Improving the Transplanting of Douglas-fir Container Stock in Coastal British Columbia

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Abstract

Seedling transplanting is a significant important part of silviculture system. Some experimental evidences show that nutrient and moisture availability, site fertilization, planting operations, root damage, transportation and storage between lifting and planting have impacts on seedling quality and field performance after outplanting. This article focused on the problems occurred during production, shipping and planting of Douglas-fir seedling in coastal British Columbia. This article provided some suggestions for problems occurred in each period during seedling transplanting. The primary focuses are mycorrhizal inoculation of nursery stock, site fertilization, and keep seedling quality and vigour during transportation and storage. This article also discussed the economic considerations, and cost-effective operations and treatments during seedling transplanting. Recommendations of increasing Douglas-fir seedling growth and survival are discussed in this article. Mycorrlizal inoculation program of Douglas-fir container seedlings is better to be conducted, since mycorrlizal inoculation offers better chance for seedling growth and survival. Spot fertilization is recommended for Douglas-fir stands in coastal British Columbia. Spot fertilization is more specific, and can avoid increased growth of non-crop plants. This article also discussed a nutrient liquor containing micromolecule that can increase seedling quality and keep vigour. The nutrient liquor has been proved can enhance root growth of agriculture crops, and increase plant vigour. Further studies are still needed to apply it to forestry crops. Apart from those major focuses, some operational tips during seedling production, transportation and storage also should be noticed.

Keywords: Transplant, Douglas-fir container stock, survival, growth, cost.

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1. Introduction

1.1 Overview and Summary

In many regions of the world, commercial forests are regenerated via natural seeding, yet in others seedlings raised in nurseries are planted to produce the next generation of crop trees. In British Columbia, seedlings grown in containers in nurseries are generally preferred for planting (Bowden, Daintith, Eerden, etc., 1998). This paper focuses on Coastal Western Hemlock (CWH) biogeoclimatic zone in the coastal region of British Columbia. Experimental evidence indicated by McKay (1997) that nutrient and moisture loss, fluctuation of temperature, inappropriate handling, root damage and loss, transportation and storage between lifting and planting have influences on seedling quality and field performance. In order to improve the transplanting of seedlings to achieve higher economic benefits from the commercial forests in the CWH zone, problems need to be identified, and effective management plans established. In the CWH zone, enhancing seedling survival rates of Douglas-fir (*Pseudotsuga menziesii*) seedlings during transplanting requires high quality stock, appropriate shipping and storage systems, and successful transplanting. For commercial forests, economic benefit is an essential aspect. If the total cost of a management strategy exceeds the resulting value of the forest, management were unnecessary in this forest. The best approach to reduce regeneration costs is to improve seedling survival rates. In addition, nurseries can aim to reduce the cost of growing seedlings.

1.2 Coastal Western Hemlock Zone

The Coastal Western Hemlock zone occurs in west of the coastal mountains, along the entire British Columbia coast (Figure 1), from sea level to 1000 meters. The Fraser and Skeena rivers cut through the coastal mountains across the CWH zone.

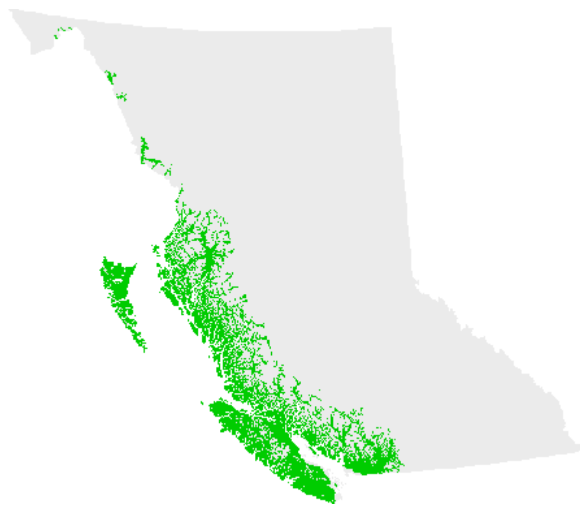

Figure 1 Location of CWH zone in British Columbia

(Source: http://www.for.gov.bc.ca/hfd/library/documents/treebook/biogeo/cwhzone1.htm)

1.2.1 Ecological Conditions

The CWH zone is generally the rainiest biogeoclimatic zone in British Columbia. The zone has a cool mesothermal climate, with cool summers and mild winters. Mean annual temperature is 8°C and ranges from 5.2 to 10.5°C. The mean annual precipitation for the zone as a whole is 2228 mm, and ranges from 1000 to 4400 mm (Pojar, Klinka and Demarchi, 1991).

