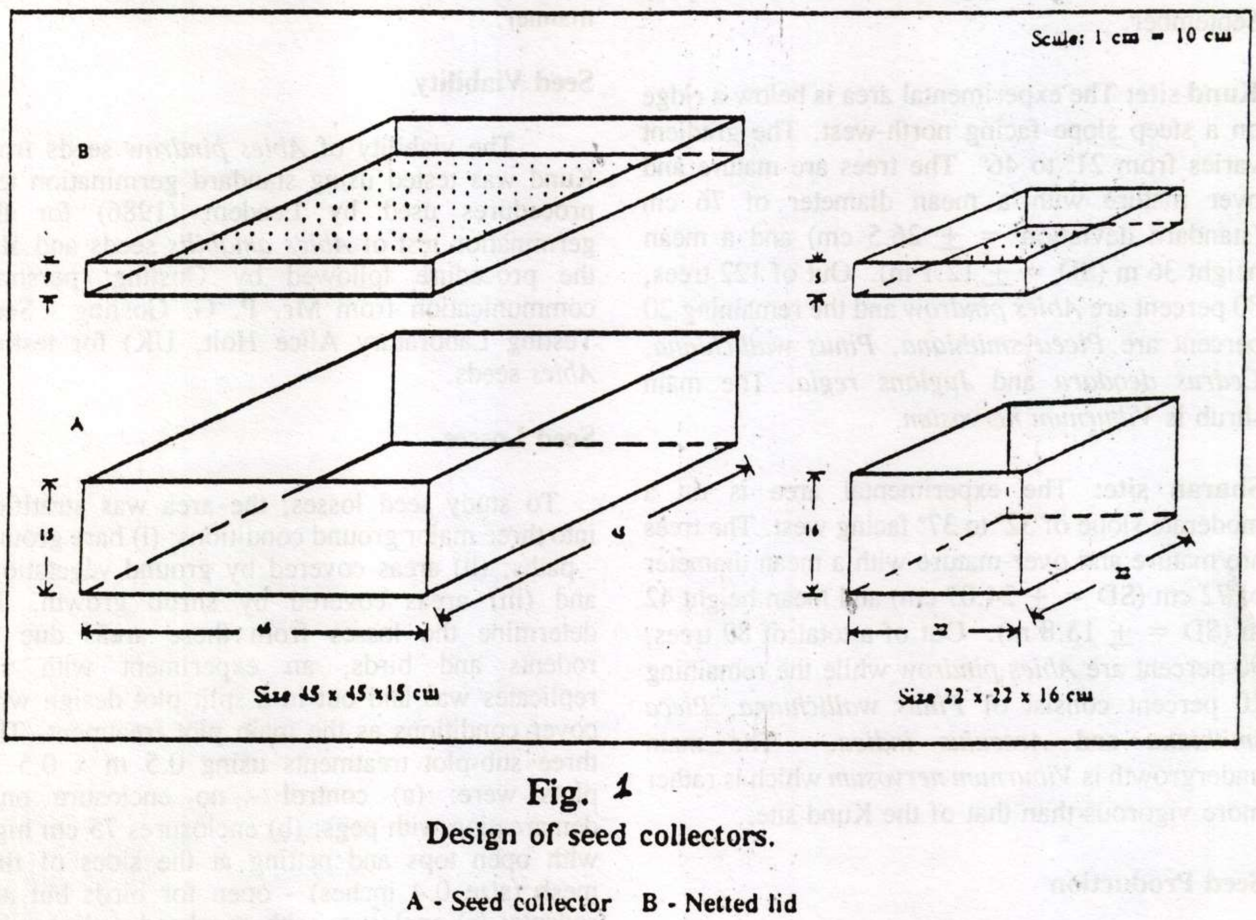
