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Injury reduction and performance enhancements in tree planters: productivity and quality analysis

Abstract

The Forest Engineering Research Institute of Canada (FERIC) participated in a study involving injury reduction and performance enhancement for tree planters. The tree planters were assigned one of three treatments: consuming a placebo drink supplement, consuming an electrolyte carbohydrate beverage as a drink supplement, or following a physical training regimen for eight weeks prior to the planting season. FERIC determined the productivity and the quality of planting for planters working in the different treatment groups, and also determined if other factors, including experience, gender, time of day, and terrain conditions, influenced the results.

Keywords

Tree planters, Productivity, Injury reduction, Performance enhancement, Quality.

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Introduction

Tree planting in Canada is done by manual labour. The ergonomic aspects of tree planting have been the subject of several studies (Giguère et al. 1991; Giguère et al. 1993; Kutscher 1991; Laing et al. 2002; Smith et al. 1986). Physiological studies of other workers in the forest industry have been done to identify the workload involved and to improve worker health, safety, and productivity (Edwards 1997; Gellerstedt 1997; Kirk and Parker 1996; Smith et al. 1985). The physiological workload of tree planters, specifically, was investigated by Trites et al. (1993). Attention to tree planter safety has been recently emphasized by safety associations (Levesque 2002; OFSWA 2002).

Because of its repetitive nature, tree planting is the source of many strain injuries. With time this constant, unvarying motion may cause temporary or permanent damage to the cartilages, tendons, ligaments, nerves, and muscles involved in producing the motion[1] (OFSWA 2002; Smith et al. 1986). Many injuries occur at the beginning of the season when the body is still unconditioned, as well as at the end of the season when the physical demands of the planting have taken a toll on the muscle mass (Lyons 2001). New planters often start at a higher than sustainable rate and may suffer temporary damage. "Furthermore, many tree-planters have planted for multiple seasons and the long-term implications for osteoarthritis and other degenerative diseases of the musculoskeletal system cannot be ignored. Any program capable of reducing repetitive use injuries in tree-planters would have strong economic, social, and long-term health benefits" (Roberts 2002).

FERIC was invited to participate in a study involving injury reduction and performance enhancement for tree planters to be carried out by Dr. Delia Roberts from the Department of Biology at Selkirk College in Castlegar, B.C. Dr. Roberts has previously worked with high-level athletes in various sports to reduce their fatigue and injury

[1] http://www.tree-planter.com. Website developed by Advanced Safety Management, Vernon, B.C.

during games or events. Her approach to this study was based on the same principles used to train these athletes.

Weyerhaeuser Company Limited's Grande Prairie Operations sponsored Dr. Roberts' study through its Forest Resource Improvement Account (FRIA). Weyerhaeuser's two planting contractors, Coast Range Contracting and Summit Reforestation, also participated.

"Tree planting demands sustained high work output and is associated with high injury rates. Research in exercise physiology has shown that the decline in mental function and physical performance that occur with fatigue can be delayed by diet and specific training. However, the physiology of tree planters as an occupational group has not previously been well characterized" (Roberts 2002).

Objectives

The objectives of the physiological study were to "evaluate physiological and bio-chemical responses to the work of tree planting and to determine if dietary modification or improved fitness levels could enhance planting productivity and quality and/or reduce the number of injuries sustained during planting" (Roberts 2003).

The objectives of the FERIC study were to determine the productivity and the quality of planting for planters working in the different treatment groups and in various terrain conditions.

Methodology

Originally, sixty planters were recruited from two different contractors—35 from one and 25 from the other—and divided into three groups of 20. However, the actual distribution differed slightly as some of the original volunteer planters changed their minds before or during the study, some planters quit their jobs, and others sustained injuries during the study period.

The three treatments were:

- Placebo: This group consumed a placebo drink supplement.
- ECHO: This group consumed an electrolyte carbohydrate beverage (ECHO) (3 mEq/L potassium, 18 mEq/L sodium, 6% carbohydrate)[2] as a drink supplement.
- Training: This group did pre-season physical training for eight weeks following a protocol described by Dr. Roberts (Roberts 2003).

The Placebo and ECHO supplements were not identified to the participants or the study personnel. These treatments were randomly assigned to the planters. Compliance with the assigned treatments was expected, but no monitoring was done.

A range of physiological information was collected by Dr. Roberts and her team prior to the planting startup and at the end of the study (Figure 1). Additional data were collected during the study (Figure 2).

For the productivity study, FERIC timed planters while they planted 50 seedlings. Timing was done throughout the day. If the timing of a planter started before 12:00 noon, the data point went into the AM data set. All other data points went into the PM data set. The AM and PM data were compared to determine the sustainability of the planting rate for the different treatments.

The terrain traversed by the planters during timing was evaluated on a scale of 1–5 for ground strength, ground roughness, and slope (Mellgren 1980). For the statistical

Figure 1. Planter being measured for skin-fold thickness prior to planting study.

