Adapting Scots pine regeneration to the Changing Climate

Swedish University of Agricultural Sciences

Matej Domevscik[1], Bodil Häggstrom[1], Hyungwoo Lim[1], Jonas Öhlund[2], Annika Nordin[1]

Contact: matej.domevscik@slu.se, Faculty of Forest Sciences, SLU, Sweden

In Sweden, new forest stands have long been artificially regenerated using conifer seedlings. This approach may, however, need to be further adapted to the changing climate, such as predicted variations in periods of drought. Considering this, we investigated the effect of planting position, arginine fertilization and environmental variables on coated seeds and nursery seedlings of Scots pine (*P. sylvestris*) across 23 sites in Sweden. Planting nursery grown seedlings in mineral soil, with an amendment of arginine, appears to be the most valuable to enhance survival and growth of seedlings subjected to dry conditions.

Coated seeds (SeedPAD)[3]

- The development of alternative planting methods using seeds reduces cost and simplifies mechanization, but their use has been limited due to the generally low establishment success of bare seeds on clearcuts.
- To improve establishment, seeds can be coated in protective layer that retains moisture and delivers nutrients to the seeds.
- We tested performance of SeedPAD (SP) coated seed system over 12 sites in Sweden using *P. sylvestris* seeds. SPs were deployed in 2017 and surveyed for survival, height and biomass in 2018 and 2019.
- We used two versions, fertilized with arginine phosphate (arGrow) and unfertilized, both deployed directly into mineral soil.
- Environmental variables associated with establishment were also collected: weather, soil, elevation, latitude, site productivity.

Coated seed results

- Two years after forest regeneration, on average 54% of the deployed fertilized SPs and 58% of the unfertilized SPs had developed into established seedlings (Table 1).
- There was no significant difference in seedling establishment and survival between fertilized and unfertilized SPs for any of the years.
- The addition of fertilizer had no significant overall effect on seedling suvival or growth (Table 1).
- Maximum wind speed and maximum precipitation within the first six weeks after SP deployment had significant effects on the seedling survival (Figure 2).
- Suspected key role of precipitation was investigated through a follow-up dissolution experiment.
- On average, SPs required 8.4 ml of water to dissolve and attach to the underlying soil (Figure 3).

