Yield and botanical composition of pastures sown under rape into an ex-*Pinus radiata* forest block

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Abstract
After the removal of *Pinus radiata* forests, conditions for establishing pastures are often sub optimal. The ability of rape to aid pasture establishment and suppress weeds was investigated at Darfield, Canterbury between November 2005 and February 2007. The strip plot experiment used pasture grass (perennial ryegrass, tall fescue or cocksfoot) as the main plot and rape sowing rate (0, 0.5 1.5 or 3.0 kg/ha) as the subplot. There was no difference in total pasture yield at the first spring harvest but 50% of the dry matter yield from pastures sown without rape was from weeds compared with ≤10% in those sown with ≥1.5 kg/ha of rape. There was no initial yield benefit from rape sown at 3.0 kg/ha compared with 1.5 kg/ha but rape regrowth was greater from the higher rate. White clover was 58% of the total legume yield initially but by February 2007 red clover was dominant (70-95%). In this forestry conversion to pasture, rape sown at 1.5 kg/ha reduced weed encroachment particularly for the tall fescue and cocksfoot which are slow establishing dryland species.
Keywords: *Brassica napus*, cover crop, *Dactylis glomerata*, *Festuca arundinacea*, forest conversion, *Lolium perenne*, pasture establishment, *Trifolium pratense*, *T. repens*, undersowing

Introduction
After forestry blocks are harvested, soils often have a compacted soil structure and low (<5.0) soil pH. Compaction results from mechanical harvesting, including windrowing and stump grinding. These actions destroy aggregate integrity and create fine soil particles prone to wind erosion. Capital fertiliser inputs of sulphur, phosphorus, trace elements and lime can overcome low fertility levels and the rate of increase is affected by the rate and timing of applications (Condron *et al*. 2007). In Canterbury, forestry plantations were historically sown on marginal land with shallow soils of low water holding capacity.

Following the removal of mature plantation trees, the high light environment encourages weed seed germination when there is adequate soil moisture. Dominant weed species in this environment include perennial species such as gorse (*Ulex europaeus*), broom (*Cytisus scoparius*) and sorrel (*Rumex acetosella*), which are adapted to low pH conditions (Keoghan & Allan 1992), and the annuals, wireweed (*Polygonum aviculare*) and fathen (*Chenopodium album*).

Cover crops, such as barley (*Hordeum vulgare*) and rape (*Brassica napus*), can be used to suppress weeds during pasture establishment (Wynn-Williams 1976). Cover crops also increase the economic return in the establishment year by the provision of valuable summer feed and create a microclimate, with reduced wind run, that can aid the establishment of slower emerging species. Cullen (1964) recommended low rates of rape for weed suppression at low fertility sites. Subsequent management should aim, through grazing or cutting, to reduce competition from the oversown species for the benefit of the establishing undersown crop or pasture.

Selection of the appropriate pasture grass depends on the biophysical characteristics of the location. Perennial ryegrass (*Lolium perenne*) is an aggressive competitor during establishment (Moot *et al.* 2000) and can be successfully established in most temperate New Zealand conditions. However, both perennial ryegrass and white clover (*Trifolium repens*) perform poorly when exposed to drought conditions (Korte & Chu 1983; Baker *et al.* 1985; Knowles *et al.* 2003). In dryland conditions on the East Coast of the South Island, both tall fescue (*Festuca arundinacea*) and cocksfoot (*Dactylis glomerata*) are successful in environments prone to summer drought conditions (Charton & Stewart 1999; Stevens & Hickey 2000). Both of these species are slower to establish than perennial ryegrass, due to higher thermal time requirements for germination and low seedling vigour (Moot *et al.* 2000). This makes pastures based on them susceptible to invasion from annual and perennial weeds. In this study, the aim was to determine the suitability of rape, sown at different rates, as a cover crop to increase pasture DM yield and suppress weed species during establishment of dryland pastures on forestry land converted to pasture on the Canterbury plains.

