Project 2.3b: Elite breeding in white spruce

Fall 2019

Overview (2018-2019)

Elite breeding takes advantage of estimates of genetic improvement based on breeding values (BV) for enhanced performance, by selecting the best parents and crossing them to produce better progeny (after the first generation is over). Tree improvement programs in Alberta have primarily been based on using BVs estimated from progeny trials using open pollinated seedlings, roguing parents in the initial first-generation orchards through backward selections and focusing on forward selections from the progeny trials to establish second generation orchards. The main result of this approach is relatively low genetic gain persists in these programs, decades after establishment. Through a well-designed breeding program using full-sibling material and full molecular pedigree analysis, breeding programs will advance beyond what is possible through traditional breeding.

Breeding Methodology

In order to investigate one opportunity to advance these programs more quickly and increase the gain between generations, controlled pollination 'CP' (e.g. controlled crosses 'CC' and controlled polymix crosses 'PM') (Figure 1) were performed through breeding parents identified as 'elite' based on height BVs from within the first generation G1 white spruce orchard. The seed performance was compared between CP techniques and open-pollination (OP) seedlots from the same parents, and their differences, trade-offs and opportunities have been investigated (Table 1).

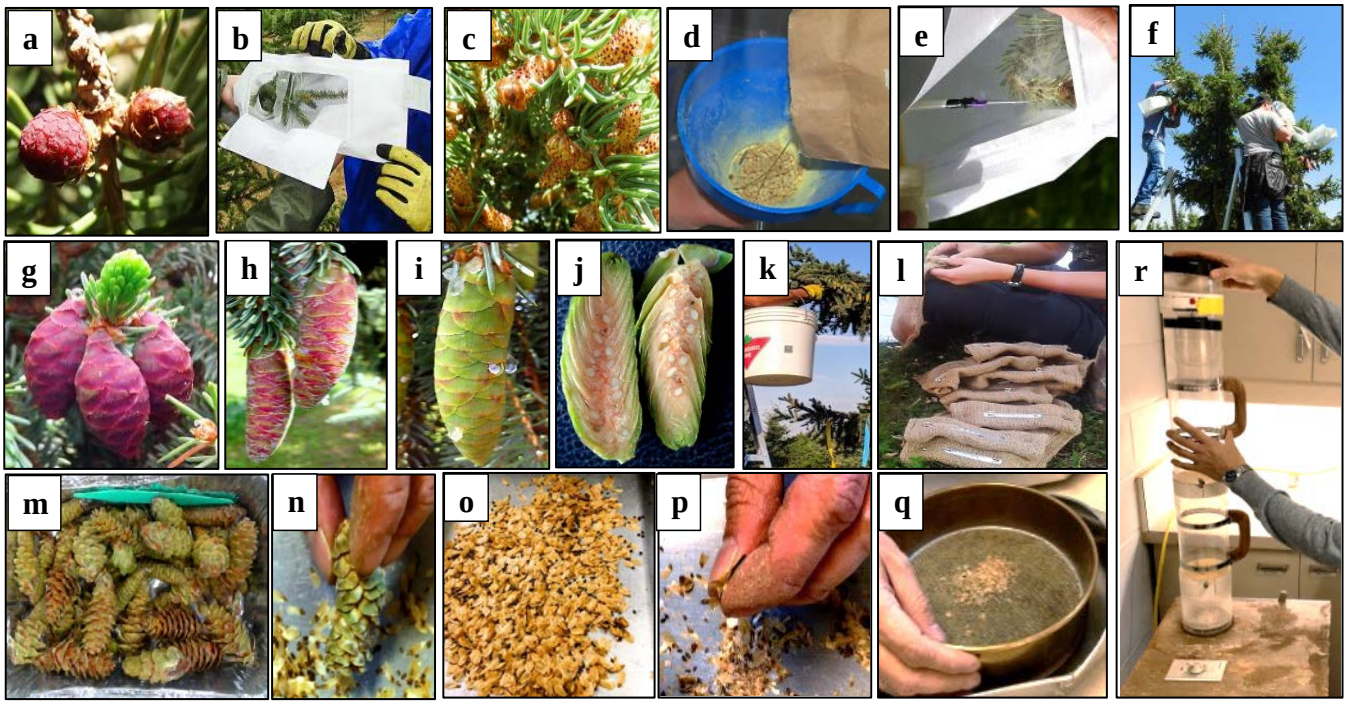

Figure 1. An example of how to breed white spruce: a) Initial examination of female strobili for breeding (1st week of May 2018); b) bagging female strobili (2nd week of May 2018); c) male strobili ready for pollen collection (3rd week of May 2018); d) grinding male strobili using funnels and sieves (3rd week of May 2018); e) pollination using a squeeze bottle & needle (3rd week of May 2018); f) removing the pollination bags (mid-June 2018), g) cones 1 month after pollination (mid-July 2018); h, i & j) cone inspection (late June to July 2018); k) cone collection (mid-August 2018); l) cone packing with burlap bags (mid-August 2018); m) cones drying & opening (late August 2018); n) tapping cones to remove seeds (end of August 2018); o) seeds attached to wings; p) releasing seeds from wings by hand; q) sieving seeds to remove debris & husks (wings); r) blowing seeds to remove aborted/unfertilized seed coats (end of August 2018).

Initial Outcomes

