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Effects of time of year and chainsaw operator experience on tree felling safety

Piotr Czyżowski[(1)], Natalia Korcz[(2)], Marian Flis[(1)][⊠]

[(1)] Department of Animal Ethology and Wildlife Management, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland

[(2)] Department of Natural Foundations of Forestry, Institute of Soil Science and Environment Management, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland

ABSTRACT

This study evaluates the effects of season and the length of service of chainsaw operators on the ability to achieve felling guidelines based on Occupational Health and Safety Regulations. The study consisted of measurements of stump cuts on three tree felling plots in two seasons: winter (in the presence of snow cover) and spring. In total, 90 stumps, 30 in each plot, were measured. Plots were similar in species composition, age, and forest habitat type, while variability in the study resulted from the age and occupational experience of saw operators. In addition, escape routes were assessed to evaluate whether they were in accordance with forest management Occupational Health and Safety Regulations.

Season had no effect on stump attributes except for stump height, for which there was a significantly greater number of excessively high stumps in winter than in spring. More experienced saw operators were more competent in making precision saw cuts (*e.g.*, depth of the notch cut, width of the hinge) and made fewer errors than a less experienced worker. In contrast, all escape routes prepared by a less experienced saw operator were prepared correctly, while about 8% of the escape routes prepared by longer-serving workers were incorrect. Since the preparation of escape routes depends only on compliance with Occupational Health and Safety Regulations and does not require special professional expertise, incorrect escape routes prepared by longer-serving saw operators probably reflect a disregard for risks caused by not following prescribed safety protocols.

KEY WORDS

saw operator's work experience, season of the year, stump attributes, tree felling

Introduction

Timber harvesting involves a series of coordinated activities related to planning, tree felling, and skidding logs to landings, as well as further transport of wood. The most difficult step in this process is tree felling, which is still often performed with manual and machine-assisted techniques using petrol chainsaws (Melemez and Tunay, 2010; Leszczyński and Jałowska, 2011; Robb and Cocking, 2014; Moskalik *et al*., 2017). Tree felling is difficult and relatively dangerous (Iftime

et al., 2020), as shown by statistics for accidents associated with forestry work in Poland (Nowacka and Moskalik, 2013). Data from the Central Statistical Office in Poland indicates there were 373 accidents in the forest sector in 2020, with the vast majority caused by unsafe work procedures (GUS, 2021). Saw operators engaged in felling trees are exposed to a number of dangers related to the profession and environment, *e.g.*, weather conditions during felling, the age and species composition of the forest stand, habitat type, and many other factors (Suwała and Jodłowski, 2002; Cividino *et al.*, 2013; Grzywiński *et al.*, 2013; Nowacka, 2013; Dos Santos and Migunga, 2014; Buczaj *et al.*, 2020; Ferreira *et al.*, 2022). Season of the year has a strong effect on felling practices. Winter is a particularly difficult time for tree felling due to the presence of snow and ice, and low temperatures that adversely affect worker comfort (Suchomel and Belanova, 2009). The work of a chainsaw operator requires great skill acquired through training and experience. Professional experience related to the length of service is considered the main factor guaranteeing the safety and correct execution of tree felling (Brzózko *et al.*, 2016).

The aim of this study was to evaluate the effects of season and length of service of chainsaw operators on sawcut safety when felling trees and establishing safe escape routes.

Material and methods

This study evaluated measurements of stump and stump sawcuts on three plots where felling occurred in two seasons: winter (in the presence of snow cover) and spring. In total, 90 stumps were measured (30 randomly selected stumps on each plot). Stumps were selected randomly by numbering all stumps in a plot and drawing 30 numbers for each area. Plots were similar in species composition, age, and forest habitat type, so that variability in results was attributable to the age and professional experience of three chainsaw operators, each of whom was assigned to one of the plots (Table 1).