Materials and Methods
This experiment was sown at Darfield, Canterbury within a 30 hectare ex-*Pinus radiata* forestry block which is part of a forest to pastures conversion process undertaken by the Selwyn Plantation Board Ltd. The third rotation forest was harvested in 2004/2005. Slash was windrowed and burnt in winter. Stump grinding and soil conditioning

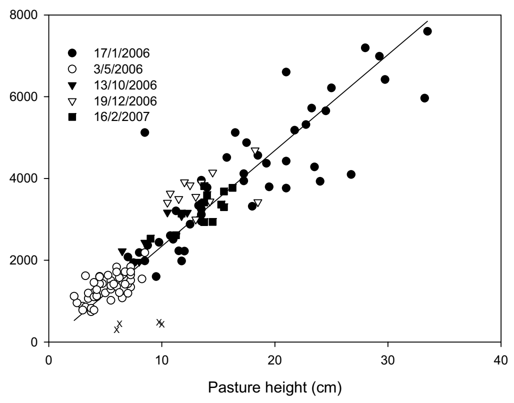
procedures were then used to create a seedbed following a winter fallow. Soil tests were taken prior to pasture establishment and are presented in a separate paper (Condron *et al*. 2007). A strip plot experiment (Petersen 1985) was sown on 6/10/2005 with three grass species as the main plot strips and replicated four times giving a total of 12 main plot strips. Pasture grasses were 'Meridian' perennial ryegrass (8 kg/ha), 'Vulcan' tall fescue (12 kg/ha) or 'Vision' cocksfoot (3 kg/ha). 'Winfred' rape was sown at four rates (0, 0.5, 1.5 and 3.0 kg/ha) in perpendicular strips across main plots as the sub plot treatment and this resulted in a total of 48 individual sub plots of 40 m^2 (10 x 4 m).

All main plot grass species were also sown with 3.5 kg/ha of 'Demand' white clover, 4 kg/ha 'Pawera' red clover (*T. pratense*), 1 kg/ha of 'Puna' chicory (*Cichorium intybus*) and 1 kg/ha of 'Lancelot' plantain (*Plantago lanceolata*). All clover sowing rates are for coated seeds. Environmental conditions were reported by Moot *et al*. (2007).

The effects of brassica sowing rate and grass species on pasture yield and botanical composition were measured through five regrowth cycles (ending 17/1/2006, 3/5/2006, 13/10/2006, 19/12/2006 and 16/2/2007). After each harvest, all plots were grazed in common for a maximum of 2 days with rising 1-year ewes (2500 hoggets/ha) until all grazeable herbage was removed. Sheep broke into the experimental plots in August 2006 and ate the winter regrowth (4/5/2006-4/8/2006) so no measurements were made for this period.

Dry matter production and botanical composition were measured from destructive harvests of 0.2 m^2 quadrats on the first two harvest dates (17/1/2006 and 3/5/2006). Samples were sorted for botanical composition (Cayley & Bird 1996) and dried to constant weight in a forced air oven at 65°C. Paired comparisons were made between DM yield and additional rising plate meter readings taken from the same area to create a calibration for dry matter (DM) measurements for the three subsequent harvests (Fig. 1). The least squares linear regression between compressed pasture height and total DM yield was DM=234x (R^2=0.84). Tall fescue based pastures did not fit with this established relationship for the harvest made on 13/10/2006 and required a separate calibration of DM=49.8x. This probably resulted from the unplanned grazing that resulted in a lower residual or slower recovery from grazing in the tall fescue based pastures. For non destructive DM determinations, 20 plate meter measurements were taken in each of the 48 plots. These values were averaged and converted to pasture height (cm) prior to conversion to DM yield using the calibration equations.