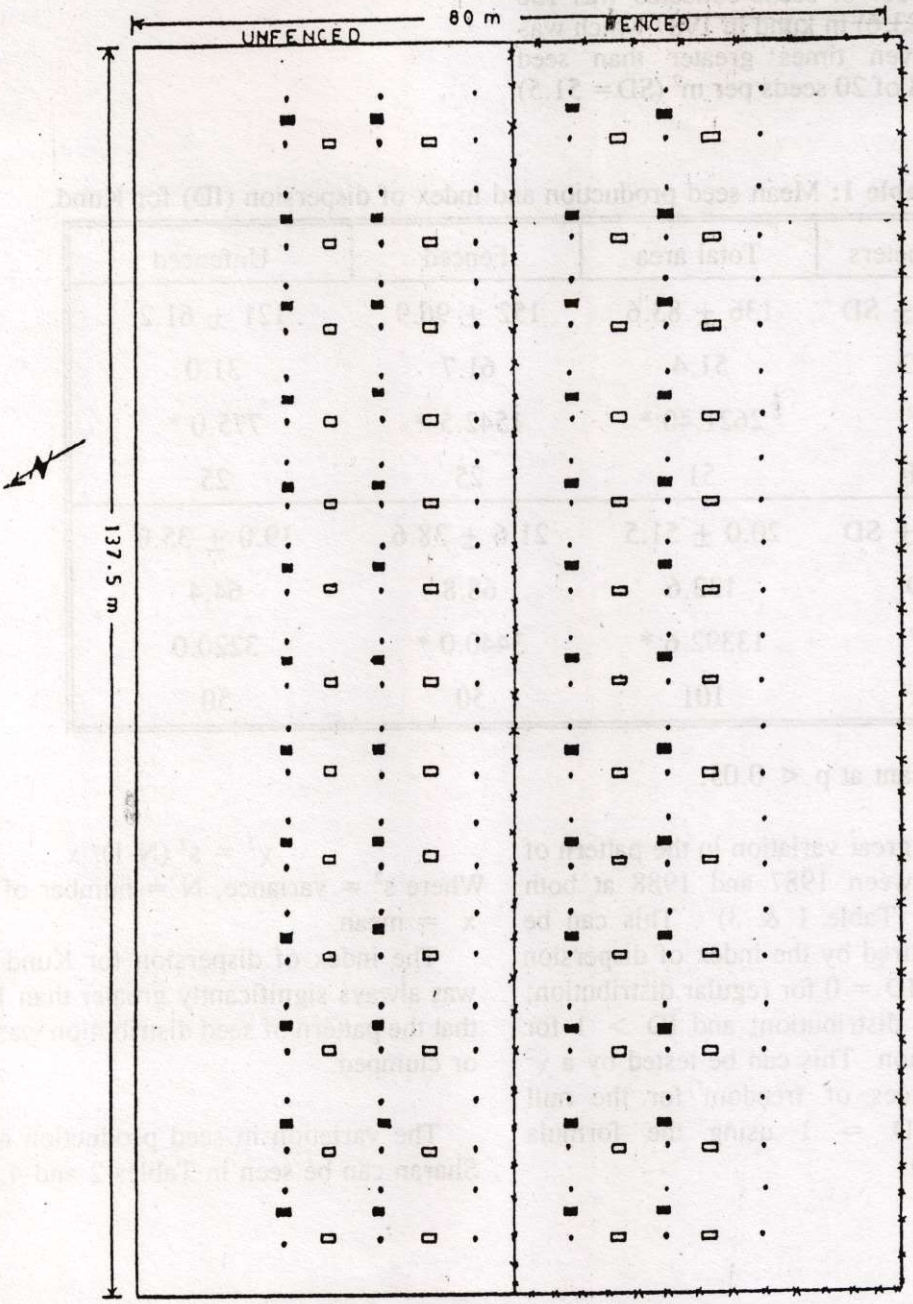