The following stump and sawcut features were measured:
– Stump height (Wp); two measurements were made (Wp1 and Wp2) at a distance of 50 cm from the edge of the stump at an angle of 90° (angle of the level) on both sides away from the felling direction. In this way, minimum and maximum stump heights were obtained and their average reduced errors resulting from topography;
– Notch cut depth (Grp) measured in the middle of the hinge stump with an accuracy of ±0.5 cm;
– Hinge width (Sz) measured in the middle of the hinge length (with an accuracy of ±0.2 cm; and

Table 1.

Characteristics of saw operators and study plots

Plot number	1	2	3
Age of saw operator [years]	59	53	45
Work experience of saw operator [years]	28	22	2
Plot area [ha]	8.04	6.02	5.92
Forest habitat type	dry coniferous forest	moist mixed coniferous forest	fresh mixed coniferous forest
Plant association	*Leucobryo-Pinetum*	*Querco roboris-Pinetum*	*Querco roboris-Pinetum*
Stand	Scots pine	Scots pine	Scots pine
Stand age [years]	93	123	98

– Height of the safety threshold (difference between shear cut and notch cut) (Wpb) measured in the middle of the stump with an accuracy of ±0.2 cm.

Additionally, assessment was made of whether escape routes were laid out in accordance with Occupational Health and Safety Regulations for forest management. If any element of the escape route did not follow the guidelines, the escape route was considered incorrect (Instrukcja, 2012) (Fig. 1).

Results from the tree felling plots were compared with tree felling guidelines from the Occupational Health and Safety Regulations, which define felling in relation to stump diameter (Manka, 2007):

– The stump should not be higher than $1/4$ of stump diameter;
– The notch cut should have a depth of $1/4$ to $1/3$ of stump diameter;
– The safety threshold should be approximately $1/10$ of stump diameter;
– Hinge width should be approximately $1/10$ of stump diameter;
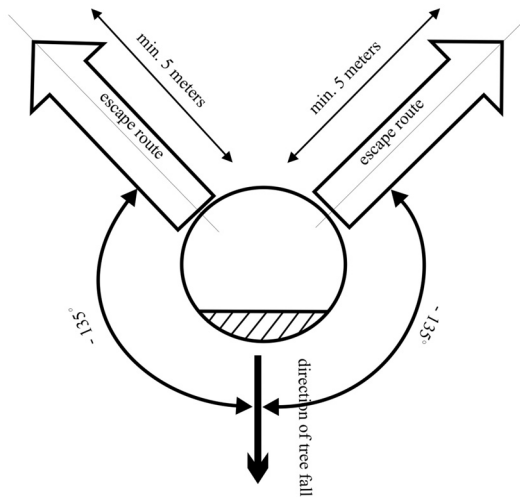– Cut surfaces should be horizontal.

Fig. 1.

Instruction for execution of escape routes in a flat area; authors' scheme based on the Occupational Health and Safety Regulations (Instrukcja, 2012)
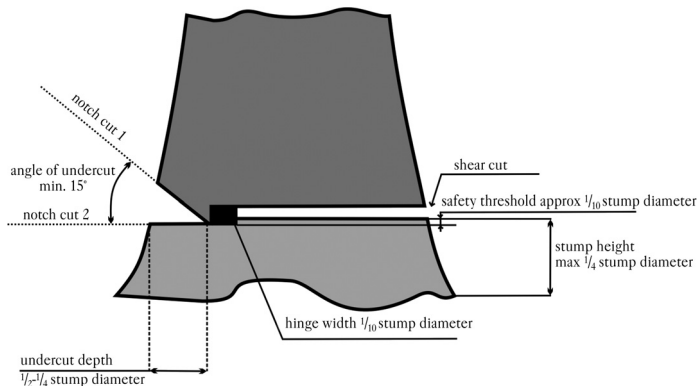

Fig. 2.

Felling attributes and principles of measurement; authors' scheme based on Chodkowska and Gendek (2009)

Since chainsaw operators make cuts without devices to help achieve cut depths and cut locations specified in Health and Safety guidelines, the following deviations from the guidelines are accepted:

- Stump height can deviate up to 5% from the guideline value;
- A 5% deviation from target values is accepted for cut depths;
- A 5% deviation is also acceptable for safety threshold height;
- Hinge width may deviate from the guideline value by 5%;
- The cut surface should not deviate more than 2.5% from horizontal.

