Breeding progress towards high oil content in oilseed rape (*Brassica napus* L.) – essential innovations to meet current and future market needs

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Abstract

High contents of oil do increase the general profitability in rapeseed and deliver significant advantages for all partners of the oilseed chain (e.g., farmers gain due to a higher gross margin and oil crushers achieve a higher margin and oil yield output per crushed seed unit). Furthermore, limited resources are used more efficiently and the energy and ecology balance is improved.

In spite of its polygenic inheritance the oil content is genetically highly stable and genotype by environment interactions are relatively low. Reproducible analysis methods like the near-infrared-reflectance-spectroscopy (NIRS) can be used for a high throughput screening on undestroyed, intact seeds, have enabled breeders to effectively screen very large numbers of genotypes in a very short time. In total, this has led to significant improvements of the oil content and continuous breeding progress. Over a period of ten years (1995-2004), an average annual increase of 0,16% can be calculated for the oil content in the official variety trials of winter oilseed rape in Germany. Examples for resulting products of the past systematic breeding activities are the recently in Germany and Great Britain released winter oilseed rape varieties Oase, Lioness and Billy which combine a high oil content with a very high seed yield and a nice agronomic performance package. Since the oil content is the last yield component formed plant health resp. a high disease resistance is essential to exploit the genetically fixed potential for oil yield. In addition, crops have to reach complete maturity in order to realize the full potential.

The advantages of a higher oil content have been recognized in several countries and are mostly rewarded in a respective premium system by a higher price for the farmer. Premium systems differ considerably and have significant effects on the variety choice and, finally, also on the profitability and competitive ability of the rapeseed cultivation.

Key words: oilseed rape, *Brassica napus*, oil content, oil yield, hybrids

Introduction

The oil content of oil seed rape belongs to the most important traits beside grain yield. Both oil content and grain yield result in the trait oil yield per growing area which is an essential criteria to evaluate the competitiveness of the crop with respect to other oil crops. Usually improving single traits for quality through breeding per se doesn't change the certified seed price on the market. Therefore, the farmer gets the increased oil content as an extra bonus. Given an established premium system, all parts of the production chain, the farmer, the oil industry and the consumer will profit. The higher the oil content, the higher is not only the oil yield but also the effectiveness of the oil crushing process, the payment to the farmer, the competitiveness of the local oil crop compared to oil imports, the value of the crop for the non food (e.g. bio fuel) sector, and the lower is the price for the consumer.

The impacts of an increase of oil content to the economy are enormous. For example, in Europe app. 15 millions tons of rape seed are produced per year. Every per cent oil increase leads to a gratis higher oil yield of 150.000 tons, moderately lowered by a price bonus paid to the farmers.

Premium systems

Increasing the oil content leads to a higher attractiveness of the crop to the oil crushers. In some countries including Germany, the farmers benefit from choosing varieties with high oil content because the oil crushers pay a bonus for this trait via a premium system. To illustrate such a system the German premium system shall be shown here. The oil crushers calculate the farmer's price according to the following formula:

Farmer's price for the harvested grain lot = market price + [(oil content of the grain lot (%) – basic oil content of 40%)*1,5%]

To the current price for rapeseed (valid for an oil content of 40% at 9% humidity of the grains) a factor is added build from the difference (%) of the real measured oil content of the farmer's grain lot multiplied by 1,5. For example, a variety with an oil content of 44% will get a 6% higher price [(44%-40%)*1,5]. As to be seen, each additional per cent of oil will be weighted 50% higher than each additional per cent of grain yield.

In addition to the premium price per se, premium systems may lower the overall risk of crop production as well. As shown in Figure 1, choosing a variety with e.g. 5% higher oil content can compensate for 7% less grain yield.