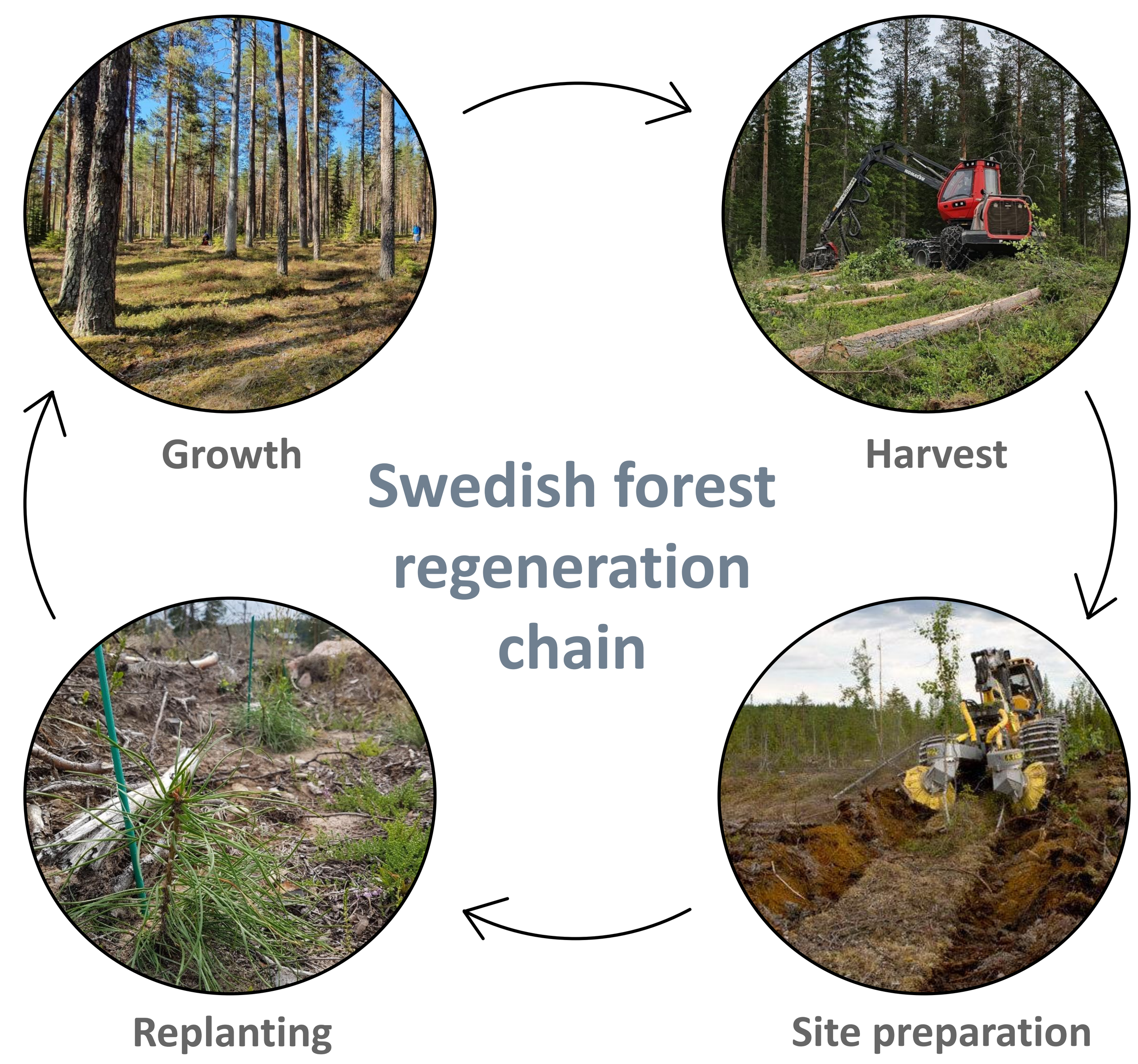

Figure 1 SeedPAD coated seed system featuring a single seed of *P. sylvestris*, covered by vermiculate and wrapped in polysaccharide foil.

Table 1 Average survival, height and biomass of seedlings established from the SeedPADs. Surveys were performed in autumn 2018 and 2019. Estimated marginal mean values ± SE.

	Unfertilized SP		Fertilized SP	
	2018	2019	2018	2019
Survival (%)	53.4 ± 4.4	57.8 ± 4.3	46.7 ± 4.9	53.7 ± 4.7
Height [cm]	6.5 ± 0.3	14.6 ± 0.9	6.8 ± 0.3	14.6 ± 0.9
Total biomass [g]		6.5 ± 0.9		5.6 ± 0.9
Shoot biomass [g]		5.6 ± 0.8		4.9 ± 0.8
Root biomass [g]		0.9 ± 0.1		0.8 ± 0.1
Root: shoot ratio		0.2 ± 0.004		0.19 ± 0.004

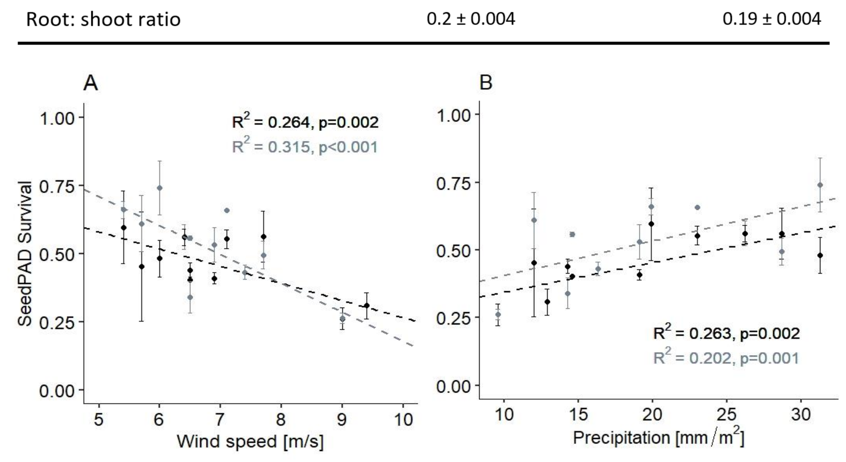

Figure 2 Effect of maximum wind speed (A) and maximum precipitation in a single day (B) within six weeks on survival of SPs in late summer 2018. Black lines and circles denote fertilized and grey ones unfertilized SPs.