Statistical analysis

Based on measurements of their attributes, stumps were classified as correct (*i.e.*, following guidelines) or incorrect. The research hypothesis was that there would be effects due to season, felling plot, and saw operator on stump height and sawcuts. The relationships between these variables were determined using the Chi^2 independence test. All variables deviated from the normal distribution, verified using the Shapiro-Wilk test. Statistical calculations were performed using Statistica 13.1 (TIBCO Software Inc., 2017).

Characteristics of the study area

Study plots were in a forest district in the Central-Eastern Poland macroregion. The region has a transitional climate typical of the Polish lowlands, with features of continentalization. It is characterized by considerable seasonal differences in temperature, from warm summers to harsh winters. The average temperature is 17.0°C in summer and –3.0°C in winter. Total annual precipitation ranges from 600-700 mm and the growing season lasts up to 200 days. In general, climatic conditions are favourable for forest management.

The characteristics of the study plots and chainsaw operators are presented in Table 1. The first two positions were staffed by operators of similar age and seniority, while the third position was occupied by an operator a decade younger than the others and with significantly shorter seniority. There were pine stands on all three plots, and they differed slightly in the degree of moisture and fertility

Results and discussion

Stump height was incorrect significantly more often in winter than in spring (Pearson's Chi^2=4.7522; p=0.0293) (Table 2). Since there is no guideline for minimum stump height, all incorrect stump

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Table 2.

Correct and incorrect stump attributes in different seasons

Stump attribute	Season	Correct [%]	Incorrect [%]	Pearson's Chi^2	p-value	Error deviation [%] (plus/minus)
Stump height	Spring	72.2	27.8	4.7522	0.0293*	–
	Winter	56.7	43.3			–
Notch cut depth	Spring	85.6	14.4	0.9742	0.3236	8/92
	Winter	80.0	20.0			6/94
Hinge width	Spring	35.6	64.4	0.3782	0.5386	47/53
	Winter	40.0	60.0			15/85
Safety threshold height	Spring	38.9	61.1	2.7160	0.0993	42/58
	Winter	51.1	48.9			36/64
Escape routes	Spring	96.7	3.3	1.6941	0.1931	–
	Winter	92.2	7.8			–

* Statistically significant differences ($p<0.05$)

heights were due to stumps being too tall. The greater proportion of incorrect stumps in winter versus spring can be explained by the difficult working conditions and snow cover. Saw operators can have greater difficulty in winter because of the need to clear snow from around the base of the tree and to make a stable, non-slippery area to work in. It has been reported (Suchomel and Belanova, 2009) that 190 of 209 accidents related to tree felling occurred in unfavourable meteorological conditions, with rain, dew, or snow cover deeper than 1 cm being the most common adverse phenomena. Accidents were usually a result of slips and falls on inadequately prepared, slippery surfaces. This emphasizes the importance of taking effective safety measures and following procedures recommended for tree felling.

The assessment of the correctness of the height of stumps achieved by the saw operators on the compared plots showed that, depending on the plot, the proportion of correct cuts was nearly twice as high as that of stumps with incorrect parameters (Table 3). The lowest percentage of incorrect stump heights were made by the least experienced saw operator. This may indicate that the worker with less experience followed guidelines in the harvesting instructions more strictly compared to workers with more experience, although differences were not statistically significant (Chi^2=0.915; p=0.633). This result differs from the results of Brzózko *et al.* (2016), who showed that saw operators with the least experience made excessively tall stumps. Brzózko *et al.* (2016) suggest that experience has a positive effect on achieving correct saw cuts and stump heights.

Most notch cuts were correct, however, incorrect notch cuts were about 5% more likely with winter logging (Table 2). There was a clear tendency for notch cuts to be shallower than recommended (over 90% of the notch cuts). In comparison, excessively deep notch cuts were found by Chodkowska and Gendek (2009) in a logged fresh mixed broadleaved forest.

