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Effect of Different Preceding Crops and Crop Rotations on Yield of Winter Oil-seed Rape (Brassica napus L.)

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With 7 tables

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Abstract

To determine the effect of different preceding crops and crop rotations on the grain yield of oil-seed rape, a long-term rotation experiment was conducted at the Hohenschulen experimental station in Kiel, NW Germany. Additional factors included the nitrogen fertilization and the fungicide application. The results reported herein are based upon the harvest years 1988 to 1993.

Averaged over the different rotations and husbandry treatments, the grain yields in the 6 experimental years varied between 2.71 t ha⁻¹ and 3.99 t ha⁻¹. In contrast, the effect of the different husbandry treatments was smaller and non significant. Averaged over 6 years, only the fungicide application caused small yield increase of 0.2 t ha⁻¹.

The highest grain yields of 3.77 t ha⁻¹ or 3.65 t ha⁻¹ occurred when oil-seed rape was directly following peas. Low yields between 3.15 t ha⁻¹ and 3.33 t ha⁻¹ were obtained when oil-seed rape was grown after oil-seed rape. The lowest grain yield of 3.13 t ha⁻¹ was produced with oil-seed rape grown in monoculture only. In rotations with oil-seed rape following a preceding cereal crop (wheat or barley), the grain yields averaged between 3.22 t ha⁻¹ in a two course rotation and up to 3.44 t ha⁻¹ in a four course rotation. In general, the yields of oil-seed rape increase with the length of the rotation and the length of the break between two oil-seed rape crops. The yield component number of seeds per m² was affected by the previous cropping accordingly, whereas the thousand seed weight did not respond to the cropping history.

Based upon disease assessments in the first years of this experiment, we argue that an increase in the incidence of fungal diseases has considerably contributed to the yield decrease of oil-seed rape in short rotations.

Key words: Winter oil-seed rape, crop rotation, preceding crop, nitrogen fertilization, fungicide application.

Introduction

The proportion of arable land cropped with oil-seed rape has increased considerably in Germany in recent years. Extensive research has been conducted on the effect of different preceding crops including oil-seed rape on the grain yield of a following cereal crop (e.g. CHRISTEN et al. 1992, CHRISTEN and SIELING 1993). Information, however, on the effect of different crop rotations or preceding crops on the grain yield of oil-seed rape is scarce.

Based upon survey data from former East Germany, MÖLLER and MAKOWSKI (1977) report grain yields of oil-seed rape grown after a clover dominated pasture of 2.36 t ha⁻¹. Oil-
seed rape following a cereal crop yielded 2.19 t ha⁻¹. If the crop rotation is also taken into account, the yield differences between a favourable and an unfavourable preceding crop tend to increase even further. George et al. (1985) report an averaged yield of oil-seed rape directly following rapeseed of 1.9 t ha⁻¹, whereas oil-seed rape in a 4 or 5 year rotation produced a grain yield of 2.48 t ha⁻¹. The results of this study were again obtained in a survey of practical farms.

Contrasting results are reported from rotation experiments with oil-seed rape. In an experiment described by Kübler (1988), the grain yield of oil-seed rape was unaffected by the crop rotation, regardless of a 2, 3 or 4 year break. This result concurs with conclusions reached by Gonet and Plozynska (1987) working in Poland. In their experiments even oil-seed rape grown in monoculture did not show a negative yield response compared with oil-seed rape grown in a four course rotation.

The yield components of oil-seed rape have often been studied in comparisons of either different plant densities and seed dates (Mendham et al. 1981a, Jenkins and Leitch 1986, Lutman and Dixon 1987, Habekotte 1993), fertiliser or plant growth regulator treatments (Mendham et al. 1981b, Scarisbrick et al. 1985) or cultivars (Mendham et al. 1984, Chay and Thurling 1989). In general, the most variable yield components, regardless of the factors compared, proved to be the number of seeds per m², the number of pods per plant or pods per m² depending on the measured parameter. In contrast, the number of plants per m² and the seed weight was in most experiments more influenced by the season than by treatments and had little effect on the seed yield.

Therefore, the objective of this research was to quantify the effect of different preceding crops and crop rotations and the interaction with different fertiliser and fungicide applications on the seed yield and the yield components of oil-seed rape.

