



Case Report

Why is it so difficult to determine the yield of indoor cannabis plantations? A case study from the Netherlands



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ABSTRACT

Together, the Netherlands and Belgium are the largest indoor cannabis producing countries in Europe. In both countries, legal prosecution procedure of convicted illicit cannabis growers usually includes recovery of the profits gained. However, it is not easy to make a reliable estimation of the latter profits, due to the wide range of factors that determine indoor cannabis yields and eventual selling prices. In the Netherlands, since 2005, a reference model is used that assumes a constant yield (g) per plant for a given indoor cannabis plant density. Later, in 2011, a new model was developed in Belgium for yield estimation of Belgian indoor cannabis plantations that assumes a constant yield per m² of growth surface, provided that a number of growth conditions are met. Indoor cannabis plantations in the Netherlands and Belgium share similar technical characteristics. As a result, for indoor cannabis plantations in both countries, both aforementioned yield estimation models should yield similar yield estimations. By means of a real-case study from the Netherlands, we show that the reliability of both models is hampered by a number of flaws and unmet preconditions. The Dutch model is based on a regression equation that makes use of ill-defined plant development stages, assumes a linear plant growth, does not discriminate between different plantation size categories and does not include other important yield determining factors (such as fertilization). The Belgian model addresses some of the latter shortcomings, but its applicability is constrained by a number of pre-conditions including plantation size between 50 and 1000 plants; cultivation in individual pots with peat soil; 600 W (electrical power) assimilation lamps; constant temperature between 20 °C and 30 °C; adequate fertilizer application and plants unaffected by pests and diseases. Judiciary in both the Netherlands and Belgium require robust indoor cannabis yield models for adequate legal prosecution of illicit indoor cannabis growth operations. To that aim, the current models should be optimized whereas the validity of their application should be examined case by case.

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1. Introduction

With an annual production of between 323 and 766 t of dried cannabis (*Cannabis* spp. L.) flower buds [1,2], the Netherlands seems to be one of the largest commercial illicit cannabis producers in Europe [3]. The latter is also reflected in the number of illegal indoor cannabis plantation seizures which, in The Netherlands, lies around 5000 plantations per year. Only in the

UK similar absolute levels of annual seizures are registered [3]. As a result of increasing international pressure on the Netherlands to contain cannabis production, the country stepped up criminal investigation and subsequent legal prosecution of illicit cannabis cultivation since 1995 [4]. As a result, it is not clear whether the seemingly high production volumes in the Netherlands result from high production volumes alone or whether they are explained by proportionally higher efforts by the Dutch police in searching, confiscation and registration of cannabis plantations, as compared with other European countries. Increased police and judicial actions in the Netherlands paradoxically led to the so-called ‘waterbed’ effect in which a shift of indoor cannabis growing from the Netherlands to other European countries, including Spain and Belgium, was observed [5,6]. As a result, Belgium nowadays is also a major indoor cannabis producer (1111 plantations seized in 2012)

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[7]. Furthermore, many Belgian indoor plantations have links with the Dutch indoor cannabis sector through Dutch growshops which often supply growing material and/or know-how, or even set up indoor plantations in Belgium through some sort of 'outgrower' scheme [5]. However, since 1 March 2015, facilitators of cannabis cultivation, such as growshops, have been outlawed in the Netherlands [8] so that these links might have disappeared or have gone underground.

After seizure and subsequent dismantling of cannabis plantations, prosecutors in the Netherlands as well as in Belgium try to make a well-informed estimate of the financial benefits of the actors involved, based – amongst others – on the confiscated assets and plants [9]. Apart from the more obvious judicial consequences of illicit cannabis growing (fines, incarceration), the latter estimates, both in the Netherlands as in Belgium, are used to determine the recovery of profits gained by illicit cannabis growers. In order to ensure equity of the judicial consequences given to illicit cannabis growing activities, it is necessary to accurately estimate the benefits gained by illicit cannabis growers. Underestimation would leave part of the capital gained in the hands of illicit growers who could reinvest it in (other) illegal activities, thus maintaining a shadow economy and causing additional burdens to society, whereas overestimation would unjustly punish cannabis growers.