Fig. 1

Design of seed collectors.

A - Seed collector B - Netted lid

Fig. 2
Distribution of seed collectors for assessing the seed production from 1987 to 1989 at Kund.



52 - 45 x 45 x 15 cm seed collectors
52 - 22 x 22 x 16 cm seed collectors
Scale: 1 cm = 5.75 m

• Shows the 0.5 m radius circular plots
Distance from collector to collector = 4.7
Distance from line to line = 10m

RESULTS

Seed production

The mean number of seeds collected was 136 per m^2 (SD = $\pm$ 83.6) in kund in 1987 which was approximately seven times greater than seed production in 1988 of 20 seeds per m^2 (SD= 51.5) (Table 1).

Table 1: Mean seed production and index of dispersion (ID) for Kund.

Year	Parameters	Total area	Fenced	Unfenced
1987	Mean $\pm$ SD	136 $\pm$ 83.6	152 $\pm$ 96.9	121 $\pm$ 61.2
	I.D	51.4	61.7	31.0
	χ^2	2621.40 *	1542.5 *	775.0 *
	DF	51	25	25
1988	Mean $\pm$ SD	20.0 $\pm$ 51.5	21.6 $\pm$ 38.6	19.0 $\pm$ 35.0
	ID	132.6	68.8	64.4
	χ^2	13392.6 *	3440.0 *	3220.0
	DF	101	50	50

* Significant at $p < 0.05$:

There was also great variation in the pattern of seed collected between 1987 and 1988 at both Kund and Sharan (Table 1 & 3) . This can be conveniently measured by the index of dispersion (ID). One expects ID = 0 for regular distribution; ID=1 for random distribution; and ID > 1 for aggregate distribution. This can be tested by a χ^2 test for N-1 degrees of freedom for the null hypothesis that ID = 1 using the formula (Southwood, 1966)

$$\chi^2 = s^2 (N-1)/ x$$

Where s^2 = variance, N = number of samples and x = mean.

The index of dispersion for Kund and Sharan was always significantly greater than 1, indicating that the pattern of seed distribution was aggregated or clumped.

The variation in seed production at Kund and Sharan can be seen in Tables 2 and 4.

Table 2: Seed production per seed collector at Kund.

1987		1988	
Range	% seed collector	Range	% seed collector
0-49	0	0-24	19
50-200	84	1-25	63
> 200	16	> 25	18

At Sharan in 1987 (Table 3), the mean number of seeds for all seed collectors was 320 per m^2 (SD = $\pm$ 98.4). The mean number of seeds in 1988 was 8.6 seeds per m^2 (SD = $\pm$ 17.8) which is even lower than that at Kund.

Table 3: Mean seed production and index of dispersion for Sharan.

Year	Parameters	Total area	Fenced	Unfenced
1987	Mean $\pm$ SD	320 $\pm$ 98.4	334 $\pm$ 92.9	293 $\pm$ 91.6
	I.D	30.3	25.8	28.7
	χ^2	10605.0 *	438.6 *	487.9 *
	DF	35	17	17
1988	Mean $\pm$ SD	8.6 $\pm$ 17.8	5.4 $\pm$ 7.8	15.0 $\pm$ 32.4
	ID	36.9	11.3	70
	χ^2	2619.9 *	395.5 *	2550.0
	DF	71	35	35

* Significant at $p < 0.05$:

Table 4: Seed production /seed collector at Sharan.

1987		1988	
Range	% seed collector	Range	% seed collector
0	0	0	39
50-200	3	1-25	55
200-300	50	> 25	6
> 300	47	-	-

Seed viability

The viability of seeds ranged from 8% to 15% using standard germination test.

Seed Losses

The observation on seed losses recorded during May, 1989 (7 months after sowing) are given in Table-5.

Table 5: Mean number of seeds per plot (0.25 m^2) at Kund in May 1989.

Treatment	Vegetation type			Mean seed
	Path	Ground vegetation	Shrubs	
Control	4.3 ± 1.1	5.3 ± 0.6	4.5 ± 0.9	4.7
No top netting	5.5 ± 0.3	6.1 ± 0.6	4.8 ± 0.7	5.4
Completely closed	7.0 ± 1.2	7.3 ± 3.3	9.3 ± 3.3	7.8

The fully protected plots lost fewer seeds than the less protected plots (Table 5). Losses from the control plots were due to rodents, birds, soil fauna and fungi while in the fenced area only birds, soil fauna and fungi could have been responsible. With complete closure only soil fauna and fungi could have been responsible for the losses. The seed losses were 90, 88 and 80 percent for treatment A (control), B (open top) and C (completely closed) respectively. The data indicate that heavy losses of seeds occurred at Kund and no seed germinated under any treatment.

The analysis of variance indicated non significant differences between different ground conditions at 5 percent probability level, while the protection treatments differed significantly.

As noted above, none of the remaining small quantities of seed germinated under any treatment. From the laboratory seed viability tests, 15 percent or about 6 seeds per plot of 40 should have been viable.

The results of all studies on seed production, viability and seed losses at Kund are shown in Table 6.

Table 6: Seed input and losses at Kund for seed fall in 1987 and 1988.

Details	Years	
	1987 / 1988	1988 / 1989
Total seed input /ha	1,360,000	200,000
With 90 % losses seeds no./ha	136,000	20,000
Viable seed (15 %) / ha	20,400	3,000
Germination / ha	583*	0
% of viable seed loss	97	100

* Seedlings germinated in 1988 were used to estimate the number of seedlings per ha.