Figure 1 Measured total DM yield (kg DM/ha) against pasture height (cm) from a rising plate meter. The regression was DM = 234x (R^2=0.84). The form of the separate regression for tall fescue outliers (X) on the 13/10/2006 was DM = 49.8x.



Analysis

Analyses were conducted with Genstat 9 for the strip plot design. Total DM yields were normally distributed and did not require transformation. Yields of individual pasture components were normalised by log transformation to ensure data met the requirement for unbiased analysis (Dytham 1999). As log 0 is undefined, data were transformed using the equation y=Ln(DM+1). Fisher's protected LSD was used to separate transformed means when the ANOVA was significant. For interactions, the most conservative LSD was used for means separation. All data are presented as arithmetic treatment means of untransformed data but tests of significance were performed on transformed data.

Results

At the first harvest (17/1/2006) there were no interactions or effects of treatment on total yield with 3960±894 kg DM/ha in all pastures but botanical composition differed between treatments (Table 1). The sown grass component of perennial ryegrass based pastures was more ($P \leq 0.05$) than double that of tall fescue and almost 10 times that produced by cocksfoot. Grass yield declined ($P \leq 0.05$) from 468 kg DM/ha for pastures sown without a cover crop to 56.4 kg DM/ha in pastures sown with rape at 3.0 kg/ha.

Rape yield more than doubled ($P \leq 0.001$) when sowing rate was increased from 0.5 kg/ha to 1.5 or 3.0 kg/ha. The brassica represented 30% of total DM yield of pastures sown with 0.5 kg/ha of rape compared with 70% of total yield in pastures with 1.5 or 3.0 kg/ha. Clover yield was similar in pastures sown with rape at 0 and 0.5 kg/ha but decreased ($P \leq 0.05$) from 719 kg DM/ha with no rape to 165 kg DM/ha in pastures which included 3.0 kg/ha of rape. Of the clovers, white clover

Table 1 Yield (kg DM/ha) of pasture components on 17/1/2006 at Darfield, Canterbury, for undersown dryland pastures established after forest conversion. Clovers represent total clover yield from white and red clovers and herbs includes yield from chicory and plantain.

		Grass	Rape	Clovers	Herbs	Weed	Dead	Total yield
Species	RG	466_a	1920	258	138	613	635_a	4030
	TF	207_{ab}	2030	439	121	852	537_{ab}	4190
	CF	49.2_b	1110	608	174	1380	344_b	3670
	Significance	*	NS	NS	NS	NS	*	NS
Rape (kg/ha)	0	468_{ab}	0_c	719_a	218_a	1660_a	236_b	3300
	0.5	301_a	1120_b	492_{ab}	225_a	1170_{ab}	395_a	3710
	1.5	63.5_{bc}	2680_a	228_b	63.6_b	291_b	598_a	3930
	3.0	56.4_c	2430_{ab}	165_b	26.1_c	384_b	636_a	3700
	Significance	*	***	*	***	*	**	NS

NOTE: Levels of significance are: * = P≤0.05, **= P≤0.01, *** =P≤0.001 and NS = non significant. Numbers followed by the same letter are similar at the P<0.05 level of significance. Analysis for total DM yield was performed on untransformed data. For botanical composition data, treatment effects were determined from log transformed data but values presented are arithmetic means of raw data.

Table 2 Yield (kg DM/ha) of pasture components on 3/5/2006 at Darfield, Canterbury, for undersown dryland pastures established after forest conversion. Clovers represents total clover yield (kg DM/ha) from white and red clovers and herbs includes yield from chicory and plantain.