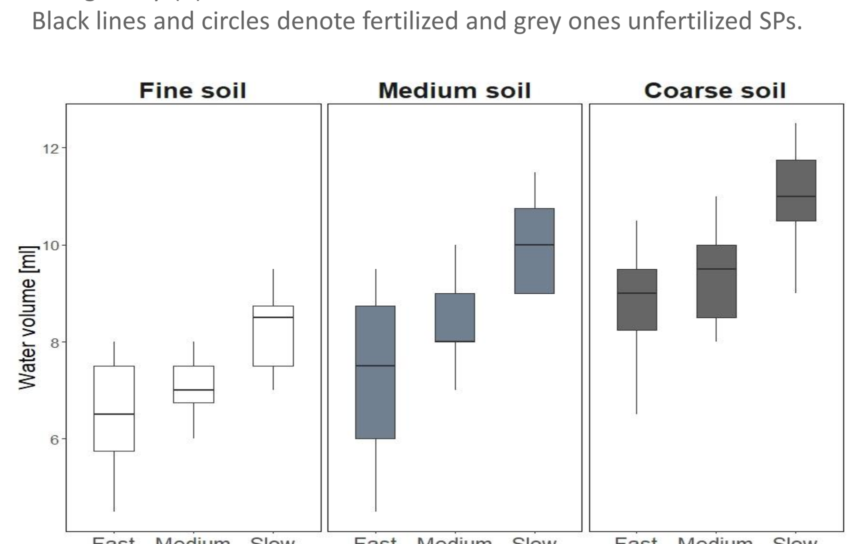

Figure 3 Water volume required for dissolution of SPs, compared across three different soil mixtures and speeds of water addition. For soil treatments, grain sizes were set to 1.7, 5.6 and 10.0 mm diameter. For speed of treatments, SPs had water dripped onto them every 1.5, 3 and 5 minutes.

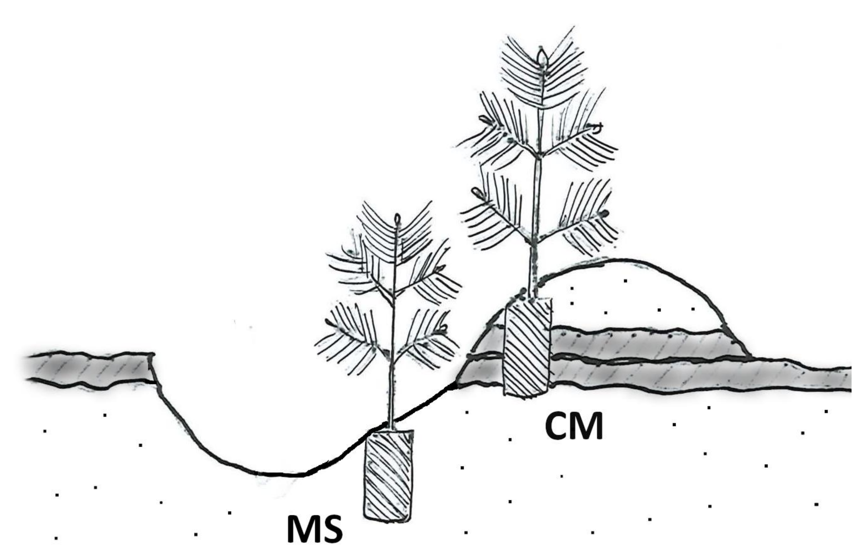

Figure 4 Cross section of the two common planting positions, mineral soil (MS) and capped mound (CM), created by mechanical soil preparation through mounding or disc trenching. The shaded area represents the organic humus layer, while the speckled white area represents mineral soil (drawing by Bodil Häggström).

Table 2 Survival and height (measured as leader shoot length) of fertilized and unfertilized nursery seedlings in the two planting positions following one year in the field. Mean values and standard errors.

	Mineral soil		Capped mound	
	Unfertilized	Fertilized	Unfertilized	Fertilized
Survival (%)	90.1 ± 0.01	93.2 ± 0.01	65.1 ± 0.02	71.2 ± 0.02
Height [cm]	9.7 ± 0.32	12.5 ± 0.3	9.7 ± 0.37	11.0 ± 0.39

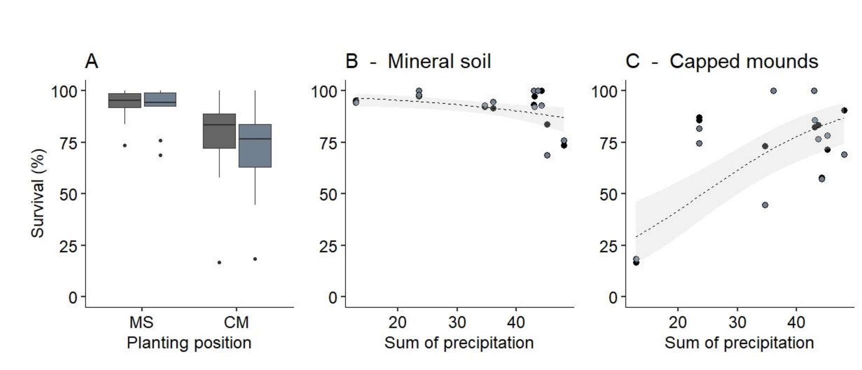

Figure 5 The effect of planting into mineral soil (MS) and capped mounds (CM) on survival (A) of nursery seedlings. The effect of sum of precipitation [mm/m2] in the first 30 days after planting on survival of seedlings planted into mineral soil (B) and capped mounds (C).