Based on one year of breeding the initial results look promising. Total seeds, total cones, seeds per cone, seed weight (1000K g), cone length (cm), genetic worth (GW) based on height, effective population size (Ne) and annual costs of the different breeding techniques were calculated and analyzed (Table 1). Our results show that both the CC and PM methods have the potential to significantly advance the G1 white spruce breeding program because they produced enough seed for the second-generation trials (particularly the PM) at low cost, enough gene diversity (Ne), and desired genetic worth; the OP seedlots can continue to be used for deployment while having elite material for establishing new generations.

Table 1. Results for the different breeding techniques regarding number of genotypes, seed and cone yield, costs, genetic worth (GW) and effective population size (Ne) obtained for white spruce, at G1 clonal seed orchard. Letters indicate differences between means (Tukey test with a p-value ≤ 0.05) among the different breeding techniques. CC= Controlled crosses, PM= Controlled polymix, OP= Open pollination.

Parameters	**BREEDING TECHNIQUES**				
	Controlled pollination (CP)			**OP**	
	CC	**PM**	**CC + PM**		
Year	2018	2018	2018	2018	2007
Number of genotypes	18	18	18	53	152
Total seeds	8,524	1,884	10,408	*na.*	93,440,000*
Costs per seed	*na.*	*na.*	**$ 0.55 CAD[1]**	**$ 0.054 CAD[2]**	*na.*
GW	6.8	6.9	6.9	5.9	1.9
Total cones	1,571	148	1,719	60,014	1,898,410*
Ne (18 parents for CP)	7.3	7.8	20	18*	51.4*
Ne (36 parents for CP) [+]	18	18	36	18*	51.4*
Seeds per cone	10.1 **a** (n=54)	18.8 **ab** (n=9)	*na.*	29.2 **b** (n=9)	49.22*
Seed weight (1000K g)	2.2 **a** (n=54)	2.5 **ab** (n=9)	*na.*	2.7 **b** (n=9)	2.7*
Cone length (cm)	4.8 **a** (n=54)	4.8 **a** (n=9)	*na.*	5.3 **a** (n=9)	*na.*

[1] Estimated total labor cost for the 2018 breeding study based on the steps detailed in Fig.1 (roughly $5,750 CAD for 186 hr @ $25/hr) and total seeds (10,408).
[2] Current cost for operationally produced seed. This calculation was done using the cost per gr/OP seed (~$1.99 CAD) (pers. comm. Incremental Forest Technologies Ltd. 2018) and weight average of one OP seed (~0.03 g) (Thomas Lab).
* Values obtained from Isabella Point Forestry Ltd. documentation and Region G1 white spruce reports and plans.
[+] Hypothetical breeding effort with 36 parents.

Conclusion

This work encourages Alberta Forest Companies and orchard managers to begin establishing second & third generation progeny using different elite breeding designs, such as controlled crosses and controlled polymix crosses, while considering price, diversity and gains. For any Alberta company, the main objective in their tree improvement programs should be to advance the breeding cycles (second & third generation orchards) as quickly and efficiently as possible to realize the economic benefits.

For more information on the Industrial Research Chair Program please contact:
Barb Thomas bthomas@ualberta.ca
For more information on this project please contact:
Esteban Galeano galeanog@ualberta.ca

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TREE IMPROVEMENT LAB

UNIVERSITY OF ALBERTA
QUAECUMQUE VERA