		Grass	Rape	Clovers	Herbs	Weed	Dead	Total yield
Species	RG	480_a	326	267	101	34.7	267	1480
	TF	358_a	336	284	95.9	34.7	205	1310
	CF	123_b	211	375	168	87.1	199	1160
	Significance	**	NS	NS	NS	NS	NS	NS
Rape (kg/ha)	0	438	0_c	362	131	44.9	235	1210
	0.5	290	239_b	270	139	57.3	191	1190
	1.5	259	257_b	236	135	45.5	204	1140
	3.0	196	578_a	272	43.9	45.0	198	1330
	Significance	NS	***	NS	NS	NS	NS	NS

NOTE: Levels of significance are: * = P≤0.05, **= P≤0.01, *** =P≤0.001 and NS = non significant. Numbers followed by the same letter are similar at the P<0.05 level of significance. Analysis for total DM yield was performed on untransformed data. For botanical composition data, treatment effects were determined from log transformed data but values presented are arithmetic means of raw data.

represented 58% of total clover yield. The herb (chicory and plantain) yield was suppressed (P≤0.001) by the inclusion of rape at 1.5 and 3.0 kg/ha (Table 1). Rape inclusion at >0.5 kg/ha reduced chicory content whereas plantain yield was only suppressed when rape was sown at 3.0 kg/ha.

Weed content was ≤10% in pastures sown with rape at 1.5 or 3.0 kg/ha compared with 32% in pastures sown with rape at 0.5 kg/ha and 50% of total DM yield when rape was not included (P≤0.05) in the pasture mix. During the course of measurements, the two dominant weed species at the site were fathen and sorrel. Surprisingly, woody weeds contributed minimally to total DM yield.

There was an interaction (P≤0.05) between grass species and rape sowing rate in the amount of dead material in the pastures (data not presented). This was primarily caused by low amounts of dead material in cocksfoot pastures sown with no rape. In all other pastures the dead material ranged from 207 kg DM/ha (tall fescue pastures with no cover crop) to 873 kg DM/ha for perennial ryegrass.

For the second harvest, in autumn, (3/5/2006) all pastures produced about 1320±261 kg DM/ha and this was unaffected by treatment (Table 2). The grass yield from both perennial ryegrass (480 kg DM/ha) and tall fescue (358 kg DM/ha) was greater (P≤0.01) than from cocksfoot (123 kg DM/ha). Rape regrowth was affected (P≤0.001) by sowing rate and increased from 20-23% of total DM yield, in pastures sown with rape at 0.5 and 1.5 kg DM/ha to 43% of total yield when rape was sown at 3.0 kg/ha. Overall, weed components were <4% of total DM yield in all pastures and unaffected by treatments. Total legume yield was between 200 and 500 kg DM/ha and represented ~24% of total DM in all pastures.

Total DM yield for the early spring rotation (4/8/2006-13/10/2006) was affected (P≤0.001) by grass species with 1990 kg DM/ha produced by perennial ryegrass based pastures compared with 1470 kg DM/ha for

Table 3 Total DM yields (kg DM/ha) for rotations ending 13/10/2006, 19/12/2006 and 16/2/2005 at Darfield, Canterbury, for undersown dryland pastures established after forest conversion.

		13/10/2006	19/12/2006	16/2/2007
Species				
	RG	1990_a	2810	2720
	TF	334_c	2460	2290
	CF	1470_b	2490	2680
Significance		***	NS	NS
Rape (kg/ha)	0	1460_a	2760_a	2710
	0.5	1360_a	2680_a	2520
	1.5	1130_b	2450_b	2450
	3.0	1100_b	2450_b	2560
Significance		**	*	NS

NOTE: Levels of significance are: * = P≤0.05, **= P≤0.01, *** =P≤0.001 and NS = non significant. Numbers followed by the same letter are similar at the P<0.05 level of significance.

cocksfoot pastures and 334 kg DM/ha for tall fescue (Table 3). In addition, rape sowing rate affected (P≤0.01) total DM yield with pastures sown with rape at 0 and 0.5 kg/ha producing 26% more total DM than pastures sown with rape at 1.5 or 3.0 kg/ha. Botanical composition was measured from replicate 1 and is shown in Figure 2. By this and subsequent harvests, rape represented <5% of total DM yield. White clover represented 35-75% of the spring legume yield and 14-50% of total DM yield.