Coastal western hemlock (*Tsuga heterophylla*) is dominant species. Douglas-fir, lodgepole pine (*Pinus contorta*), grand fir (*Abies grandis*) and western red cedar (*Thuja plicata*) occur in drier portion, and amabilis fir (*Abies amabilis*), Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*) and yellow-cedar (*Cupressus nootkatensis*) appear in wetter portion of the zone.

Since the climate is wet, nutrients are quickly leached out of the mineral soil. Many of the nutrients are held in the soil by organic matter such as humus and rotting wood, and in the vegetation itself (Pojar, Klinka and Demarchi, 1991).

1.2.2 Douglas-fir Distribution in British Columbia

Douglas-fir is generally distributed in western North America. In British Columbia, Douglas-fir is widespread south from Dean Channel or around 53°, south, and is most abundant in drier parts of the CWH zone (Pojar, Klinka and Demarchi, 1991). (Figure 2)

Figure 2 Distribution of Douglas-fir in British Columbia

(Source: http://www.for.gov.bc.ca/hfp/silviculture/Compendium/DouglasFir.htm)

1.2.3 Wildlife Habitats and Resource Values

The CWH zone has a greater diversity and abundance of habitat elements than any other zone in British Columbia because of the cool, mild, maritime climate, dense coniferous forests and variety of landforms. It is also the most productive forest Region in British Columbia. The majority of CWH ecosystems are used primarily for forestry. Valleys in the driest and southern most portion of the zone are supposed for agriculture and urban development (Pojar, Klinka, and Demarchi, 1991).

2. Literature Review

2.1 Early Growth in Containers

2.1.1 Advantages of Containers

According to Brissette (2001), in British Columbia, container seedlings tend to grow better than bare-root seedlings on plantation sites. Container Douglas-fir seedlings can be produced quickly. Production flexibility allows Douglas-fir container seedlings to be planted throughout an extended planting season (Brissette, Barnett and Landis, 2001 Duryea and Dougherty, 1991). The mild climate of the CWH zone allows a longer planting season provides favorable soil moisture and climatic conditions for growth (Brissette, Barnett and Landis, 2001). Growing conditions of container seedlings can be better controlled in nurseries, than bare-root production in fields (Brissette, Barnett and Landis, 2001 Duryea and Dougherty, 1990). Temperature, water, humidity and fertilizer can be slightly or strictly controlled in nurseries which brings higher seedling production (Colorado State University website, 2012). According to Trofymow and Driessche (1991), container seedlings performed better in plantation sites than root-bared seedlings when both stock types were in relatively dry soil.

2.1.2 Problems

There are some problems found in using container seedlings. Favorable growing conditions in containers are also conducive to diseases and nutrition imbalance. Container density and container size also have impact on the development of seedlings. Yet Barnett and Brissette reported (2001) that container size is less critical than seedling density in the containers. Density exceeding about 1000/m^2 results in reduction of initial development of Douglas-fir seedlings (Brissette, Barnett and Landis, 2001). For a given container size, the influence of container density during seedling development period becomes much clearer.