[2] Gatorade was the ECHO drink supplement used in this study. Gatorade is a registered trademark of Stokely-Van Camp, Inc., which is a subsidiary of the Quaker Oats Company, Barrington, Ill.

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analysis, a Cumulative Terrain Index (CTI) was developed by adding the three numbers. Therefore, the lowest category was 3 and the highest was 15. See Appendix I for a description of the scales used.

The planting crew bosses recorded the total productivity by planter each day. FERIC used this information to assess productivity by treatment, contractor, gender, and experience.

The centres of 100 m^2 plots were marked, when feasible, after timing a planter. Quality assessment was then done by an independent quality checker based on the company's planting criteria (Weyerhaeuser Canada 2001).

A weather station in a central clearcut recorded temperature and relative humidity throughout the study.

The statistical model used in the data analysis was a split-split plot in a replicated, completely randomized design. Analysis was done using SAS software.[3] Statistically significant differences were reported at the 95% level of confidence.

Results and discussion

The treatments, experience, and gender factors were analyzed and are discussed both in the Timing results and Production sections. The time of day, terrain, and quality factors could only be determined in the timing study.

Data and planter population

The two contractors were different in terms of planter experience and culture. Planters employed by Contractor 1 were primarily students with varying levels of planting experience. Very few planters had more than two or three years of experience, and experience in the study group averaged 1.61 years at the start of the study (Figure 3). Planting crews were limited to about a dozen planters. Contractor 2 employed slightly more experienced planters, and experience for those in the study group averaged 1.67 years. The company employed about 60–65% students, and had larger crew sizes of 16–18 planters.

The timing study involved about 25 000 seedlings covering 25 hours of actual planting time. There were gaps in the distribution, especially in the new planters' (rookie) group and most experienced planters' group in the Placebo treatment (Table IIa, Appendix II). These gaps resulted from several factors: the availability of planters in the different experience classes, the distribution of planters among treatments, and the logistics of timing planters who were widely disbursed in different cutblocks.

Figure 2. Blood sampling in the field.

Figure 3. Experienced planter in action. Notice multi-tasking: walking, looking for planting spot, and reaching for next seedling (CTI=3).

Timing results

During this study, the average time to plant 50 seedlings was 8.5 minutes. On average, it took planters working for Contractor 1 about 11 seconds per tree compared to about 9 seconds for those working for Contractor 2. This difference of about 18% was statistically significant. The following results considers only one effect at a time.

Treatment

Overall, planters in the ECHO group took 8% longer to plant the 50 seedlings

[3] Copyright SAS Institute Inc., Cary, N.C. Version 8e was used in this study.

than those in the Placebo group, and those in the Training group took 7% less. The difference between the Training group and the ECHO group was statistically significant. There was no statistically significant difference between the Placebo group and the ECHO group, nor between the Placebo group and the Training group. Contractor 1's ECHO group took 3% more time, and its Training group took 4% less time, than its Placebo group. Contractor 2's ECHO group took 19% more time than its Placebo group, and its Training group used virtually the same amount of time as the Placebo group.

The planting time data obtained for the planters in the Training group indicate that the training did have some effect on their ability to sustain planting rates. Planters had voluntarily carried out an eight-week exercise program prior to the planting season. However, the extent to which the exercise program was followed is not known as the compliance was not monitored.

The difference between the two contractors in terms of time to plant the 50 seedlings may be attributable to the makeup of the crews and the working conditions. The terrain conditions encountered in the study period were also variable, which could partly explain the high variability in the timing data.

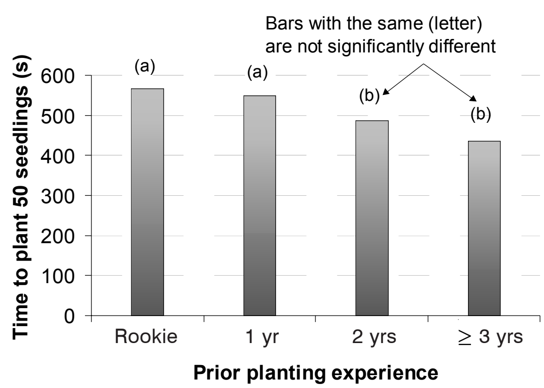


Figure 4.
Time to plant 50 seedlings by level of experience.

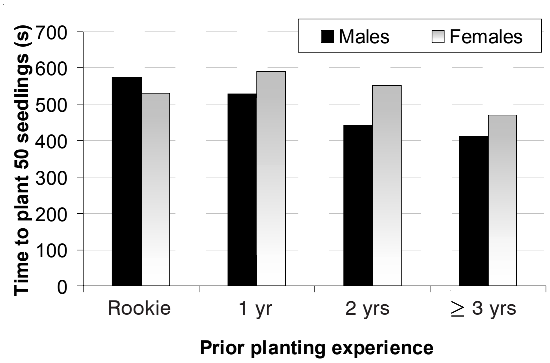


Figure 5.
Comparison of male and female planters by level of experience.