In Year 2 the spring rotation (ending 19/12/2006) showed pastures established with rape at 1.5 or 3.0 kg/ha produced 2450±2.00 kg DM/ha which was less (P≤0.05) than the 2720±43.0 kg DM/ha in pastures sown with rape at 0 or 0.5 kg/ha (Table 3). Botanical composition was not determined at this harvest. For the summer regrowth cycle (ending 16/2/2007) yield was 2560±468 kg DM/ha in all pastures and was unaffected by treatment. Botanical composition, determined from replicate 1, is shown in Figure 3. At this time, the clovers represented 60% of total DM yield and 70-95% of this total legume was from red clover.

Discussion

As expected in forestry conversions, the experimental site was highly variable particularly in areas that were formerly windrows. This variability affected the uniformity of plots and consequently the ability to detect significant differences. Despite this, several key results were apparent for dryland forest conversion, particularly when using slow establishing pasture species.

Specifically, Table 1 showed total DM yield at the first harvest (17/1/2006) was not affected by grass species or rape sowing rate, but rape rate did affect pasture composition. The value of the cover crop for weed suppression was shown as 50% of total DM yield, or 1660 kg DM/ha, contributed by weeds in pastures established without a cover crop compared with ≤10% (<400 kg DM/ha) in pastures which included rape at 1.5 or 3.0 kg/ha. Yields of grass, legume and herb components were all reduced by the inclusion of rape at 1.5 or 3.0 kg/ha (Table 1). Pasture species affected sown grass yield with perennial ryegrass production more than double that of tall fescue and 10 times that of the cocksfoot. This advantage in perennial ryegrass production is consistent with its low thermal time requirements for germination and establishment and high seedling vigour even in dry conditions (McWilliam *et al.* 1970).

The suppression of white clover by rape was shown by the reduction of clover from 22% of the pasture when no rape was included to <5% when 3.0 kg/ha of rape was used. This is consistent with reports that white clover is less competitive than other species (Cullen 1964). Similar trends were observed for the grass and herb components. The inclusion of rape as a cover crop at 1.5 or 3.0 kg/ha produced 2560±127 kg DM/ha with no additional DM yield from the high rape sowing rate. The lack of perennial woody weeds, specifically gorse and broom, at this site was unexpected, particularly because 40 gorse seedlings/m^2 were counted at an adjacent site prior to pasture establishment (Edwards *et al*. 2007). The lack of woody weeds reflects their slow growth and consequently their low contributions to total DM yield. Hard grazing has been recommended for gorse suppression during pasture establishment and lime application is also known to suppress gorse (Edwards *et al*. 2007: Hartley & Phung 1979).

By the second harvest, total yield and contributions from clover, herbs, weed and dead fractions were similar (Table 2). The inclusion of 1.5 kg/ha of rape was sufficient to continue suppression of weeds and maintain pasture yield at this dryland ex-forestry site although this differed between grass species. The yield of the slower establishing cocksfoot (Moot *et al.* 2000) was lower than the other grass species which probably contributed to the increased (P<0.10) clover and weed content in these pastures. Rape regrowth from pastures established

Figure 2 Grass (■), brassica (▧), clover (□), herb (▥), weed (▨) and dead (⊠) DM yields, on 13/10/2006 in replicate 1, of perennial ryegrass, tall fescue or cocksfoot based pastures sown in combination with rape at 0, 0.5, 1.5 or 3.0 kg/ha for undersown dryland pastures established after forest conversion.