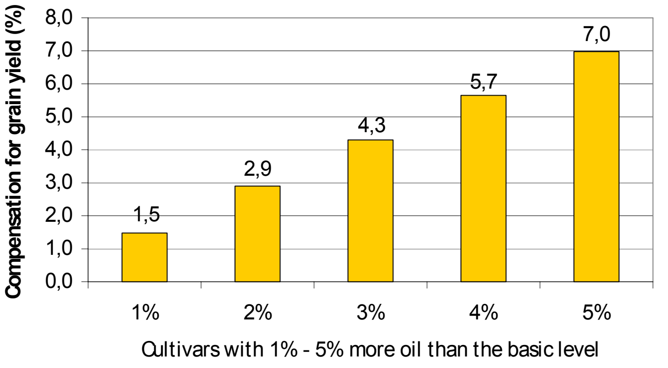

Fig.1. Compensation for lower grain yield via bonus for higher oil content in oilseed rape.

It is expected that the trend to an overproportional payment for the oil content will continue or even increase. Especially the trend to build small decentral oil crushers will strengthen the demand for higher oil contents. This is due to the fact that small oil crushings cannot use high temperatures or chemical additives like hexan. In consequence, the residues after crushing show a relatively high level of oil which cannot be further exploited as oil.

Genetics and Breeding

Oil content in rape seed has been found to be highly heritable (Becker et al. 1999, Wu et al. 2006). Although the absolute oil content may vary considerably due to environment, the relative oil content, i.e., the range of different cultivars to each other will be highly stable.

However, oil content is determined by a relatively high number of genes with mostly additive gene action, whereas dominance effects have been found to be not significant (Grami and Stephansson 1977, Grami et al. 1977, Engqvist and Becker 1991). In addition, epistatic effects may contribute to the variation in oil content (Zhao et al. 2005). Hitherto, a number of at least 18 and of up to 36 QTLs/genes influencing oil content have been reported (Zhao et al. 2005, Li et al. 2006, Zhao et al. 2006). This explains the considerable challenge for the breeder to simultaneously breed for higher oil content combined with improved grain yield and the many other agronomical traits. Indeed the breeders felt often a negative correlation between oil content and grain yield. However, this might be only due to the limited resources of a breeding programme. In order to enhance the selection gain for this complex package of breeding goals, breeding methods such as convergence breeding and doubled haploid technique have been applied. Furthermore, the search for new genes/alleles in prebreeding material like land races, resynthesized rape seed and rape seed accessions of geographical distant origin may be successful.

But beside the use of improved breeding strategies, the development of the NIRS technique (near infrared spectroscopy) has lead to an essential breakthrough in breeding for high oil content. Usage of this high throughput technique has enabled a fast, non-destructive and cost effective measurement.

The breeding progress for oil content can further be exploited through the development of hybrids which have been more and more applied in oilseed rape during the last decades. To current knowledge, it seems that there is no heterosis for oil content. Although some smaller heterotic effects seem to have occurred (own results), these findings could have been due to heterotic effects on agronomical traits which had an indirect impact on oil content. However, the improved genetics for oil content may be directly transferred to hybrid components via backcrossing techniques. Furthermore, depending on the hybrid system applied, high-oil lines may be directly used as a hybrid component. Combining the additive genes for oil content with the heterosis for grain yield in hybrids offers the chance to benefit overproportionally from oil genetics via the trait oil yield.

Breeding Progress

Enhancing the oil content while simultaneously improving grain yield and agronomical traits is a major challenge to the breeder. Since the oil content is based on a high number of genes only a relatively small but continuous progress seems to be possible. Figure 2 shows the development of the oil content of winter oilseed rape (WOSR) in Germany over a period of 10 years.

As to be seen in Figure 2 an average annual increase of 0,16% can be calculated for the respectively best line. However, especially during the last 3 years 2002-2004 the rise of the oil content has been shown to be overproportionally high. This may be caused by the outcome of clear focussed breeding programmes but also by the application of modern breeding techniques. Recently in Germany and Great Britain released WOSR cultivars like Oase, Lioness, Billy, Lilian, and Barrel are now available on the market. The cultivars combine the high oil content with a very high seed yield and a nice agronomic performance package. Table 1 shows the breeding progress in oil content for some new German WOSR cultivars compared to the best standard cultivars in the German official trial.