2.1.3 Container Selection

Three types of containers are used for seedling growth, plug, tube and block. (Figure 3, 4 and 5) Tubes are containers with an exterior wall that provides wall rigidity. When seedlings planted in dry soil, tubes protect seedlings from desiccating (Brissette, Barnett and Landis, 2001). The major problem of tubes is that root egress into soil slowly. Plugs are easily planted by hand or machine. Before outplanting, the root seedlings should be moved out of plug containers. Roots rapidly develop themselves after being planted without the constraints from container walls. However, John C. Brissette reported (2001) that seedlings should be grown in the nursery in containers for generally at least 3 to 5 months in order to let roots bind the soil. Blocks combine the advantages of plugs and tubes. The entire block container is planted into the soil when transplanting seedlings, since the block itself is not only the container, but also the growing medium. In coastal British Columbia, the plug styroblock (PSB) is mainly preferred for growing Douglas-fir container seedlings (Bowden, Daintith, Eerden, etc., 1998).

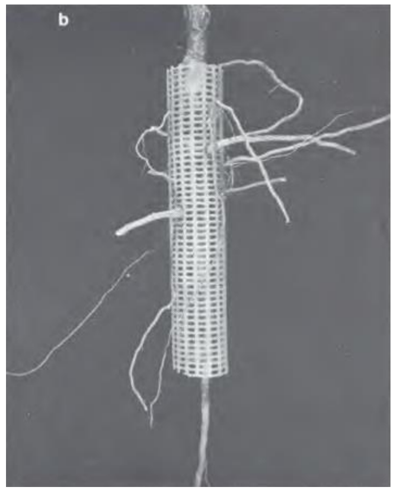

Figure 3 Plastic-mesh tube

(Source: http://books.google.ca/)

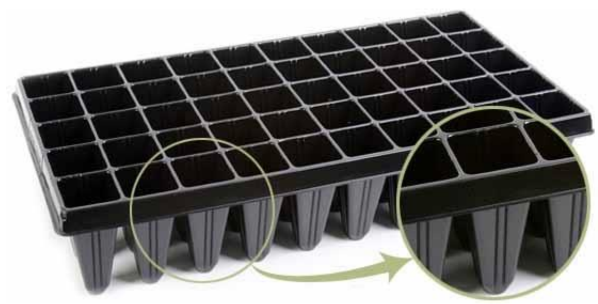

Figure 4 1400 cc plug

(Source: http://www.transplantsystems.co.nz/index.php/trays/plug-trays/50-cell-plug-trays)

Figure 5 Gro-Blocks

(Source: http://www.grodan101.com/products/grodan-stonewool/gro-blocks)

Figure 6 Loblolly pine seedlings grown in three container types: (a) biodegradable plastic tube, (b) peat moss-vermiculite molded block, (c) plug from Styroblock-2.
(Source: http://link.springer.com)

2.2 Seedling Containers Shipping

2.2.1 Transportation

Availability of suitable transportation is one of the major concerns for planting projects. Transporting seedlings to and temporarily storing seedlings at planting sites far away from nurseries can be costly (Bowden, Daintith, Eerden, etc., 1998). Getting those seedlings safely to the field and keeping them healthy and vigorous can also be a problem (Brinkman, 2000). Choosing suitable locations for nursery sites must be a main concern that could influence the total cost of transplanting. In interior British Columbia, greenhouses are needed for seedlings to keep favorable environment conditions. Greenhouses need to be heated in winter to provide favorable temperature for seedling growth. Greenhouse heating systems cost $ 372, 840 and the natural gas costs $ 3.97 per Gigajoule. (Table 1) In traditional operations, boxed seedlings were loaded onto trucks, and then were delivered to planting sites. The cost of storing and transporting PSB 615A 1+0 container is 8.9 cents per seedling in spring and 11.54 cents per seedling in fall. (Table 2) Compared with greenhouse heating costs, trucking cost is lower. In order to avoid greenhouse heating cost, nurseries should be in coastal region of British Columbia.

