EFFECT OF GROWTH CONDITIONS AND VARIETY ON DAMAGE SUSCEPTIBILITY OF SUGAR BEET

A.C.P.M. VAN SWAAIJ[1], J.P. VAN DER LINDEN[1] AND
J.-P. VANDERGETEN[2]

[1]IRS (Institute of Sugar Beet Research), P.O. Box 32,
NL-4600 AA BERGEN OP ZOOM.
[2]Institut Royal pour l'Amélioration de la Bettarave, Molenstraat 45,
B-3300 TIENEN

ABSTRACT

Damage to sugar beet causes sugar losses either by loss of beet tissue during harvest, by increased respiration of sugar due to wound healing during storage or by leaching to the wash water during processing. One way to reduce damage is the careful handling of beet at harvest and transport. However, efforts to reduce soil tare often have the opposite effect.

Another possible strategy to reduce beet damage is to grow less susceptible beet. This may be achieved by choosing the right variety or growth conditions. Therefore, we want to know more about the effect of these factors on damage susceptibility.

During a three-year collaborative study this has been investigated in a number of field trials in The Netherlands and Belgium. Manually harvested beet samples were treated on a turbine to inflict damage in a standardized way and were then visually examined for root tip breakage and surface damage. In other beet samples from the same plots, the internal quality and the elasticity were assessed.

Significant effects of beet weight, variety, N fertilizer, year and harvest period on damage susceptibility were found. Multiple regression showed that a considerable part of the root damage could be attributed to beet weight, elasticity and composition. However, the predictive value of individual parameters was poor.

From the results it can be concluded that variety and growing conditions affect damage susceptibility of sugar beet. Further research will have to focus on simple and reliable methods for assessing this property.

ABRÉGÉ - L'IMPACT DES CONDITIONS DE RÉCOLTE ET DE VARIÉTÉ SUR LA SENSIBILITÉ DES BETTERAVES AUX DOMMAGES

Les dommages causés aux racines provoquent des pertes en sucre en raison des pertes de matière au moment de la récolte, d'une respiration accrue en cours de stockage ou de pertes dans les eaux de lavages. Une des possibilités

pour réduire les dommages causés aux racines est de manipuler les betteraves avec précaution lors de la récolte et du transport, bien que les efforts pour réduire la tare terre ont souvent un effet opposé.

Une autre stratégie possible pour réduire les dommages aux betteraves est d'opter pour des variétés ou des conditions de récolte appropriées. L'objectif du travail est de mieux cerner l'impact de ces facteurs sur la sensibilité des racines aux dommages.

Ceci a été étudié dans différents sites expérimentaux aux Pays-Bas et en Belgique pendant 3 années de travail en collaboration. Des betteraves arrachées manuellement ont été placées sur une turbine pour provoquer des blessures aux racines dans des conditions standardisées. Elles ont ensuite été examinées visuellement pour déterminer l'importance des bris de pivots et des blessures superficielles. La qualité interne et l'élasticité des tissus des racines ont été mesurées sur des échantillons de betteraves issus des mêmes parcelles.

Des effets significatifs sur les dommages subis par les racines ont été relevés pour différents facteurs comme le poids des racines, la variété, la fertilisation azotée, l'année et la période de récolte. Les régressions multiples montrent qu'une partie importante des dommages peuvent être attribuées au poids de la racine, l'élasticité et la composition. La valeur prévisionnelle de chacun des éléments pris séparément est relativement faible.

Les résultats permettent de conclure que la variété et les conditions de croissance affectent la sensibilité aux dommages des racines. La recherche future doit s'orienter vers méthodes simples et fiables pour mesurer ces propriétés

KURZFASSUNG - EINFLUSS VON WACHSTUMSBEDINGUNGEN UND SORTE AUF DIE BESCHÄDIGUNGSEMPFINDLICHKEIT VON ZUCKERRÜBEN

Beschädigungen des Rübenkörpers führen zu Zuckerverlusten durch (a) Gewebeverluste während der Ernte, (b) erhöhte Zuckerveratmung bedingt durch Wundheilung während der Lagerung und (c) Zuckerauswaschung mit dem Waschwasser im Verarbeitungsprozess. Eine schonende Rübenbehandlung bei Ernte und Transport kann Beschädigungen wirksam reduzieren, während Maßnahmen zur Senkung des Erdanhangs oft den gegenteiligen Effekt haben.