Experience

Planter experience showed clearly in the time it took to plant 50 seedlings (Figure 4). Compared to rookies, those with one year of experience used 3% less time, those with two years of experience used 14% less time, and those with three or more years of experience used 23% less time to plant the 50 seedlings. The times for the most experienced planters are statistically significantly different from rookies and from those with one year of experience. A clear trend of decreasing time required to plant the 50 seedlings is indicated with increasing experience and shows in all combinations of effects.

The differences between levels of experience were also clear when broken down by contractor. Planters with one, two, and three or more years of experience working for Contractor 1 needed 3, 14, and 26% less time than rookies, respectively, to plant 50 seedlings, whereas the planters working for Contractor 2 needed 1, 14, and 10% less time, respectively. For Contractor 2, the smaller difference for the planters with three or more years of experience is likely the result of the limited sample size.

However, rookies gain experience throughout the season, which of course also applies to the other planters, and are only truly inexperienced in the beginning. This study was carried out at the beginning of the planting season, and it can be expected that the speed of planting for all groups would improve during the season.

Gender

The difference in planting time between genders was analyzed. Overall, female planters required 10% more time to plant 50 seedlings compared to male planters. When analyzed by contractor, female planters required 5% more planting time in each case.

Compared to rookie males, rookie females required 8% less time to plant 50 seedlings. Females with one, two, and three or more years of experience required 12, 25, and 14% more time, respectively (Figure 5). The differences are statistically significant.

In this physical, highly demanding type of work, females took longer to plant the

50 seedlings but there were some exceptions. Again, the level of experience was a factor and this was also reflected in the difference between contractors—Contractor 2 had more experienced planters than Contractor 1.

When the data were sorted by treatment, the study found that while females required about the same time regardless of treatment, there were differences between their times and the males' times. Males in the Placebo group required 10% less time than females. Males in the ECHO group took 3% longer, while those in the Training group needed 24% less time than the females. These differences are not statistically significant.

Time of day

No statistically significant differences in time to plant 50 seedlings were found between the morning and afternoon sessions. Overall, 9% more time was required to plant in the afternoon than in the morning.

During the study period, those planters working for Contractor 1 took 7% more time in the afternoon to plant the 50 seedlings than in the morning, but those employed by Contractor 2 used 12% more time (Figure 6). The differences between the morning and afternoon sessions seem logical considering that it was cooler in the mornings and the planters were rested. Overall for the study, the Placebo group needed 10% more time in the afternoon, the ECHO group needed 4% more time, and the Training group took 13% more time compared to the morning.

When the data are sorted by experience, the rookies took 18% more time in the afternoon to plant 50 seedlings compared to the morning. For those with one and two years of experience, the additional times needed in the afternoon compared to in the morning were 6% and 7%, respectively, and the most experienced planters needed 12% more time (Figure 7).

The difference in time between morning and afternoon was relatively small but was fairly consistent for each level of experience, gender, treatment, and contractor. There were more data points for the afternoon because effective planting time was longer. Distance from camp and difficult access to the blocks often limited the amount of planting time before noon.

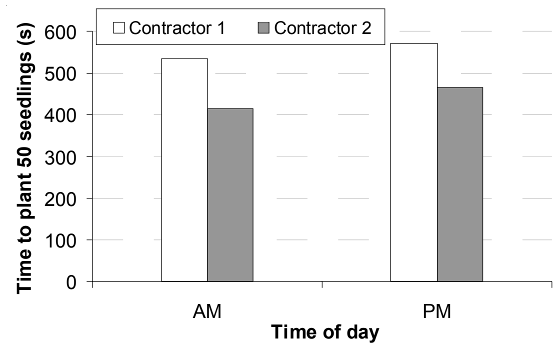


Figure 6. Comparison of morning and afternoon productivity by contractor.

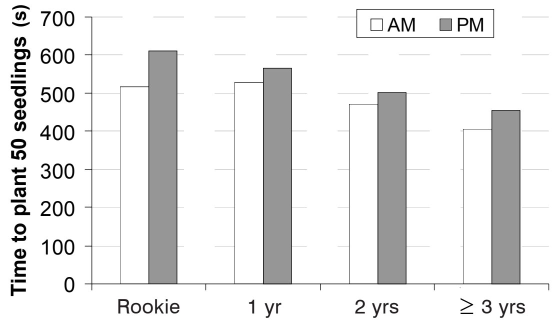


Figure 7. Comparison of time required to plant 50 seedlings by level of experience and time of day.

Overall, males took 9% more time in the afternoon to plant 50 seedlings and females took 7% more time. Compared to males, females took 11% longer to plant 50 seedlings in the morning and 9% longer in the afternoon.