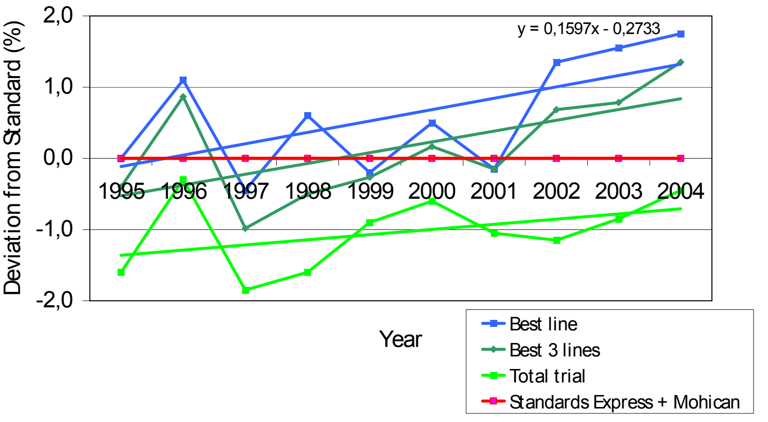

Fig. 2. Development of oil content of the respectively best line, three best lines and total entries in the German official trial in WOSR from 1995 to 2004. In order to widely eliminate environmental effects over the years the average of the two standard cultivars Express and Mohican was set to zero (source: Bundessortenamt 1995-2004, series K2; each point represents the arithmetical mean value averaged over app. 10 locations per year).

Table 1. Oil content and other important traits of recently released German WOSR cultivars compared to the best standard cultivars (mean results from 3 years 2004-2006, averaged over app. 10 locations per year; source: Bundessortenamt 2006).

Cultivar	Type	Oil content % at 91% DM	Grain Yield dt/ha at 91% DM	Oil yield dt/ha	Lodging 1 = very good	Phoma 1 = very good
Best standard	Hybrid	42,3	53,0	22,3	3	5
Best standard	Line	43,3	52,6	22,9	2	4
Oase	Line	44,4	51,9	23,1	2	5
Billy	Line	44,6	53,0	23,7	1	5
Lilian	Line	44,5	52,2	23,2	4	5

As for hybrids, examples for the successful transfer of higher oil content genes to hybrids are to be seen in the German official trials in WOSR (Table 2). In these trials, the newly released high-oil cultivar Oase was already used as best standard line. The new applied hybrids WRH287 and WRH288 reached an oil content of 42,8% which was at the same level as Oase.

Table 2. Oil content and other important traits of best WOSR hybrids compared to the best line and hybrid standards in German official trial series 1st year (WP1) in 2006 (source: Bundessortenamt 2006).

Cultivar/Variety	Type	Oil content % at 91% DM	Grain Yield dt/ha at 91% DM	Oil yield dt/ha	Lodging 1 = very good	Phoma 1 = very good
Best standard	Hybrid	41,5	51,8	21,6	2,0	5,3
Best standard	Line	42,8	50,5	21,6	1,7	4,4
WRH287	Hybrid	42,8	55,0	23,6	1,6	4,4
WRH288	Hybrid	42,8	54,8	23,4	1,5	5,0

The oil content is the last yield component formed during plant growth. As there is often a strong correlation between oil content and the number of days between flowering and maturity, a good disease and lodging resistance of the cultivars has to be ensured. On the other hand, in order to get the benefit from outstanding oil content, the farmer but also the experimental trial manager has to bear in mind that the crop has to be brought to its full maturity before harvesting. Too early combining will result in slightly reduced oil contents and heavily reduced seed yields due to seed losses by unthreshed seed.

Prospects

Conventional (hybrid) breeding in combination with modern biotechnology tools will offer further options for identification and generation of new genotypic variation for oil content which then can be efficiently exploited for the development of significantly improved varieties. To which extent special traits like changed fatty acid profiles (Ecke et al. 1995, Möllers and Schierholt 2002) or yellow seeds (Eckstein et al. 2003) may limit or enhance the increase of oil content and whether a biological maximum does exist needs further clarification. The obvious economic advantages should generally be rewarded by the establishment of premium systems along the whole chain in all oilseed rape growing countries. In addition, the high oil content may further increase the relative preference of rapeseed worldwide.

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