DISCUSSION

The seed production data from both sites (Tables 1 & 3) show that 1987 was a much better seed year than 1988. In 1987, seed production at Kund was seven times greater than in 1988, while in Sharan it was nearly 40 times greater. In 1987, seed production at Sharan was more than twice that of Kund, showing that large variations exist between the localities in both good and poor seed years. This may be due to difference in grazing pressure on the two sites. The Kund site is heavily grazed by local domestic animals and by sheep and goats during migrations to and from summer pastures, while Sharan experiences grazing problems from only the local domestic animals. The Kund site is also more exposed and drier than Sharan which is located in a valley. Similar situation of good and poor seed years occur in case of *A. balseema* for which Houle and Payette (1991) reported that 72 seeds per m^2 were released in the autumn during a good seed year of which only 30.5 percent were viable. No seed was produced the following year. The seed production for *A. pindrow* (132 seeds/m^2) at Kund was approximately two times more than that reported for *A. balsaema*. However, only 15 percent of the seeds were found to be viable. This low viability may be due to the old age of the seed trees. *A. balsamea* does not maintain a persistent seed bank in the soil (Houle and Payette 1991; Frank and Safford 1970). The existence of a seed bank for *A. pindrow* was not determined in this study, but is unlikely.

The index of dispersion for both years and both sites indicated that seed distribution was not random but aggregated. Schopmeyer (1974) reported that dispersion of *Abies* seeds, which are light and winged, is governed by wind direction, and wind pattern is significantly affected by site related-factors such as exposure, topography, and vertical and horizontal vegetation structures (Johnson *et al.* 1981).

As per Table-6 during 1987 the seed fall data show an average input of 1,360,000 seeds per hectare at Kund and, assuming 15 percent viability the maximum germination during 1988 should have been about 204,000 per ha (20 seeds/m^2). However, in June 1988 the number of one year old seedlings was only 583 per ha. Ninety-seven percent of the viable seeds failed to germinate and were most probably lost due to rodents, birds, soil fauna and fungi. It is likely that selective losses of viable seeds occurred, as the birds and rodents tend to eat healthy seeds. During 1988, 200,000 seeds per ha. fell at Kund. Expected germination from the viable seeds was 3,000 per ha after deductions of 97 percent for environmental losses and an assessed viability of 15 percent, but no germination occurred in the summer of 1989. Germination rates for this species are known to be poor. Singh and Singh (1984) reported a germination rate of only 8 percent under natural conditions. These studies showed that the major part of this loss is likely to be due to animals, birds, insects etc.

The 3 to 4 year seeding cycle for adequate seed production in *Abies pindrow* has been mentioned as a cause of poor regeneration (Troup, 1921; Sharma *et al*; 1987; Khan, 1979). Such cycles are characteristic of the genus *Abies* and it is common for each cycle to last two or three years (Powell, 1977; Owens *et al*; 1977; Singh and Owens, 1981). This period can be reduced by the application of hormonal treatment as observed in other conifers (Owens, 1984). Cone-bud differentiation is one of the most important events in the long reproductive cycle of conifers. The failure of cone buds to differentiate is frequently cited as the reason for the absence of cone crop, and later problems encountered in pollination, embryo development, or seed development (Owens, 1980). Morris (1951) reported that *A.*

balsamea produces abundant seed crops every two years and one of the causes for this periodicity is related to carbohydrate reserve replenishment within a tree after a good seed year. In terms of seed numbers, 1987 was a good seed year for *A. pindrow*. Seed production in 1987 at Kund was seven times higher than in 1988. No seed was produced in 1989 indicating that a 3 or more years seeding cycle is likely to be occurring at Kund.

In 1987, the trees at Kund, though mature and over mature, produced 136 seeds per m^2, but only 15 percent (20 seeds per m^2) were viable (Haq, 1992). The low seed viability combined with seed losses seem to be a major factor in the poor regeneration in the natural fir forest, even if other soil and microclimatic conditions were favourable.

CONCLUSIONS

While seed production from mature and overmature tree crops is numerically adequate in some years, the amount of viable seed produced is very low and does not exceed 15 percent. Furthermore seed dispersion is aggregated and heavy seed losses occur due to rodents, birds and microbial attacks in the natural fir forests.

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