Terrain

The Cumulative Terrain Index (CTI) is the sum of the three scaled numbers denoting ground strength, roughness, and slope (Figure 8). It was used to classify the terrain, and its effect on planting time is shown in Figure 9. Only the difference between the two highest categories (8 and 9) and the lower ones (3 to 7) are statistically significant, although there was no significant difference between categories 5, 6, and 8. This analysis does not consider the individual components of terrain, only the cumulative effect. There was not enough variability in the terrain to allow an analysis based on each separate combination. Thus, several combinations (e.g., 2,3,3; 2,2,4; 3,4,1 etc.) of ground strength, roughness, and slope would result in a CTI of 8 and affect planting time.

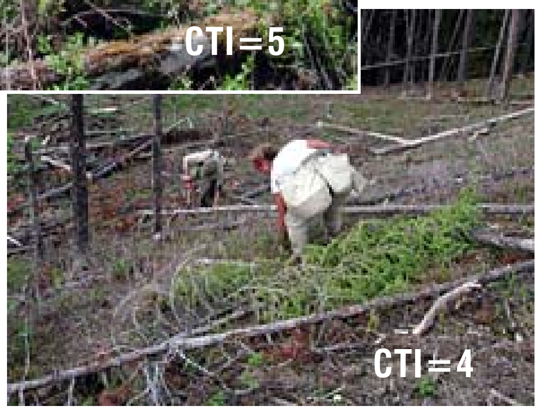


Figure 8. Roughness is one of the factors in the Cumulative Terrain Index (CTI).

There has to be considerable wetness, debris, and slope before the cumulative effect of these factors influence the planting performance. In the study, few places exhibited these characteristics in combination even though many spots had a high rating for one of the factors. The trend for the higher categories of CTI is therefore somewhat fragile.

Another uncertainty in these results originates from the potential differences in classifying the terrain by the different study personnel. Each person doing the timing may have had a somewhat different view of how to classify a site since this was based only on observation without any measurements.

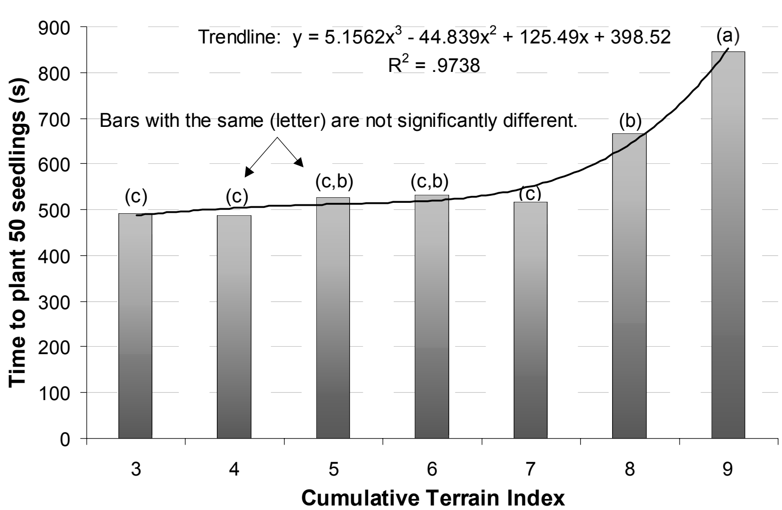


Figure 9. Effect of the Cumulative Terrain Index (CTI) on the time to plant 50 seedlings. A trendline is shown.

Some site preparation such as mounding had been done in some blocks. While it was not considered in this study, site preparation can have considerable influence on productivity. However, timing was carried out in many blocks so that both site-prepared and raw ground were well represented. In addition, there was anecdotal information from the planters that some preferred site-prepared ground and others raw ground. This suggests that timed productivity in this study was not compromised by not considering site preparation.

Quality

The overall quality achieved was 96.9%. The quality achieved for Contractor 1's planters was 96.6%, based on 74 plots surveyed. The planters working for Contractor 2 usually worked in pairs, and it was very difficult to associate planted seedlings to a specific planter. Consequently, only 18 quality plots were established for planters in that operation. Based on these plots, the quality achieved was 97.3%. Minimum quality for the contractors to receive full payment was 95%. The quality achieved by contractor, experience, and treatment are shown in various combinations in Tables IIIa, IIIb, and IIIc, Appendix III. The Training group planters with experience achieved the lowest quality, but the number of plots per group is limited so the data may not accurately reflect the quality.

Planting quality was not statistically significantly different between any of the factors analyzed in the study. The crew bosses checked the planting quality on an ongoing basis and corrective measures were implemented immediately when problems were found. The rookies' quality was higher, perhaps because they were watched more closely. The more experienced planters knew how to keep productivity up while maintaining the minimum quality required.

Production

The production data were analyzed for differences between contractors, treatments, experience levels, and genders. These data show the same trends as the timing data. There was, however, no statistically significant difference between the contractors as indicated by the timing data. This may be because the data give an overall picture rather than a snapshot in time where individual efforts have a greater influence.

The total production per day by planter was obtained from the planting contractors. The two contractors had somewhat different philosophies in determining the length of the workday. Contractor 1 was flexible in the sense that longer days were allowed depending on the location of the block and if the block could be completed by spending some extra hours of planting. Meal times were adjusted accordingly. Contractor 2 worked on a fixed schedule with meals always served at the same time. Thus, comparisons of daily production should consider these differences although adjustments for them could not be made in the data analysis. Days with scheduled time less than the normal nine hours for Contractor 1 were not included in the analysis.