Materials and Methods

A long-term rotation experiment was established in 1985 on a sandy loam (Luvisol) at the Fohmenschenk Experimental Farm of the University of Kiel, located in the NW of Germany some 15 km north-west of Kiel (Schleswig-Holstein). Soil analyses indicated that possible yield limiting macro nutrients were above the critical levels for oil-seed production in the top soil and 30–60 cm depth. The field experiment was originally laid out to compare 15 different crop rotations. These included the crops winter wheat, winter barley, rapeseed, peas and oats, and ranged from monocultures to five course rotations, summarised in Table 6. According to the principles of crop rotation experiments each single component of these 15 rotations had to be present every season, i.e. 45 components randomly arranged in one block. With a total of three blocks this accounted for 135 plots in the entire field trial. The results reported herein are based on a total of 51 plots oil-seed rape every year. Further details on the experimental site and design are given in Christen et al. (1992), as well as Christen and Seling (1993).

The climate of NW Germany can be described as humid. Precipitation averages 716 mm annually in the long term mean at the experimental site with about 400 mm received from April to September, the main growing season, and some 300 mm during October to March. Standard cultural practices were employed in all experimental years. After harvest all plots were disc-harrowed and the seed bed preparation consisted of ploughing and harrowing. The winter oil-seed rape was planted each year between 18th of August and the 4th of September. Regardless of the rotation, all plots of oil-seed rape were planted at the same date in every year. Therefore the response of the seed yield and yield formation are solely caused by the different rotational situations without any interaction caused by different seed dates. In the first years the experiments were carried out with the cultivar Ceres. Since 1992 the experiments were continued with the cultivar LiraJet. Three different input treatments were compared in the experiment. In agreement with common husbandry practice, nitrogen fertilization was split into two applications, at the beginning of the growing season in spring and the second at the beginning of stem elongation in late March or the beginning of April. Due to technical problems, the results for the yield formation do not include the harvest year 1990.

The treatments consisted of two levels of nitrogen, either 180 or 220 kg N ha⁻¹ and spraying or not spraying of a fungicide to control sclerotinia sclerotiorum (Table 1). The nitrogen dressing in each year was not adjusted for differences in the soil mineral nitrogen. Insecticide applications that did not involve the treatments were applied in all 5 years as necessary. The grain yields are based on a harvest area of 1.5 x 6 m² for each plot and were calculated on a 9% moisture content.

Results

Highly significant differences in the grain yield of oil-seed rape were caused by the weather in the experimental years (Y), the various rotations (R) as well as by the interaction between years vs. husbandry treatments.
Table 1. Husbondry treatments including different fertilizer treatments and fungicide strategies

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Amount (kg N ha⁻¹)</th>
<th>Distribution (kg N ha⁻¹)</th>
<th>Fungicide application</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-, F+</td>
<td>180</td>
<td>80/100</td>
<td>yes</td>
</tr>
<tr>
<td>N+, F+</td>
<td>220</td>
<td>120/100</td>
<td>yes</td>
</tr>
<tr>
<td>N+, F-</td>
<td>220</td>
<td>120/100</td>
<td>no</td>
</tr>
</tbody>
</table>

Table 2. Analysis of variance of rotation and husbandry effects on the seed yield of oil-seed rape (1988 to 1993)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean square</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>5</td>
<td>1150.18</td>
<td>60.19***</td>
</tr>
<tr>
<td>Rotation (R)</td>
<td>16</td>
<td>53.15</td>
<td>2.78**</td>
</tr>
<tr>
<td>Husbandry (H)</td>
<td>2</td>
<td>144.40</td>
<td>7.56</td>
</tr>
<tr>
<td>Y × R</td>
<td>80</td>
<td>25.09</td>
<td>1.31</td>
</tr>
<tr>
<td>Y × H</td>
<td>10</td>
<td>68.34</td>
<td>3.63***</td>
</tr>
<tr>
<td>R × H</td>
<td>32</td>
<td>25.06</td>
<td>0.14</td>
</tr>
<tr>
<td>Error</td>
<td>152</td>
<td>19.1</td>
<td></td>
</tr>
</tbody>
</table>

*** significant at the 0.001 level of probability

Table 3. Analysis of variance of rotation and husbandry effects on the number of seeds per m² of oil-seed rape (1988, 1989, 1991 to 1993)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean square</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>4</td>
<td>5491.73</td>
<td>56.66***</td>
</tr>
<tr>
<td>Rotation (R)</td>
<td>16</td>
<td>124.42</td>
<td>1.28</td>
</tr>
<tr>
<td>Husbandry (H)</td>
<td>2</td>
<td>319.07</td>
<td>3.29***</td>
</tr>
<tr>
<td>Y × R</td>
<td>64</td>
<td>114.79</td>
<td>1.18</td>
</tr>
<tr>
<td>Y × H</td>
<td>8</td>
<td>163.66</td>
<td>1.69</td>
</tr>
<tr>
<td>R × H</td>
<td>32</td>
<td>96.04</td>
<td>0.99</td>
</tr>
<tr>
<td>Error</td>
<td>126</td>
<td>288.30</td>
<td></td>
</tr>
</tbody>
</table>

* significant at the 0.05 level of probability

*** significant at the 0.001 level of probability

(Y × H) (Table 2). In contrast, the husbandry treatments (H) as well as the interaction between years vs. rotations (Y × R) and rotation vs. husbandry treatments (R × H) had no significant effect on the grain yield of oil-seed rape.