Two factors play an important role in estimating the latter benefits: amount of cannabis produced with plantations and sales prices obtained by the cannabis grower. The amount produced depends on the number of crop cycles that were performed in the period during which the plantation has been operational and the agricultural yield obtained in each cycle. For the latter estimation, in the Netherlands judiciary relies on a study performed by Toonen et al. [10], results of which were earlier published by the Dutch Criminal Assets Deprivation Bureau [11], and which has set an allegedly reliable lower bound of cannabis yield in Dutch indoor plantations at 28.1 g of female flower buds per plant. The latter study subsequently became the reference for indoor cannabis yield in The Netherlands. The same yield estimate was also used by the Belgian judiciary until 2015, when a study by Vanhove et al. [12] became the official reference for yield estimates of Belgian indoor cannabis production. The latter Belgian researchers claimed that indoor cannabis yield can be more accurately expressed as consumable weight of harvested and dried cannabis flower buds per m² of cultivation surface under a well-defined set of standard factors, rather than as yield per plant. Following this approach, Vanhove et al. [12] set a lower bound of indoor cannabis yield at 575 g per m².

Because of the links between Belgian and Dutch indoor cannabis cultivation (cf. supra), growth rooms in both countries share similar characteristics in terms of material used, growth room design and cultivation techniques. As a result, yield estimate models should normally be applicable to indoor cannabis cultivation in both countries. In this paper, we analyse a case study of the Dutch jurisdiction in 2014, in which 4 growth rooms were linked to a single indoor cannabis grower in the Netherlands.

We critically assess the assumptions made by the judicial court and the subsequent application of the Dutch reference model, used in estimating the amount of cannabis produced in our case study. Then we assess whether the Belgian reference model can be reliably applied to the same case and to what extent the yield estimations of both models differ from each other. Finally, recommendations will be presented to improve currently applied yield models.

2. The case

Information on the case was obtained from the order of the judicial court of North Holland in May 2014 [13,14] which was entirely based on information supplied by the Public Prosecutor. Judicial case was against an indoor cannabis grower who was charged with operating 4 growth rooms. Upon confiscation, data were gathered by police on the number of plants per growth room, plant density (plants per m² of cultivated surface in each growth room) and number of lamps. Not all data were available for all growth rooms. Data on the total surface cultivated was lacking for all growth rooms. In the first growth room only 1500 cannabis cuttings in Grodan[®] cutting rock wool cubes (sides: 2.5 cm) were found for which it was assumed they were subsequently used in real cannabis production in the same and the other growth rooms. In the second growth room, zones with two different lamp densities were observed and reported as 2a (15.5 plants per lamp) and 2b (12.1 plants per lamp), respectively. Plant densities (Table 1) were mentioned by the grower during interrogation (first and second grower) or reported by the police based on direct observation (fourth growth room). The court assumed that plant density in the third growth room (20 per m²) was the same as in the fourth growth room, because both rooms shared similar characteristics (unspecified). For the second growth room, under both lamp densities, the same plant density is reported (12 plant per m²). The court then assumed that the number of plants per assimilation lamp used in the first growth room, equals the average of the number of plants per lamp (13.8 plants per lamp) observed in the zones 2a and 2b of the second growth rooms. With 58 lamps, it was then calculated that the first growth room had contained 800 plants for cannabis production. The third and fourth growth rooms were considerably larger (sheds) than the former two (Table 1).

Other data on the growth rooms and practices were obtained from the suspect's interrogation. According to the latter, all plants were of the Power Plant variety, which – according to open source information (e.g. <https://www.wikileaf.com/strain/power-plant/>) – is renowned for its very high THC content (15–20% in dried cannabis flower buds). Plants were cultivated in soil-containing plant trays of unknown dimension, with assimilation lamps of 600 W (electrical power) that were placed at densities that for the first growth room, part of the second growth room (2a) and the third growth room deviates from the lamp density (1 lamp per m²) commonly used in indoor cannabis growing [7] (Table 1). Turbines, typically used in indoor plantations to evacuate air from the

Table 1
Growth room parameters of the case study reported by the order of the judicial court of North Holland [13,14].

Growth room	Number of plants (n)	Plant density (m ⁻²)	Number of lamps	Plants per lamp	m ² per lamp
1	^a 1500	12	58	13.8	1.15
2a	744	12	48	15.5	1.29
2b	266	12	22	12.1	1.01
3	5152	20	341	15.1	0.75
4 ^b	3679	20	–	–	–

^a In the first growth room, upon confiscation, only 1500 rooted cuttings were found.

^b According to the grower, this room does not belong to him. The police and prosecutor assume it does, because of (unspecified) similarities with the third room.

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