Table 1 Greenhouse heating system cost and heating (with natural gas) cost in 2011. *(Source: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex4369/$file/821-59.pdf?OpenElement)*

	Equipment Cost	Fuel Cost
Heating	$ 372,840.00	$ 3.975/GJ

Table 2 Containers storage and transplantation cost in Thompson/Okanagan Region in 2011. (*Source: http://www.for.gov.bc.ca/nursery/headqtrs/storage_transport.htm*)

Stock Type	Storage Cost (cents/seedling)	Transportation Cost (cents/seedling)	
		Spring	Fall
PSB 313B 1+0	2.14	.15	.65
PSB 410 1+0	2.14	.15	.65
PSB 412 A 1+0, PSB 415D 1+0	3.93	.29	1.80
PSB 512A 1+0, PSB 515A 1+0	6.55	.48	2.70
PSB 615A 1+0	7.94	.96	3.60

In British Columbia, spring and fall are preferred for transplanting coastal Douglas-fir seedlings. (Table 3) Before shipping fall stock, the seedlings should be cooled between 10 to 15°C to minimize heat build up (Bowden, Daintith, Eerden, etc., 1998). Refrigerated transportation should be used. During transportation, keep seedling temperature constant approximately 10°C is necessary to avoid loss of vigour (Skila, 1999). Without adequate room for seedling containers, seedlings can heat during transportation due to compaction. Tight packaging reduces air exchange and speeds the heating process. Trucks with openings should not be used, since openings can allow solar radiation to go into seedling containers. Leave seedling containers loaded upon trucks overnight can decline the quality of seedlings rapidly. Refrigerated storage is essential, especially during remote shipment. (Kanges, 2013)

Table 3 Stock types and plantation seasons of Douglas-fir seedlings.
(Source: http://www.for.gov.bc.ca/hfd/pubs/docs/sil/stcktype.pdf)

Fdc		**Fdi**	
Stock type	**Season**	**Stock type**	**Season**
PSB 313B 1+0	Sp, Fa	PSB 313B 1+0	Sp
PSB 410 1+0	Sp, Fa	PSB 410 1+0	Sp
PSB 415B 1+0	Sp, Fa	PSB 415B 1+0	Sp
PSB 412A 1+0	Sp, Fa	PSB 412A 1+0	Sp
PSB 415D 1+0	Sp, Fa	PSB 415D 1+0	Sp
PSB 512A 1+0	Sp	PSB 512A 1+0	Sp
PSB 515A 1+0	Sp	PSB 515A 1+0	Sp
PSB 615A 1+0	Sp	PSB 615A 1+0	Sp
BBR 2+0*	Sp	-	-
PBR .5+1.5*	Sp	-	-

* Fdc = coastal Douglas-fir, Fdi = interior Douglas-fir, PSB = plug stoyblock, Sp = spring, Fa = fall

2.2.2 Storage

The quality and vigour of all stock type will decrease quickly without adequate interim storage. More space for interim storage is required for larger stock types. As Douglas-fir stock types are mainly spring-shipped, they are the least sensitive to rapid deterioration of stock quality caused by long storage time and unfavorable conditions (Bowden, Daintith, Eerden, etc., 1998). High temperature of storage place could reduce stock quality and vigour. The temperature of storage location for Douglas-fir should below 10°C for overnight storage (Ministry of Forests, 1999). If refrigerated storage is not available, spread the seedling boxes or use spacers to allow air circulation to prevent overheating and plant them as soon as possible. (Kangas, 2013) If the plug containers appear to be dry, a light mist should be applied.

2.3 Seedling Transplanting

To determine the vigour of stock after storage, outplanting trials are conducted. Samples are taken and outplanted at a controlled nursery environment. This test is designed to provide information on the health of seedlings for planters before transplanting (Bowden, Daintith, Eerden, etc., 1998).

Although the best plans are made, problems still can arise. As a result, at each stage of the planting program, stock condition and suitability should be taken into consideration when making decisions. The following are some common logistical problems that may occur during the planting of Douglas-fir container seedlings (Bowden, Daintith, Eerden, etc., 1998):