Eine andere Strategie zur Verminderung von Beschädigungen könnte die Wahl der richtigen Sorte oder Wachstumsbedingungen sein. Unser Ziel war es deshalb, den Einfluss dieser Faktoren auf die Beschädigungsempfindlichkeit zu untersuchen. Dazu wurde eine 3jährige gemeinsame Studie mit einer Reihe von Feldversuchen in den Niederlanden und Belgien durchgeführt. Handgeerntete Rüben wurden auf einem Sternrad standardisiert beschädigt und visuell auf Spitzenbruch und Oberflächen-beschädigungen untersucht. An einer unbeschädigten Parallelprobe wurde die technische Qualität und die Elastizität des Rübenkörpers erfasst.

Signifikant waren die Effekte von Einzelrübengewicht, Sorte, N-Düngung, Jahr und Erntezeitpunkt. Durch multiple Regression konnte gezeigt werden, dass die Faktoren Rübengewicht, Elastizität und Zusammensetzung einen beträchtlichen Einfluss auf die Beschädigung haben. Demgegenüber war die Vorhersagekraft einzelner Parameter nur gering. Aus den Ergebnissen wird gefolgert, dass Sortenwahl und Wachstumsbedingungen die Beschädigungsempfindlichkeit von Zuckerrüben maßgeblich beeinflussen. Weitere Untersuchungen müssen auf die Entwicklung einfacher und zuverlässiger Methoden zur Erfassung dieser Eigenschaft gerichtet sein.

INTRODUCTION

The practice of intense cleaning of sugar beet at harvest, together with the handling of beet between harvesting and processing, result in considerable root tip breakage and surface injury. Beet damage may in turn cause large losses (DeVletter, R, & Van Gils, W., 1976; Uhlenbrock, W., 1972; Steensen, J.K. *et al.*, 1996; Wiltshire, J.J.J. & Cobb, A.H., 2000). The main source of loss are the root tips and other fragments that stay behind after harvest and cleaning. This may account for 2 – 3 % of sugar loss. Apart from that, injured beet will loose extra sugar during storage by respiration or due to invasion by bacteria and fungi. Extra losses during storage can be up to 2.5% of the total amount of sugar. Finally, leaching of sugar from injured beet during processing may give rise to another 0.8% of sugar loss.

Adaptations to the methods of cleaning and handling may reduce the level of damage. Several studies have been carried out on this topic (Bartlett, D.I.,1998; Steensen, J.K., 2002). Another possible strategy is to decrease the damage susceptibility of the sugar beet. However, little is known about the factors that influence susceptibility.

In the present study sugar beet from several field trials were injured under controlled conditions, to investigate the influence of variety, N-fertilizer, beet size and harvest date on damage susceptibility. Damage rates were compared to internal quality parameters and to elasticity of the beet tissue, as assessed by a pendulum. The objective of this study was to identify the most important factors in determining damage susceptibility in sugar beet.

MATERIALS AND METHODS

1.- FIELD TRIALS

To investigate the effect of beet size, variety and harvest date on damage susceptibility, two trials were conducted in The Netherlands in three consecutive years (2000 – 2002). In one trial three sugar beet varieties were grown at either 12 or 36 cm spacing (small and large beet respectively). In the other trial the same varieties were sawn at 18 cm and harvested at approximately four-week intervals in September, October and November.

To investigate the effect of N-fertilization, two trials were conducted at different locations in Belgium in 2000 as well as in 2002. In these trials two varieties were tested (high and low sugar content) at three N-fertilization rates (0, 100 and 200 kg/ha).