Table 4. Analysis of variance of rotation and husbandry effects on the number of thousand seed weight (g) of oil-seed rape (1988, 1989, 1991 to 1993)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean square</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>4</td>
<td>12.38</td>
<td>148.79***</td>
</tr>
<tr>
<td>Rotation (R)</td>
<td>16</td>
<td>0.08</td>
<td>1.06</td>
</tr>
<tr>
<td>Husbandry (H)</td>
<td>2</td>
<td>1.95</td>
<td>0.14</td>
</tr>
<tr>
<td>Y × R</td>
<td>64</td>
<td>0.11</td>
<td>1.41</td>
</tr>
<tr>
<td>Y × H</td>
<td>8</td>
<td>0.34</td>
<td>4.09***</td>
</tr>
<tr>
<td>R × H</td>
<td>32</td>
<td>0.11</td>
<td>1.38</td>
</tr>
<tr>
<td>Error</td>
<td>126</td>
<td>0.51</td>
<td></td>
</tr>
</tbody>
</table>

*** significant at the 0.001 level of probability

Table 5. Seed yield (t ha⁻¹) of winter oil-seed rape with different husbandry treatments (1988 to 1993)

<table>
<thead>
<tr>
<th>Year</th>
<th>N-, F+</th>
<th>N+, F+</th>
<th>N+, F-</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>4.04</td>
<td>4.03</td>
<td>3.90</td>
<td>3.99</td>
</tr>
<tr>
<td>1989</td>
<td>3.17</td>
<td>3.38</td>
<td>3.48</td>
<td>3.34</td>
</tr>
<tr>
<td>1990</td>
<td>3.20</td>
<td>3.01</td>
<td>2.76</td>
<td>2.99</td>
</tr>
<tr>
<td>1991</td>
<td>2.73</td>
<td>2.62</td>
<td>2.77</td>
<td>2.71</td>
</tr>
<tr>
<td>1992</td>
<td>3.64</td>
<td>3.66</td>
<td>3.16</td>
<td>3.49</td>
</tr>
<tr>
<td>1993</td>
<td>3.94</td>
<td>3.96</td>
<td>3.36</td>
<td>3.76</td>
</tr>
</tbody>
</table>

Mean 3.46 3.44 3.24

LSD (0.05) for years = 0.17
LSD (0.05) for husbandry treatments = 0.12

The yield components, number of seeds per m² as well as the thousand seed weight were mostly affected by the seasonal weather patterns (Y) (Tables 3 and 4). The effect of the crop rotation shows no statistically significant effect.
Table 6. Grain yield (t ha\(^{-1}\)) of winter oil-seed rape grown in different crop rotations. Average of the harvest years 1988 to 1993

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>Crops in rotation grain yield t ha(^{-1})</th>
<th>Percentage of rapeseed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monoculture 3.13 Rapeseed 3.22</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Wheat 3.15</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Barley 3.34</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Rapeseed 3.22 Wheat</td>
<td>66</td>
</tr>
<tr>
<td>5</td>
<td>Rapeseed 3.43 Wheat Barley</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>Rapeseed 3.36 Wheat</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>Rapeseed 3.77 Wheat Peas</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>Rapeseed 3.43 Wheat Rapeseed 3.33</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>Rapeseed 3.48 Wheat Peas</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>Rapeseed 3.46 Wheat Peas</td>
<td>25</td>
</tr>
<tr>
<td>11</td>
<td>Rapeseed 3.44 Wheat Oats Barley</td>
<td>25</td>
</tr>
<tr>
<td>12</td>
<td>Rapeseed 3.57 Wheat Peas Wheat Barley</td>
<td>20</td>
</tr>
<tr>
<td>13</td>
<td>Rapeseed 3.27 Wheat Peas Rapeseed 3.65</td>
<td>40</td>
</tr>
</tbody>
</table>

LSD (0.05) for rotations = 0.28

The different weather patterns in the 6 years included in this experiment caused considerable differences in the grain yield (Table 5). Averaged over the other treatments the highest yield of almost 4 t ha\(^{-1}\) was obtained in the first harvest year. The lowest yield with 2.71 t ha\(^{-1}\) occurred in 1991. In all 6 experimental years, the differences between the two nitrogen fertiliser levels (N\(-\), F+ and N+, F+) were small and of no agronomic significance. The differences in the seasonal environment also affected the response of oil-seed rape to the different husbandry treatments. The effect of the fungicide treatment, which, averaged over the experimental years, caused a yield increase of 0.2 t ha\(^{-1}\), did only occur in 4 out of 6 years. The differences were not consistent.