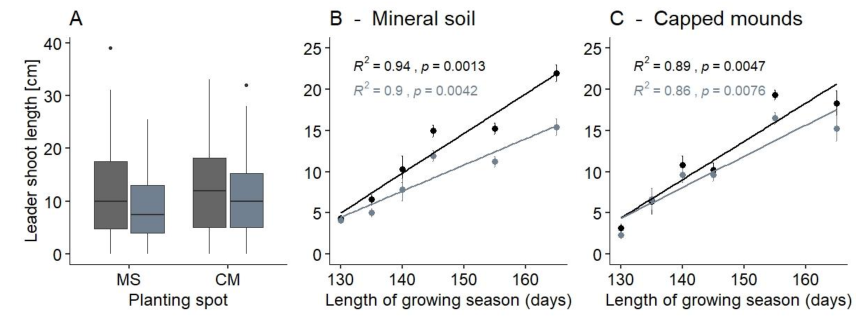

Figure 6 The effect of planting into mineral soil (MS) and capped mounds (CM) on length of leader shoot (A) of nursery seedlings. The effect of length of growing season in days on the length of leader shoot of seedlings planted into mineral soil (B) and capped mounds (C).

Planting position[4]

- To improve survival and growth of nursery seedlings, mechanical site preparation is commonly used. This creates two planting positions of different height, nutrient content and soil properties (Figure 4).
- Large variations in quality of soil preparation and moisture retention indicate that planting positions may need to be adapted to the climate changed future.
- We compared survival and growth of *P. sylvestris* nursery seedlings in two planting positions (MS, CM), over 11 sites in Sweden.
- Seedlings were planted in 2018 and surveyed for survival and leader shoot length in 2019.
- We used two versions, fertilized with arginine phosphate (arGrow) and unfertilized.
- Environmental variables associated with establishment were also collected: weather, soil, elevation, latitude, site productivity.

Planting position results

- After one year in the field survival of nursery seedlings was higher and less variable in MS position, compared to CM position (Table 2).
- Fertilization with arGrow had a significant positive effect on seedling survival after on year in the field, as the positive effect of fertilization on seedling survival occurred independently of site and planting position (p=0.03).
- Increased precipitation during the first 30 days after planting increased survival in CM position (p<0.001), while opposite is true for MS position (p=0.01) (Figure 5).
- Results for growth analysis are less clear as there was a high degree of variation between sites (Figure 6A).
- Length of growing season was the most significant factor as it increased shoot growth for both positions and treatments (Figure 6).
- Positive effect of fertilization increased with length of growing season.

Discussion and Conclusions

- Precipitation directly after planting/deployment was key to both coated seeds and nursery seedlings, which suggests we should adapt forest regeneration to the variables of the local area. With predictions of increased frequency and length of droughts in early summer, planting in mineral soil position should increasingly be used as more areas become dry.
- Coated seeds (SeedPAD) have the potential to be used as an alternative method for forest regeneration, especially in areas with heavy precipitation events in early summer or when combined with manual watering directly after deployment. This opens possibilities of either large-scale mechanized deployment, or small-scale private forest owner use.
- Fertilization with arginine phosphate had a positive effect on nursery seedlings but not SPs. This may be linked to the system of delivery, where fertilizer may have dispersed over larger area with the SPs, thus reducing effective uptake. Positive effect of fertilization also increased with length of growing season, indicating possible further increases in the future.

1 Swedish University of Agricultural Sciences, 2 Skogforsk (Forestry Institute of Sweden), 3 M. Domevscik, B. Häggström, H. Lim, J. Öhlund, A. Nordin. Large-scale assessment of artificially coated seeds for forest regeneration across Sweden (accepted manuscript), 4 B. Häggström, M. Domevscik, J. Öhlund, A. Nordin. (2021) Survival and growth of Scots pine (Pinus sylvestris) seedlings in north Sweden: effects of planting position and arginine-phosphate addition. Scandinavian Journal of Forest Research, vol. 36 (6), pp. 423–433.