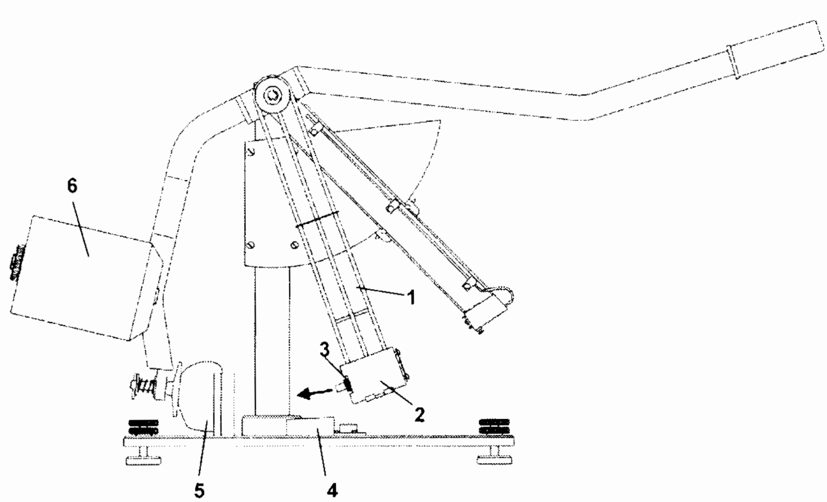
In all trials each treatment was replicated four times in a randomised block design. From each plot six samples of approximately 25 kg were manually harvested: three for damage and three for elasticity assessment. In some trials, the rest of the plot was harvested conventionally and the beet were visually examined for surface damage and tip breakage.

2.- ASSESSMENT OF DAMAGE SUSCEPTIBILITY AND ELASTICITY

The manually harvested beet samples were all acclimated at 10°C overnight to exclude a possible effect of temperature on the physical properties of the beet tissue. To assess damage susceptibility, acclimated samples were separately brought onto a turbine revolving at 45 rpm for 15 seconds. At least 10 minutes after the beet were collected, surface damage (cm²/kg beet) and tip breakage (g/kg beet) were estimated visually. After visual examination, the beet samples were analysed for internal quality assessment (sugar, K, Na, α-amino-N, dry matter, and marc content).

The elasticity of the root tissue was assessed using a pendulum (MIDAS 88P; Figure 1) according to Gall and Zachow (1992). Elasticity is expressed as Pendulum Index (PI), i.e. the percentage of beet that absorb less energy at the second impact than at the first impact. A lower absorption of energy at the second impact means that the beet tissue has been changed during the first impact. A high PI correlates with high elasticity, and expectations are, with a lower damage susceptibility.

Figure 1. Pendulum MIDAS 88P. 1 = arm; 2 = weight; 3 = head; 4 = sensor for measuring the speed; 5 = object, i.e. root part; 6 = counter weight. The energy absorption of the object is derived from the speed of the pendulum before and after the impact.



RESULTS

1.- USE OF A TURBINE TO STANDARDISE DAMAGE TO BEET SAMPLES

To find the right conditions to injure the beet samples, several combinations of turbine speed and treatment time were tested. Surface damage and tip breakage appeared linearly proportional to the turbine speed (Figure 2). Thus, damage and breakage could be controlled easily by changing the turbine speed. For damage assessments, the speed was adjusted to 45 rpm and the treatment time to 15 seconds. The damage caused by the standardised treatment in the turbine correlated well (r^2 = 0.94) with damage caused by machine harvesting in the field (Figure 3).

Figure 2. Effect of turbine speed on surface damage and tip breakage. Treatment time of the beet samples (approximately 25 kg) was 15 seconds.

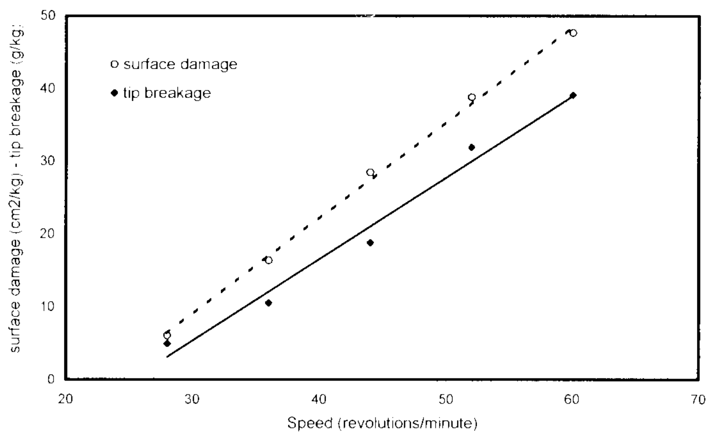
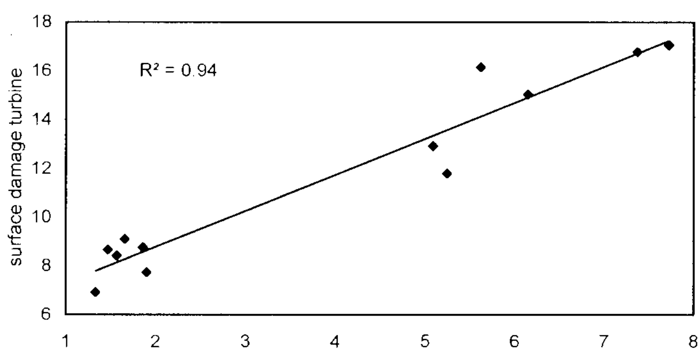