Based on the available data, which does not include the precise hours worked per day by each contractor, the average daily production for the study period was 1904 and 1948 seedlings per day per planter for Contractors 1 and 2, respectively. This 2% difference is not statistically significant. The average daily production by category is shown in Table IIb, Appendix II. In the following sections, only one effect is considered at a time.

Treatment

Differences in average daily production between the treatment groups were not statistically significant. The ECHO group had 3% lower production and the Training group had 6% higher production than the Placebo group (Figure 10).

The productivity differences between treatment groups were small and not statistically significant but showed the same trend as the timed planting. As in the timed planting, the Training group had higher production than those without prior physical training. This suggests that prior conditioning is important and should be considered as a prerequisite for planting work. Not only is the production higher, but the injury/infection rate was also lower according to the physiological study (Roberts 2003). This finding is supported by Miranda et al. (2001) in a study of Finnish forest industry workers.

Experience

Average daily production by experience is shown in Figure 11. Only some differences are statistically significant, but the general trend of increased production with increased level of experience is clear and follows the trend found in the timing data.

Those with two and three or more years of experience have 25% and 32%, respectively, higher production than rookies. These differences are statistically significant. Also, there is a statistically significant difference of 20% between those with one year of experience and those with three or more years of experience.

Having the right mix of rookies and experienced planters could be important in achieving production targets. While more

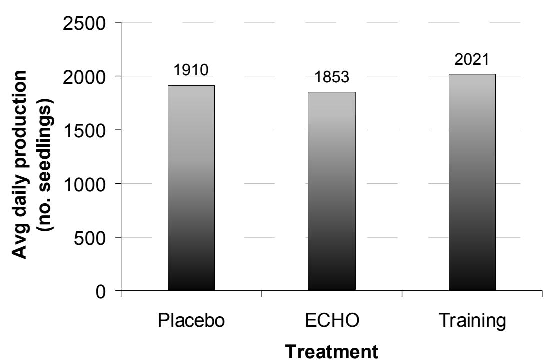


Figure 10. Average daily production by treatment.

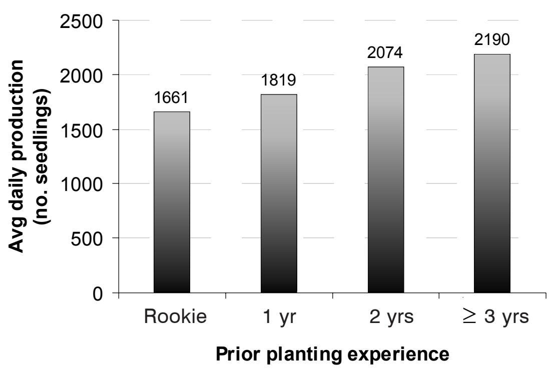


Figure 11. Average daily production by level of experience.

experience results in higher production, the study did not separately consider experiences above three years at the start of the season. However, there seems to be a somewhat lower rate of increase in production after two years of experience. Intensive training of rookies in planting technique and spot selection at the start of the season may speed the rate of increased production as the season progresses.

Gender

The female planters had on average 6% less daily production compared to male planters (Table IIc, Appendix II). The lack of prior experience had the greatest effect on differences in production between male and female planters, with about 8–10% lower production for female planters compared to males. This trend was also seen in the timing results with the exception that rookie females were somewhat faster than rookie males, but the sample size in that case was small.

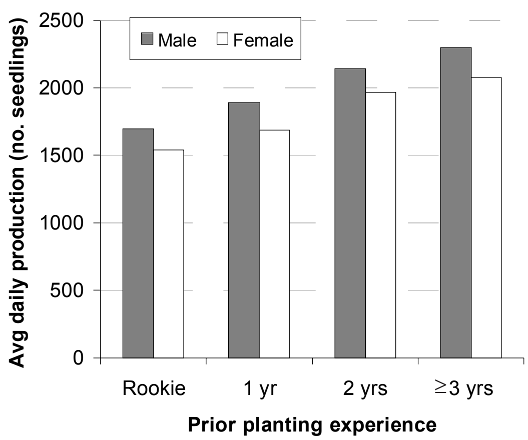


Figure 12. Average daily production by gender and experience.

Male planters with one year of experience had 12% higher production than rookie males, while the difference for females was 10% (Figure 12). Males with two years of experience had 14% higher production than those with one year, while the difference for females was 16%. The increase levelled off so that planters with three or more years of experience had only 7% and 6% higher average daily production for males and females, respectively, compared to those with two years of experience.

The general trend of lower productivity for female planters seen in the timing data was confirmed in the productivity data. This is not a surprising result considering the heavy physical work. However, several female planters outperformed the males, so this suggests that technique and physical fitness play an important part in planter productivity.