- **Seedlings for spring planting are still frozen when they are required for planting.** If this problem occurs, stock should be thawed rapidly, and transported to plantation site as soon as possible. If unfrozen stock is available, assess the feasibility of changing the planting schedule. If the adjusted schedule is feasible, planters can establish a new planting plan.
- **Stock for fall planting is not ready for planting at the proposed delivery date.** This problem may occur because of poor growing conditions in nurseries. First of all, stock condition assessment should be conducted to determine if the stock could be shipped. Stock succulence for Douglas-fir is decided based on the condition of the foliage, stems, and buds. If any of the morphology is considered soft, shipment should be delayed (Bowden, Daintith, Eerden, etc., 1998). Delay shipment until stock is ready to plant. If the problem is severe, cancel the project, and come up with other solutions such as selling the stock and holding stock over. In some situations, if planting is restricted to sites with poor conditions, decisions should be made very carefully. If in doubt, then delay planting.
- **Stock health is in question when transported to plantation site.** This problem may be easy to be observed, if there are symptoms such as dry brittle roots, mould on needles or stems, and insect holes in stems. For seedling damage, actions taken will depend on the severity of damage. If only some trees are affected, get rid of damaged seedlings and provide best ones for planters to allow commencement plantation. If large amounts of seedlings are damaged, do not plant and arrange for destruction of the stock. Diseases can be avoided by reducing stock density during early

growth, keeping temperature cool during transportation, and keeping storage times short for non-frozen seedlings (Bowden, Daintith, Eerden, etc., 1998). Shipping frozen stock decreases the likelihood of diseases development. (FRDA Report, 1990)

- **Planting should be delayed due to late snow melt or other factors.** When spring planting delays occur, seedling transportation may be delayed to early summer. However, planting spring stock in summer will decrease stock vigour due to prolonged storage. Stock destroying usually occurs in this situation (Bowden, Daintith, Eerden, etc., 1998).
- **A scheduled planting site is not ready for planting.** This problem occurs when a site has not been harvested or only partially harvested, or have not conducted site preparation. Possible solutions for this problem are selling stocks and looking for alternative planting sites. If site preparation is delayed, then planters should reassess the site to determine if regeneration objectives can be achieved by raw planting.

Fertilization of plantation sites after planting should be applied to enhance the growth of newly planted Douglas-fir seedlings. Broadcast fertilization distributes materials uniformly on soil surface. Broadcast fertilization is easy to apply and requires inexpensive application equipment. Also, it results in relatively uniform fertilizer distribution, and benefit most crops (Mahler, 2001). However, broadcast fertilization enhances growth in whole stand, including weeds and other undesirable plants (Volz, 2012). Spot fertilization is more specialized. It applies the material only to spots next to certain plants or distributes material near target areas. This can prevent growth of undesirable plants within stands.

2.4 Cost of Douglas-fir Seedling Transplanting

There are various ways of reducing overall costs and improving plantation quality. The total cost of transplanting Douglas-fir container seedlings includes five major components: nursery production cost, transportation cost, storage cost, site preparation cost and planting cost. In some cases, replanting cost is required when planting failure appears.

2.4.1 Container Production

According to Bowden and Daintith (1998), larger seedlings cost more because larger seedlings consume more nursery space. Besides, with the increase of seedling age, production costs increase. The cost of growing Douglas-fir seedlings includes nursery site preparation cost, container cost, labor cost, cost of greenhouse system, and cost irrigation system (Edwards, 2002). Larger seedlings have higher greenhouse cost because they require larger greenhouses and consume more resources for growing. However, larger seedlings have higher values.

2.4.2 Container Transportation

In terms of transportation, remote shipment definitely will be costly. However, in British Columbia, costs of greenhouses heating are much higher than those of remote shipments. (Table 1, Table 2) Therefore, the locations of nurseries should be in coastal region to avoid greenhouses heating costs. There are some approaches to avoid heating such as refrigerated transportation. Before shipping, assessment should be conducted to determine the most cost-effective transportation approach. Transporting larger seedlings costs more (Ministry of Forests, 1992). (Table 4)

Table 4 Transportation cost of small and larger container seedlings in Thompson/Okanagan Region in 2011. *(Source: http://www.for.gov.bc.ca/nursery/headqtrs/storage_transport.htm)*

Stock Type	Transportation Cost (cents/seedling)	
	Spring	Fall
PSB 313B 1+0	.15	.65
PSB 410 1+0	.15	.65
PSB 412 A 1+0	.29	1.80
PSB 515A 1+0	.48	2.70
PSB 615A 1+0	.96	3.60

2.4.3 Stock Storage

Smaller stock types are more cost-effective to ship and to keep in interim storage than larger stock types. (Table 5) For example, store PSB 415D 1+0 seedlings (3.93 cents/seedling) cost almost twice as much as PSB 313B 1+0 seedlings (2.14 cents per seedling).