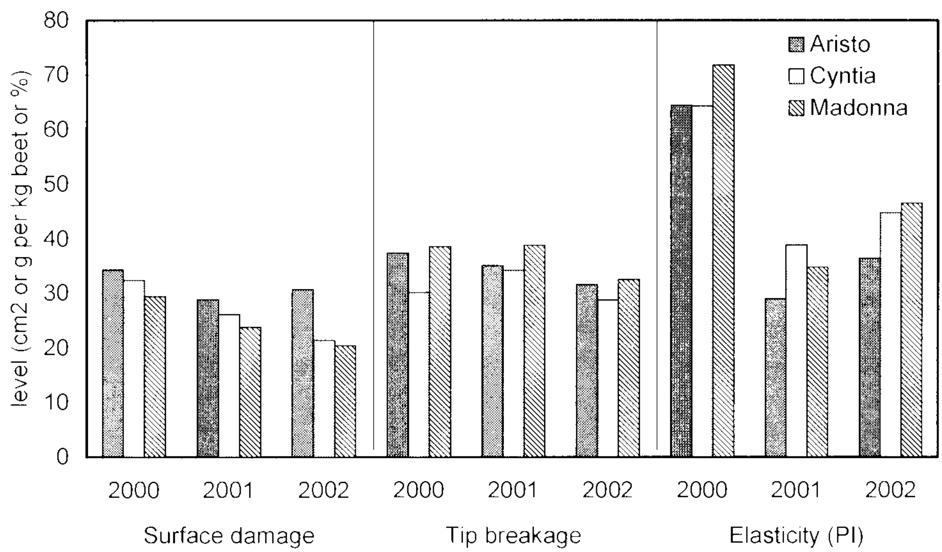
Figure 3. Correlation between surface damage after machine harvesting and after manual harvest followed by treatment on a turbine. Each value in the graph represents the average damage of 12 samples.



2.- EFFECT OF VARIETY

In all three years, susceptibility to surface damage decreased in the order Aristo, Cyntia and Madonna (Figure 4). Except for Aristo in 2000 and Madonna in 2001, these differences were inversely correlated to the differences in elasticity as measured by PI. Tip breakage was least for Cyntia in all three years, whereas Aristo and Madonna were never significantly different.

Figure 4. Influence of variety on surface damage, tip breakage and elasticity (as measured by pendulum index, PI) in three trial years. LSD 5%: 2.7 cm²/kg, 3.5 g/kg and 3.9 % for the three parameters respectively.



3.- EFFECT OF BEET SIZE

By using two sowing distances (12 and 36 cm) two populations with different average beet sizes were obtained, i.e. "large" beet were approximately three times heavier than "small" beet. The elasticity tended to be larger for the smaller beet but this difference was not significant (Figure 5). Surface damage was greatest for the small beet in 2000 and 2001, but least in 2002. Tip breakage did not seem to be affected by beet size.

4.- EFFECT OF HARVEST DATE

Harvest date affected the susceptibility to surface damage significantly (Figure 6). In 2000 and 2001 beet samples from the second harvest (October) showed least surface damage, whereas in 2002 the September samples were damaged least. Tip breakage was significantly worse for the November harvest in 2001 and for the September harvest in 2002. Elasticity of the beet tissue showed a consistent decrease from September to November.