Stock type

The seedling stock planted during the study period was almost entirely made up of either spruce or pine in Styroblock 415B or 410A and B sizes. No attempt was made to analyze the data based on stock type or size. A smaller stock size would have changed the production results as planters would be able to carry more seedlings and not have to return as often for bag-ups. However, if the time between bag-ups is increased to more than an hour, there may be a physiological effect unless the planter maintains the blood glucose level (Roberts 2002). This could have changed the results found in this study.

Figure 13. Average daily production by planter and experience for Contractor 1.

Contractor

Figure 13 shows average daily production for the study period by individual planters working for Contractor 1. The planter's corresponding prior experience is shown with a black triangle in the figure. The trendline for the prior experience shows good correlation with the trendline for the planters' production. Figure 14 gives the same information for Contractor 2, and also shows a good correlation between experience and production.

When the average daily production is plotted by date, there is a distinct increase in production as time goes by for Contractor 1, while this is not as well defined for Contractor 2 (Figure 15).

The production in the periods between shift breaks was different between contractors. Figure 15 shows the average contractor output by date for full days of planting. The crews working for Contractor 1 worked for five days between breaks, while those working for Contractor 2 had a four-day planting period between breaks. It appears there is a reduction in output for Contractor 1 on the fifth day before each break. This is consistent with the shorter scheduled workday that allows the planters time to have an evening of rest and recreation in town.

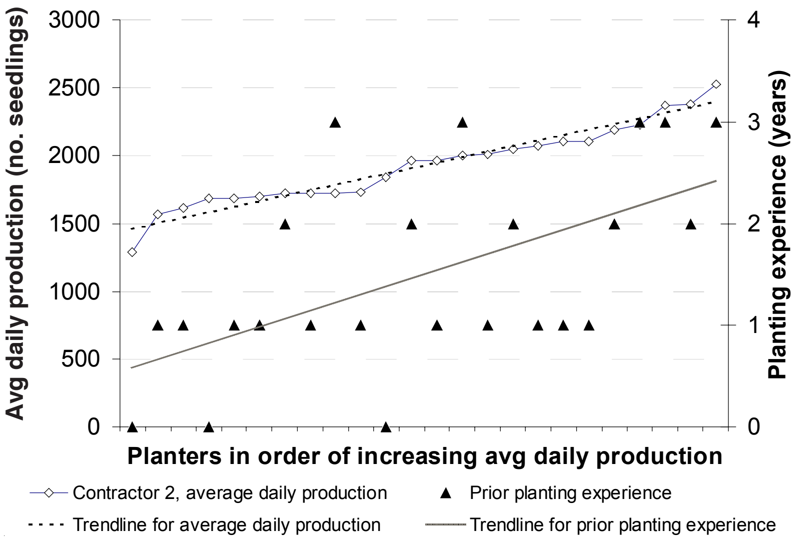


Figure 14. Average daily production by planter and experience for Contractor 2.

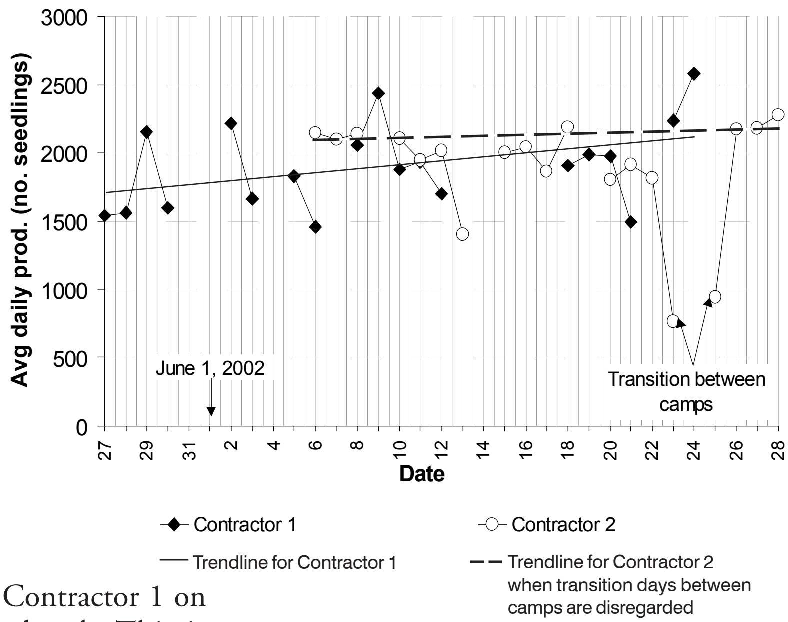


Figure 15. Average daily production by date and contractor.

Weather conditions

The daily maximum temperature and relative humidity data are shown in Figure 16.