There was a statistically significant effect of saw operator experience on notch cut depth (Pearson's Chi^2=6.158; p=0.046) (Table 3). Significantly more incorrect notch cuts were made by the youngest, least experienced operator than the oldest, longest-serving operator. Interestingly, 96% of the incorrect notch cuts were too shallow rather than too deep. This result shows the importance of saw operator experience and skill in notch cutting, since saw cuts for tree felling are made without the use of measuring instruments. Inexperienced saw operators are involved in a substantial percentage of tree felling accidents. Young workers not only are more likely to make sawcuts that raise the risk of injury, but they also have poorer ability to

Table 3.

Stump attributes in relation to operator age and experience

Stump attributes	Plot	Age/Saw operator work experience [years]	Correct [%]	Incorrect [%]	Pearson's Chi²	*p*-value	Error deviation [%] (plus/minus)
Stump height	1	59/28	61.7	38.3			–
	2	53/22	63.3	36.7	0.6304	0.7297	–
	3	45/2	68.3	31.7			–
Notch cut depth	1	59/28	90.0	10.0			17/83
	2	53/22	85.0	15.0	6.1572	0.0460	0/100
	3	45/2	73.3	26.7			6/94
Hinge width	1	59/28	38.3	61.7			43/57
	2	53/22	46.7	53.3	4.3015	0.1164	34/66
	3	45/2	28.3	71.7			19/81
Safety threshold height	1	59/28	36.7	63.3			47/53
	2	53/22	50.0	50.0	2.5589	0.2782	27/73
	3	45/2	48.3	51.7			42/58
Escape routes	1	59/28	91.7	8.3			–
	2	53/22	91.7	8.3	8.4007	0.0150	–
	3	45/2	100.0	0.0			–

assess dangerous work situations and are more likely to make incorrect decisions under the influence of stress and emotions. This is undoubtedly related to the lack of professional experience (Bentley *et al.*, 2005).

The proportion of incorrect hinge widths was high in both seasons. The proportion of incorrect hinge widths was approximately 4% higher in spring than in winter, but the effect of season was not significant (Table 2). An equal number of hinge width errors were too deep and too shallow in spring, whereas in winter 85% of the incorrect hinges were too narrow.

The saw operator with the least experience had the lowest percentage of correct hinges, with over 80% of their incorrect hinges being too narrow (Table 3). From a safety perspective, this error is significant as it can result in hinge breakage and loss of control over the falling tree. As shown by Brzózko *et al.* (2016), experience does not guarantee hinge correctness, as both experienced and inexperienced workers make similar mistakes, emphasizing the importance of training to minimize this error.

The safety threshold height was incorrect more often in spring than in winter (Table 2). Since according to the Chi² test, the difference was close to, but not, significant (Chi²=2.7160; *p*=0.0993), this result may indicate the influence of season on implementing the safety threshold. Slightly more safety thresholds were too high, rather than too low.

Differences in the safety threshold did not differ significantly between saw operators, although the most experienced saw operator made more than 60% of the thresholds incorrectly (Table 3), usually because the thresholds were too high. Similarly, Brzózko *et al.* (2016) report that most saw operators do not focus on making a correct safety threshold. This suggests that they often ignore the importance of this attribute, although it is important for safe felling, especially in the case of leaning trees or felling trees on slopes.

Season did not significantly affect the correctness of escape route layout (Table 2), however, the proportion of incorrect escape routes in winter (7.8%) was more than twice that in spring (3.3%). In addition, while more than 90% of the escape routes prepared by all saw operators were correct,

only those prepared by the least experienced operator were all correctly laid out (Table 3), significantly more (p=0.01) than the more experienced workers. This indicates that the least experienced saw operator, with only 2-years work history, was focused on this aspect of safety. Despite having more than 20-years experience, the other workers at times disregarded the need to correctly prepare escape routes.

As shown by Grzywiński *et al*. (2020), season significantly affected the time required to fell a tree. Their analysis of tasks performed by saw operators shows that felling time is significantly longer in winter due to difficulties caused by low temperature and snow, which impede preparation of the felling site.