Figure 5. Influence of beet size on surface damage, tip breakage and elasticity, (as measured by pendulum index, PI) in three trial years. LSD 5%: 3.4 cm²/kg, 4.5 g/kg and 5.0 % for the three parameters respectively

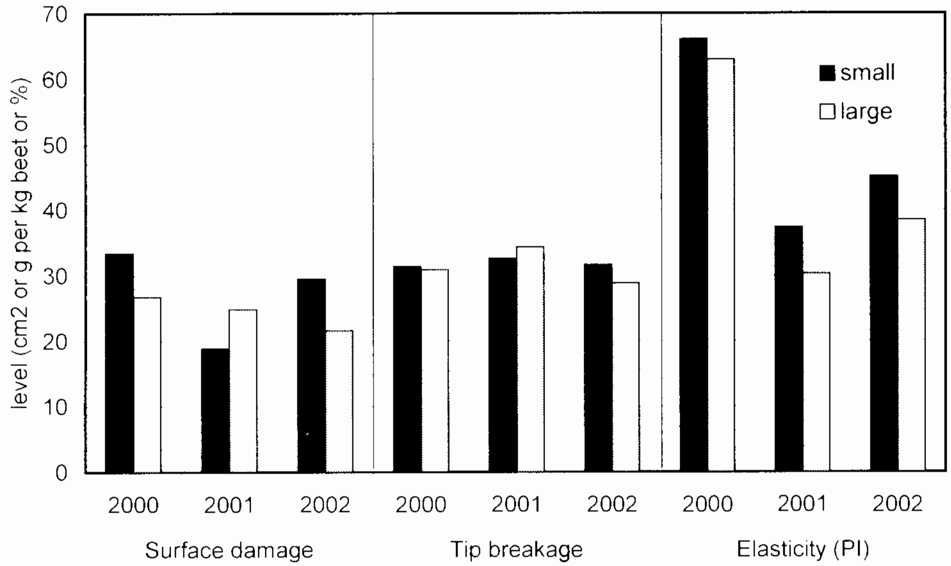
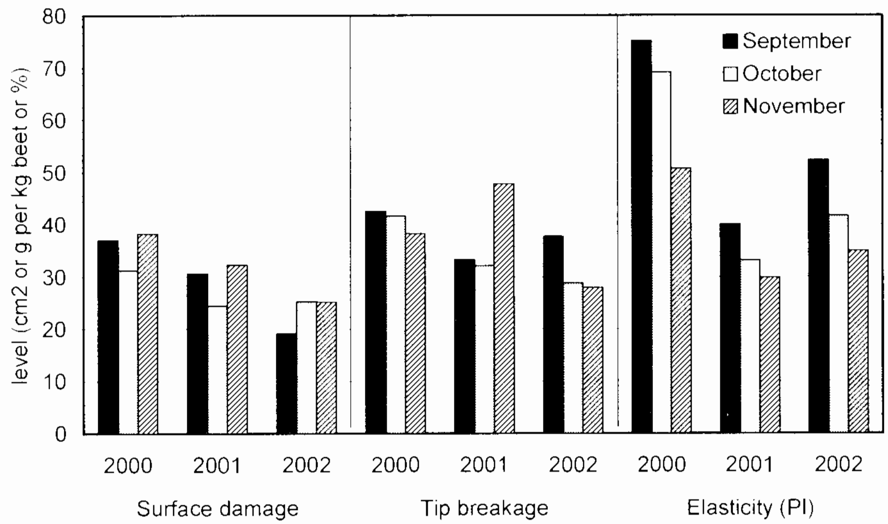