Table 5 Storage costs of small and larger container seedlings in Thompson/Okanagan Region in 2011. *(Source: http://www.for.gov.bc.ca/nursery/headqtrs/storage_transport.htm)*

Stock Type	Storage Cost (cents/seedling)
PSB 313B 1+0	2.14
PSB 410 1+0	2.14
PSB 412 A 1+0	3.93
PSB 515A 1+0	6.55
PSB 615A 1+0	7.94

2.4.4 Stock Transplanting

Site preparation before planting is important. Site preparation can help to alleviate frost and winter desiccation, cold soil temperature, soil moisture, vegetation composition and animal damage. The most important cost is the overall cost of the surviving seedling at free growing. The cost of failure and replanting can be great. In some cases, cost of replanting is over twice as much as the cost of site preparation (Ministry of Forests, 1992). Other costs include cost of applying site preparation techniques and cost of vegetation management. In addition to the website of Ministry of Forests (2014), the cost of site preparation is approximately $500 per hector in CWH zone.

3. Discussion

From the time seedlings are lifted at the nursery to the time seedlings are outplanted, seedlings can be exposed to many stresses that can adversely impact seedling survival. The key to ensuring planting success are minimizing stress and injury to seedlings during shipping, storage, and handling (Kangas, 2013). Apart from avoiding moisture loss, expose to temperature extremes and physical injury during transportation, storage and planting, acquiring healthy Douglas-fir seedlings is also essential to successful transplanting. In order to improve transplanting of Douglas-fir seedlings in Coastal British Columbia, more efforts are required to discover new technology and management operations. There are three major aspects that we can focus on to improve Douglas-fir seedling survival and growth in coastal British Columbia. They are mycorrhizal inoculation of nursery stock, fertilizing plantation sites, and increasing seedling quality and keeping seedling vigour.

3.1 Mycorrhizal inoculation of nursery stock

Plant nutrition, growth, and survival benefit form mycorrhizae in many aspects, especially the enhanced uptake of water and mineral nutrients such as nitrogen and phosphorus (Castellano and Botanist, 1989). Nonmycorrhizal seedlings can grow well of water and nutrients are supplied in nurseries. However, Castellano reported (1989) that evidences show a lag in growth and a reduction in survival, of nonmucorrhizal seedlings after outplanting. Although mycorrhizal inoculation may not enhance seedling growth in nurseries, it provides seedlings better chance to survive or grow better after being outplanted (Castellano, 1987).

3.2 Seedling Quality and Vigour

Apart from nutrients and moisture from containers, additional nutrients are essential sometimes, especially when shipping. More nutrients provide higher seedling vigour. Agriculture Department of Nanjing University of Technology has indicated (2012) plants can absorb micromolecule rapidly and efficiently. They discovered a kind of nutrient liquor containing micromolecule organism. Experiments show that appropriate use of this nutrient liquor enhances the root growth of celery. Nutrient water with a concentration of 500g/L increased the root growth of celery. Both the length and amount of celery roots increased significantly after being treated by the nutrient water with a concentration of 500g/L. (Figure 7) Although there are no experiments done on forestry crops, we believe that the nutrient liquor discovered by Nanjing University of Technology can be applied to container seedling production. Container seedlings can absorb mircomolecule quickly. In other words, we can make a hypothesis: nutrient water with a concentration of 500g/L can enhance root growth of Douglas-fir seedlings.