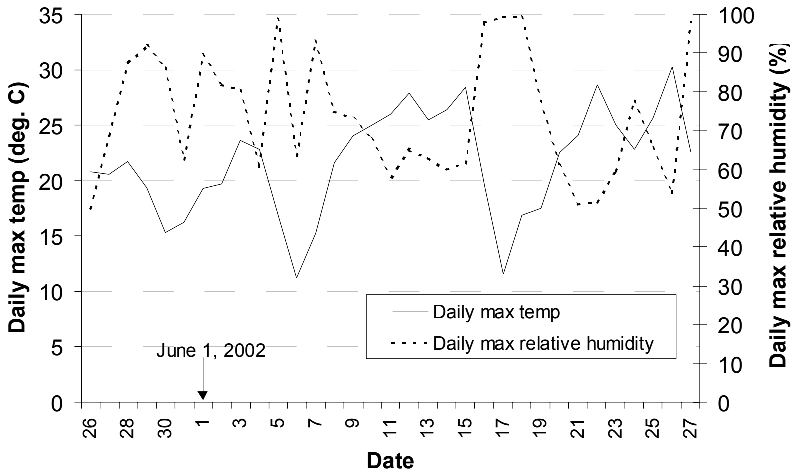
The air temperature was recorded as daily maximums and minimums as well as at 15-minute intervals (data not shown). A substantial drop in temperature was recorded in the beginning and in the middle of June with the daily maximum dropping to below 12°C. A corresponding increase in relative humidity was also recorded. No weather-related effects were found to be directly attributable to the timing or productivity results.

General observations

The fact that the planters volunteered to participate, even though some may have been reluctant volunteers, may have biased the results somewhat compared to a study of randomly selected planters. Volunteers, by nature, are typically more motivated to participate in an activity and follow instructions. However, this type of study could only be done with volunteers.

The results of the timing correspond well with the average daily production data. The planters generally were not bothered by the presence of the observers and it is unlikely that the planters changed their pace as a result. However, their productivity showed considerable variability. Some of the

Figure 16.
Daily maximum temperature and relative humidity recorded in a cutover central to both contractors' operations.



One of the confounding factors here is compliance. Since the planters themselves were responsible for adhering to the treatment regime, there is no record of the amounts of ECHO or Placebo that were consumed. It is known, anecdotally, that some planters did not drink the supplied ECHO or Placebo every day and that some switched between the drinks. Many planters found the taste of the drink supplements to be less to their liking and drank more water instead or diluted the supplements.

The planters were given a hands-free hydration system that could be worn while planting to provide them with an easily accessible drink. However, few used this system in the intended way, and many planters left the hands-free system at the cache and drank from it only at bag-up times. Because of the easy terrain conditions and the size of the planting stock, most planters were back at the cache for refills in less than an hour. This allowed them an opportunity to eat and drink frequently, and probably prevented their blood sugar levels from dropping enough for fatigue to be an important factor (Roberts 2003). It has been previously demonstrated that fatigue and nutrition affect performance among forest workers (Brown-Haysom 2000, Edwards 1997). For a comprehensive discussion of the physiological factors, see Roberts (2003).

variability reflected different terrain and maybe weather conditions, and some is related to the inherent differences in experience and motivation among planters.

There was a statistically significant difference in the timing results between the ECHO and the Training treatments. The hypothesis was that the ECHO would provide the planters with a more consistent level of glucose in their blood and allow them to maintain a high rate of planting throughout the day. However, the data seem to indicate that there was no effect between treatments, most likely because the planters' energy reserves were not depleted during the periods between replenishing their seedling bags (Roberts 2003).

The timing data suggest the planters in the ECHO treatment took 8% longer to plant the 50 seedlings compared to those drinking the Placebo supplement. The day temperatures during the study period were moderate and thus limited the need for fluid consumption. Had the temperatures been higher, there would have been a higher intake of fluids and any differences between the ECHO and the Placebo treatments may have been more pronounced.

Conclusions and implementation

Tree planters that had taken the pre-season physical training performed better than those that had not. This could be the basis for offering an incentive to planters willing to carry out a prescribed training program prior to planting. Such incentives or perks could include reduced or no camp fees for a period of time, free items of planting equipment, t-shirts or other items of recognition, and perhaps travel cost assistance. It could also be a hiring criteria for contractors. Creating a category of planters (e.g., "elite planters") with a prerequisite of physical training and on-line training[4] may attract planters that have potential for high production and keep them coming back. Recognition and exclusivity are motivating factors.

In this study, the ECHO supplement had no effect on the productivity of the planters.

There is a clear trend showing that production increases with more experience. Extensive training of rookie tree planters at the start of the season may be beneficial in accelerating their rate of increase in production. Experience levels could also be considered when the crews are made up so that adequate supervision is provided to less experienced planters. This could be offset by less supervision for crews of experienced planters as long as quality is checked regularly. Quality, based on the study plots, was high in general with the best results achieved by the rookies in all treatments. The Training group may have traded quality for production.

Female planters have about 6% less production compared to males, with some exceptions. This could be a consideration when crews are assembled.

The time required to plant 50 seedlings was 9% longer in the afternoon than in the morning. This suggests that it would be useful to maximize the productive time in the morning. Improved access would reduce the time spent travelling to the site and increase the time available for planting.