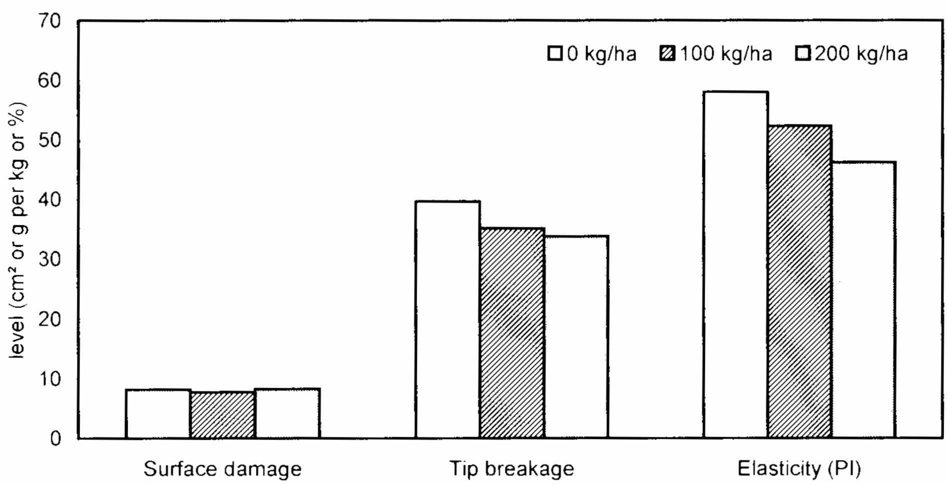
Figure 6. Influence of harvest time on surface damage, tip breakage and elasticity, (as measured by pendulum index, PI) in three trial years. LSD 5%: 3.3 cm²/kg, 4.3 g/kg and 4.7 % for the three parameters respectively.



5.- EFFECT OF N FERTILIZER

The effect of N fertilizer was similar in both years (Figure 7). It did not significantly affect surface damage or tip breakage, but elasticity decreased with increasing N rate.

Figure 7. Average effect of N fertilizer on surface damage, tip breakage and elasticity, (as measured by pendulum index, PI) in two trial years. LSD 5%: 1.6 cm^2/kg, 6.6 g/kg and 7.5 % for the three parameters respectively.



6.- CORRELATION BETWEEN DAMAGE SUSCEPTIBILITY AND PHYSICAL AND CHEMICAL PROPERTIES

When comparing data from the same plots, no significant correlation could be found between surface damage and tip breakage. There was a weak correlation between surface damage and elasticity ($r = 0.37$). Tip breakage and elasticity were not significantly correlated. No consistent correlations between damage scores and internal quality parameters nor average weight per beet could be detected either. A multiple linear regression showed that 36% of the variation in the damage parameters could be accounted for by a model that included marc, sugar content, elasticity and weight per beet.

DISCUSSION

In this study a standardized method was used to damage beet in a controlled way. Standardization was accomplished by manual harvesting and subsequent acclimation of beet samples at about 10°C, then injuring the samples in a turbine rotating for a preset time and at a preset speed.

Even under these controlled conditions there was much variability of damage scores between samples from the same plot. This variability may be due to large variations in the physical and chemical properties of individual beet, to variability in the effect of separate treatments, or to inaccuracy of the visual assessment of surface damage and tip breakage. This suggests that large samples are needed for assessing damage susceptibility, although this may even decrease the accuracy of visual assessments.

Assessing damage by visual examination is subjective. The advantage of using elasticity as an indicator for damage susceptibility is the objectivity of the pendulum measurement. The pendulum index was weakly correlated with surface damage but not with tip breakage. Thus, the predictive value of the pendulum index is low.

The weight of the beet is one important factor influencing susceptibility to damage. Large beet have a large kinetic energy on impact, but conversely have a small surface to weight ratio which, per tonne of beet, decreases the surface exposed to damaging agents and the number of tips at risk of being broken. Thus the weight of individual beet might have two opposite effects on damage susceptibility. In the present study it appeared that beet weight did not affect tip breakage, probably because its effect on the kinetic energy equalled the effect on the relative number of tips. On the other hand, beet weight affected surface damage, but its effect was not consistent over the three years. Thus, it appeared that surface damage and tip breakage were not influenced in the same way.

Apart from N fertilizer, all other factors (variety, location, year, sowing distance and time of harvest) affected damage susceptibility. This will either be caused by an effect on the physical properties of the beet or on their weight. Many interactions existed between the factors. At present it is difficult to estimate the individual effect of these factors and to use them for modelling damage susceptibility.

CONCLUSION

Susceptibility to damage appeared to be influenced by several properties of the sugar beet that may be controlled by variety choice and growing conditions. However, many factors affecting damage interact and the assessment of damage susceptibility is still quite variable. Further research will be needed to improve the methods for damage assessment and to distinguish between the effect of individual factors. It is not yet possible to advise farmers which variety to grow and what culture methods to use in order to minimize damage.

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