Gendek *et al*. (2018) report that most saw operators in Poland are between 36 to 50-years-old. They showed that workers with longer periods of service tend to strongly believe in their occupational skills. This attitude may consequently lead to routine execution of work that do not comply with the Occupational Health and Safety Regulations and other safety recommendations (Brzózko *et al*., 2016). It has been reported (Weyrauch and Gill, 2021) that unskilled saw operators over 40-years-old are the most common victims of fatal accidents. Therefore, experience and skill level are key determinants of the safety and correctness of tree felling (Xu *et al*., 2014; Suhartana, 2020). Additionally, tree felling skills require at least three-years of professional experience to reach their full performance potential, and trained saw operators exhibit 40% better performance than untrained workers (Hiesl, 2013). Furthermore, as chainsaw operators age, even though they may be more experienced, they are more likely to have musculoskeletal disorders (Grzywiński *et al*., 2016), which can affect the quality of their work.

Summary and conclusions

Season did not significantly affect stump sawcuts. Stump height, however, was significantly taller in winter than in spring.

More experienced saw operators had greater success in meeting sawcut safety measures when the work required more precision (*e.g.*, notch cut depth, hinge width), and they made fewer errors than a less experienced worker. In contrast, all the escape routes prepared by the less experienced worker were correctly made, unlike the longer-serving saw operators whose escape routes were slightly less likely to meet correct standards. Preparation of correct escape routes requires compliance with the Occupational Health and Safety Regulations but does not need specialized professional experience. The failure of more experienced operators to follow escape route guidelines is probably related to their personal work routines that may disregard risks caused by not following prescribed safety protocols.

Authors' contributions

P.Cz. – investigation, conceptualization, data curation, methodology, analysis, writing-original design, visualization; N.K. – investigation, data curation, analysis, writing-original design, visualization, review and editing; M.F. – investigation, data curation, methodology, analysis, writing-original design, review and editing.

Conflicts of interest

The authors declare the absence of potential conflicts of interest.

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STRESZCZENIE

Wpływ wybranych czynników środowiskowych i stażu pracy operatorów pilarek na prawidłowość wycinki drzew

Celem badań była ocena wpływu pory roku oraz długości stażu pracy pilarzy pracujących przy ścince drzew na poprawność wykonania parametrów pniaka. Badania polegały na pomierzeniu parametrów pniaków na trzech powierzchniach zrębowych w dwóch okresach: wiosennym oraz zimowym przy zalegającej pokrywie śnieżnej (tab. 1, 2). Pomiarom poddano 90 pniaków, po 30 na każdej powierzchni. Powierzchnie badawcze były zbliżone pod względem składu gatunkowego, wieku oraz typu siedliskowego lasu, natomiast zróżnicowanie badań wynikało z wieku i doświadczenia zawodowego pilarzy wykonujących ścinkę na porównywanych powierzchniach (tab. 1). W pracy dokonano także oceny prawidłowości wykonania ścieżek oddalania zgodnie z instrukcją BHP (ryc. 1) podczas podstawowych prac z zakresu gospodarki leśnej.

Badania wykazały, że pora roku nie miała wpływu na prawidłowe lub nieprawidłowe parametry pniaków (tab. 2, ryc. 2). Tylko w przypadku wysokości pniaka stwierdzono, że w okresie zimowym pilarze wykonali istotnie więcej zbyt wysokich pniaków w porównaniu z okresem wiosennym. Wykazano natomiast, że pilarze z dłuższym stażem zawodowym lepiej wykonywali prace wymagające większej precyzji i doświadczenia (głębokość rzazu podcinającego, szerokość zawiasy), popełniając przy tym mniej błędów w porównaniu do pracownika z krótkim stażem (tab. 3). Pracownik z krótkim stażem zawodowym nie wykonał z kolei żadnej nieprawidłowej ścieżki oddalania w porównaniu do pracowników o długim stażu pracy. Przygotowanie ścieżek oddalania wymaga jedynie dostosowania się do przepisów BHP, a poprawne ich wykonanie nie zależy od doświadczenia zawodowego. W tym przypadku błędy popełnione przez pracowników z dłuższym stażem są prawdopodobnie związane z rutyną i lekceważeniem zagrożenia.