There was no statistically significant difference between contractors in terms of average daily production. This is interesting considering the flexible versus fixed length of the planting day, and the difference in the number of days worked between breaks. Increased production during long workdays was offset by reduced production on the shortened fifth day before the break. The average daily production for the contractor working a 4-day shift and with a fixed planting-day length did not vary as much. For example, over a period of two months, the theoretical number of breaks would be 10 with a 5-day shift compared to 12 for the 4-day shift. In practice, many other factors would come into play.

Important:
Confounding factors may have influenced the results of this study. The data represent the timing of about 57 planters planting 25 000 trees over 25 hours, as well as the production over about 19 planting days. However, several thousand people plant hundreds of millions of trees every year in western Canada in many different work, weather, and terrain conditions. Conclusions drawn should be seen in this light.

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Appendix I

Terrain classification factors (after Mellgren 1980)

Ground strength

Class	Main factor
Class 1 - very good	very freely drained
Class 2 - good	freely drained
Class 3 - moderate	fresh
Class 4 - poor–very poor	moist-wet
Class 5 - very poor	very wet

Roughness

Class	Obstacle height or depth (cm)	Number of obstacles per 100 m^2
Class 1 - very even	10–30	0–4
Class 2 - slightly uneven	10–30	>4
	30–50	1–4
Class 3 - uneven	10–30	>4
	30–50	5–40
	50–70	1–4
Class 4 - rough	10–30	>4
	30–50	5–40
	50–70	1–4
	70–90	1–4
Class 5 - very rough	all combinations more severe than Class 4	

Slope

Class	Slope (%)
Class 1 - Level	0–10
Class 2 - Gentle	10–20
Class 3 - Moderate	20–33
Class 4 - Steep	33–50
Class 5 - Very Steep	>50

Appendix II

Data distribution and average daily production

Table IIa. Number of planters and collected data points

	Number of planters (data points)		
	Placebo	ECHO	Training
Experience (years)			
0	2 (7)	4 (38)	4 (24)
1	12 (101)	6 (51)	7 (59)
2	6 (62)	4 (39)	3 (18)
≥3	0 (0)	6 (52)	4 (38)
Total	20 (170)	20 (180)	18 (139)

Table IIb. Average daily production by treatment, experience, gender, and contractor

	Average daily production (no. of seedlings)						
	Contractor 1			Contractor 2			Contractors 1 & 2
	Male	Female	Both genders	Male	Female	Both genders	Male & female
Placebo							
Rookie	0	0	0	1842	0	1842	1842
1 yr	1924	1577	1806	1818	0	1818	1809
2 yrs	2423	1922	2070	2112	2379	2210	2137
≥3 yrs	0	0	0	0	0	0	0
All levels	1987	1715	0	1914	2379	0	1910
ECHO							
Rookie	1481	1688	1533	0	0	0	1533
1 yr	1694	1609	1651	1857	0	1857	1777
2 yrs	2097	1816	1958	0	0	0	1958
≥3 yrs	2383	1972	2122	2000	2050	2033	2077
All levels	1819	1805	0	1890	2050	0	1853
Training							
Rookie	2181	0	2181	1685	1287	1539	1788
1 yr	0	1828	1828	1994	1686	1920	1874
2 yrs	2703	0	2703	1838	0	1838	2121
≥3 yrs	2348	2347	2348	2396	0	2396	2371
All levels	2402	1947	0	2006	1510	0	2021

Table IIc. Average daily production by treatment, experience, and gender

	Average daily production (no. of seedlings)	
	Male	Female
Placebo		
Rookie	1842	0
1 yr	1891	1577
2 yrs	2218	2069
≥3 yrs	0	0
All levels	1955	1821
ECHO		
Rookie	1481	1688
1 yr	1818	1609
2 yrs	2097	1816
≥3 yrs	2197	2012
All levels	1845	1866
Training		
Rookie	1933	1287
1 yr	1994	1800
2 yrs	2121	0
≥3 yrs	2379	2347
All levels	2121	1837
Overall	1966	1843

Appendix III

Quality control plot results

Table IIIa. Quality control plot results by contractor and experience

	Experience			
	Rookies	1 yr	2 yrs	≥3 yrs
Contractor 1	97.3	97.1	95.8	95.3
Contractor 2	100.0	96.3	100.0	97.8
Overall	97.8	96.9	96.0	96.2

Table IIIb. Quality control plot results by contractor and treatment

	Treatment		
	Placebo	ECHO	Training
Contractor 1	97.7	97.9	92.9
Contractor 2	100.0	95.1	97.8
Overall	97.9	97.4	94.6

Table IIIc. Quality control plot results by experience and treatment

	Treatment		
	Placebo	ECHO	Training
Rookies	100.0	96.8	100.0
1 yr	98.7	97.3	93.7
2 yrs	95.7	98.2	92.7
≥3 yrs	-	97.6	95.0