The yield component number of seeds per m\(^2\) (date not shown) responded in the same way previously described for the seed yield, whereas in plants per m\(^2\) the thousand seed weight was mainly affected by the seasonal weather.

The magnitude of the grain yield response of oil-seed rape to the different crop rotations as well as the different preceding crops is given in Table 6. The percentage of rapeseed in the different rotations had a profound effect on the grain yield. Oil-seed rape grown in monoculture yielded 3.13 t ha\(^{-1}\). In contrast, rotations with only 20 or 25 % of rapeseed (rotations 10, 11 or 12) had a grain yield of between 3.44 t ha\(^{-1}\) to 3.57 t ha\(^{-1}\), respectively. A similar trend is shown in the rotations with 50 % of oil-seed rape like rotations 2 and 3.
Table 7. Number of seeds per m² and thousand seed weight (g) of winter oil-seed rape grown in different crop rotations. Average of the harvest years 1988, 1989 and 1991 to 1993

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>Crops in rotation</th>
<th>Number of seeds per m²</th>
<th>Thousand seed weight (g)</th>
<th>Percentage of rapeseed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monoculture</td>
<td>59845</td>
<td>5.40</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Rapeseed</td>
<td>Wheat</td>
<td>61422</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Rapeseed</td>
<td>Barley</td>
<td>65684</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Rapeseed</td>
<td>Wheat</td>
<td>62587</td>
<td>66</td>
</tr>
<tr>
<td>5</td>
<td>Rapeseed</td>
<td>Wheat</td>
<td>65363</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>Rapeseed</td>
<td>Wheat</td>
<td>64102</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>Rapeseed</td>
<td>Peas</td>
<td>67989</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>Rapeseed</td>
<td>Wheat</td>
<td>66101</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>Rapeseed</td>
<td>Wheat</td>
<td>65039</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>Rapeseed</td>
<td>Peas</td>
<td>64214</td>
<td>50</td>
</tr>
<tr>
<td>11</td>
<td>Rapeseed</td>
<td>Wheat</td>
<td>65554</td>
<td>25</td>
</tr>
<tr>
<td>12</td>
<td>Rapeseed</td>
<td>Oats</td>
<td>64434</td>
<td>25</td>
</tr>
<tr>
<td>13</td>
<td>Rapeseed</td>
<td>Peas</td>
<td>68857</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapeseed</td>
<td>71521</td>
<td>40</td>
</tr>
</tbody>
</table>

However, the effect of the percentage of oil-seed rape was mitigated by the influence of the directly preceding crop. Therefore, the highest yields always occurred in the crop rotations with oil-seed rape following directly after peas (rotations 7 and 13). On the other hand, oil-seed rape suffered a yield decrease when directly grown after rapeseed (rotations 4, 8 and 9). The
comparison of the first oil-seed rape in rotation 9 with the oil-seed rape in rotation 7 reveals an interaction between the directly preceding crop and the percentage of rapeseed in the rotation. The positive effect of the peas only occurred in the rotation with a lower percentage of rapeseed.

The effect of the different crop rotations on the yield components number of seeds per m² and the thousand seed weight were not statistically significant (Table 7). However, especially in the case of the number of seeds per m² some tendencies can be described. According to the differences in the seed yields, the number of pods per m² showed a response to the previous cropping as well as to the cropping sequence. The lowest number of seeds per m² occurred in the rapeseed monoculture (rotation 1). In contrast, the highest number of seeds per m² were observed in the rotations with rapeseed following directly after peas (rotations 7 and 13). The effect of the different rotations on the thousand seed weight was negligible.