Figure 7 Root growth of celery treated by micromolecule with a concerntration of 500g/L (right) and by Hoagland. *(Source from Nanjing University of Technology website)*

Another experiment conducted by Agriculture Department of Nanjing University of Technology indicated (2012) that the nutrient liquor is able to enhance plant vigour in a short period. The experiment showed (2012) that plants in poor conditions could recover in six hours. That means the nutrient liquor could be helpful for keeping seedling vigour during shipping of Douglas-fir container seedlings. If loss of vigour appears, the nutrient water could let the seedlings recover.

3.3 Fertilization of Plantation Sites

CWH zone is the rainiest zone in British Columbia. Nutrients in soils have been rapidly washed away by rainwater. Therefore, fertilization of plantation sites before planting is significant important to survival rate of Douglas-fir seedlings. In coastal British Columbia, Douglas-fir meets the expectation of a positive growth response to fertilization. (Carter, McWilliams and Klinka, 2010) However, in that region, the response of some other species such as coastal western hemlock do not result increased growth.

4. Recommendations

Although a couple of problems in enhancing survival rate of Douglas-fir seedlings during shipping, storage and planting have been solved, additional studies are needed for further improvement. Nonmycorrhizal inoculation of nursery stock, immature transportation system and inappropriate transplanting plans and treatments are three major causes of the reducting growth and survival of Douglas-fir seedlings. Although some suggestions are provided, yet further studies are still needed for management.

In coastal British Columbia, the survival rate of planted Douglas-fir seedlings with fertilize at planting (FAP) treatment was 75% for first year (Coastal Silviculture Committee, 2010). According to the research conducted by Coastal Silviculture Committee (CSC) (2010), combining trenching treatment with FAP treatment, the survival rate of planted Douglas-fir increased to 95% for first year. The cost of applying both trenching and FAP treatments is approximately 20% higher than that of applying only trenching or FAP treatment (Anjou, 1999). Pulling treatments also can be applied during transplanting. Appropriate site treatments during transplanting can significantly enhance seedling survival rate. Before planting, experiments should be done to determine the best site treatments for growth of seedlings.

Mycorrhical inoculation program of Douglas-fir nursery stock is better to be conducted. An effective inoculation program requires appropriate selection of mycorrhizal fungi. Also, the nursery inoculation program must have clear objectives, including reduction in cull percentage, increased growth in nurseries and/or fields and increasing of outplanting survival (Castellano, 1989). A major focus is the selection of mycorrhizal fungi for nursery inoculation based on ecological benefits.

Site fertilization is also an important aspect for enhancing seedling survival and growth. Selection of fertilization method depends on assessment of species, stock density, stand age, forest healthy conditions, and site conditions (Hanley et al, 2006). Evans has reported (2001) that spot fertilization can enhance the growth of newly planted seedlings. Spot fertilization at planting may be particularly beneficial on sites that have not been burned (Evans, 2001).

The nutrient liquor discovered by Agriculture Department of Nanjing University of Technology is able to enhance celery root growth and increase seedling vigour.

However, agriculture department of Nanjing University of Technology only conducted experiments in some agricultural crops such as celery, cucumber and radish. There is no experiment to prove that the micromolecule discovered by Nanjing University of Technology can increase root growth of Douglas-fir seedlings. Experiments should be designed to prove the hypothesis on Douglas-fir seedlings. On one hand, experiments to determine the best concentration of the nutrient water for enhancing root growth of Douglas-fir are essential. Also, experiments to see if the nutrient water can increase seedling vigour are also necessary. On the other hand, further studies are needed to determine the influence of the nutrient water on local environment.

5. Conclusions

In conclusion, in order to enhance the growth and survival of Douglas-fir container seedlings in coastal British Columbia, mycorrlizal inoculation of nursery stock, spot fertilization when planting, and successful transportation and storage system are necessary. Also, the operational tips during seedling production, container transportation and storage, and seedling plantation are important for increasing seedling growth and survival. Although some recommendations already have been provided to enhance Douglas-fir seedling growth and survival in coastal British Columbia, further studies including selection of mycorrlizal fungi for Douglas-fir stock and best use of nutrient liquor discovered by Nanjing University of Technology, are still needed to achieve more confident.

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