Discussion

The principal aim of this study was to quantify the effect of various crop rotations and different preceding crops on the grain yield of oil-seed rape. A decrease in grain yield of oil-seed rape grown in short rotations as well as following an unfavourable preceding crop confirms reports by Möller and Makowski (1977) and George et al. (1985). The magnitude of the response is comparable with results obtained for wheat and barley in the same experiment which have already been reported (Christen et al. 1992, Christen and Siebling 1993). However, compared with the survey data given by Möller and Makowski (1977) as well as George et al. (1985), the yield response is slightly lower in our experiment. One reason for this discrepancy might be the high input level used in this experiment. Additionally, the structure of survey data does not normally allow clear distinction between treatment factors. For example, Möller and Makowski (1977) explain the differences in their experiments between a preceding clover pasture and a preceding cereal crop solely with differences in the seed date. Our data, however, support the results by Kübler (1988), that oil-seed rape only shows a small response to the percentage in the crop rotation as long as no extreme treatments like monocultures or five course rotations are included. The opinion expressed by Gonet and Ploszynska (1987) that oil-seed rape does not show a yield decrease when grown in monoculture is not supported by our results.

Though not statistically significant, the results of the yield formation analysis confirm that the effect of different crop rotations on oil-seed rape is mostly due to changes in the number of seeds per m². This finding concurs with other experimental results comparing the effect of various husbandry factors on the yield components of oil-seed rape, which have proved the main effect of the season on the thousand seed weight.

The results of the three compared husbandry treatments indicate that, given the level of external input used in this experiment, mineralised nitrogen from crop residues contributed little to the yield differences. Since detailed analyses of the incidence and severity of diseases were only taken in the first 2 years of the experiment reported herein, we can only speculate about the causes of the observed yield differences. Nemati (1991) observed a slight increase with stem canker (Phoma lingam syn. Leptosphaeria maculans) and verticillium wilt (Verticillium dahliae), however, it remains unclear whether the small differences are sufficient to explain the yield response. Kübler (1988) described an increase in the nematode population, but could not relate this increase to differences in the grain yield. Other experiments indicate that diseases like rhizoctonia solani might also contribute to yield differences in short oil-seed rotations (Svensson and Lenerius 1987, Tahvonen et al. 1984). Further studies should concentrate on the effect of different preceding crops and crop rotations on the incidence and severity of pests and diseases in short oil-seed rotations.

Zusammenfassung
Einfluß unterschiedlicher Vorfrüchte auf den Ertrag von Winterraps

Zur Quantifizierung des Einflusses der Vorfruchtwirkung und der Fruchtfolge auf den Ertrag von Winterraps wird auf der Versuchsstation Hohenschule der Universität Kiel ein Langzeitversuch durchgeführt. Weitere Versuchs faktoren sind Stickstoffdüngung
sowie Fungizidapplikation. Die Ergebnisse
derer Untersuchung basieren auf den Ernte-

Im Mittel der geprüften Fruchtfolgen
und produktions-technischen Varianten
schwankten die Erträge in den 6 Ver- suchsjahren zwischen
27.1 dt ha⁻¹ und 39.9 dt ha⁻¹. Im Unterschied
dazu war der Einfluß der geprüften pro-
duktions-technischen Varianten wesent- lich
geringer. Allein die Fungizidapplikation führte
im Durchschnitt der Jahre zu einer nicht
signifikanten Ertragssteigerung von 2 dt ha⁻¹.

Die absolut höchsten Erträge mit 37.7 dt ha⁻¹
und 36.5 dt ha⁻¹ wurden beim Raps nach
Erbse beobachtet. Niedrige Erträge zwischen
31.5 dt h⁻¹ und 33.3 dt ha⁻¹ traten auf, wenn
Raps in einer Fruchtfolge direkt auf Raps folgt.
Der niedrigst durchschnittlichen Ertrag von
nur 31.3 dt ha⁻¹ erzielte Raps in Monokultur.
Eine Zwischenstellung nahmen die Rotation
mit Winterraps nach Getreidevorfrucht ein.
Hier lagen die Erträge bei 32.2 dt ha⁻¹
in einer zweifeldrigen Fruchtfolge bzw. 34.4 dt ha⁻¹
in einer vierfeldrigen Rotation. Grundsätzlich
stiegen die Erträge von Winterraps mit der
Dauer der Anbauunterbrechung in der Frucht-
folge sowie mit größerem direkten Abstand
zwischen zwei Winterrapskulturen in der
Rotation. Von den Ertragsskomponenten zeigt
die Anzahl der Samen je m⁻² eine entsprechende
Reaktion auf die unterschiedlichen Frucht-
folgen. Die Tausendsamenmasse wurde da-
gegen durch die Fruchtfolgen nicht beeinflußt.
Im Hinblick auf die Ursachen der beschriebenen
Ertragsreaktionen kann vermutet werden,
dafs in den engen Rotation ein vermehrtes Auftreten
von pilzlichen Schaderregern zu den beschrie-
benen Ertragesinbußen geführt hat.

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