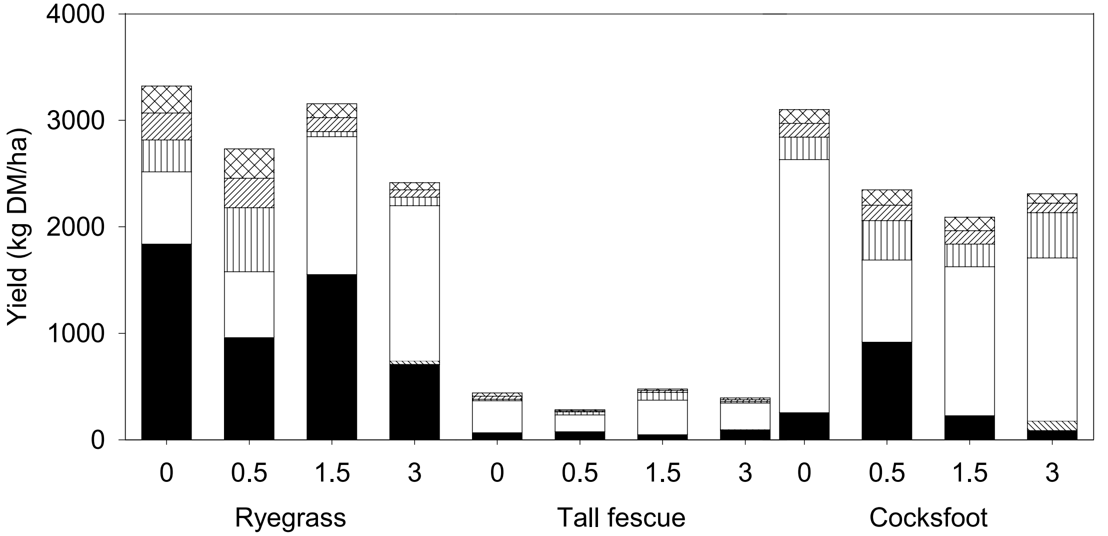
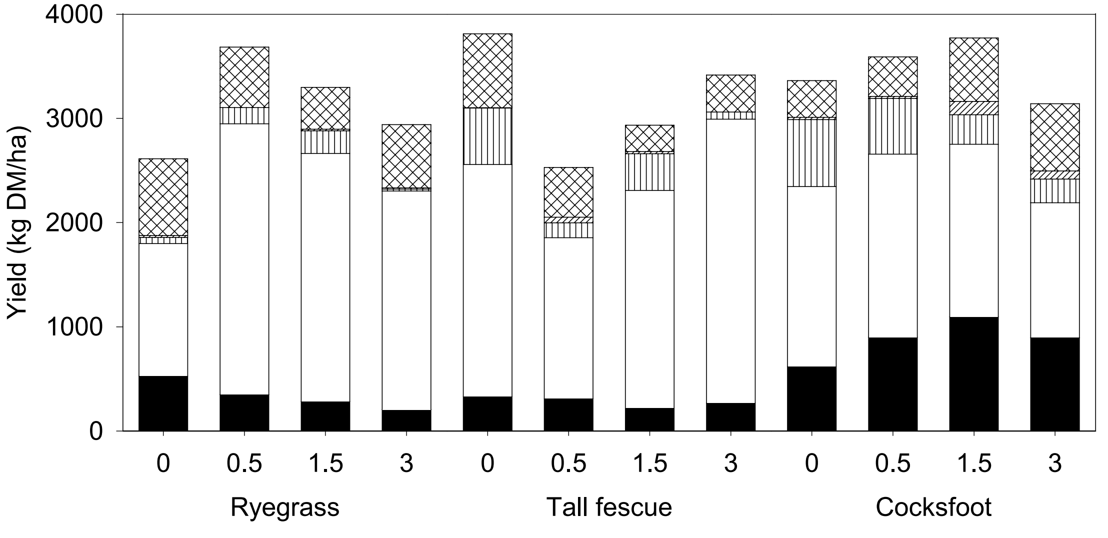


Figure 3 Grass (■), clover (□), herb (▥), weed (▨) and dead (⊠) DM yields of perennial ryegrass, tall fescue or cocksfoot pastures sown in combination with rape at 0, 0.5, 1.5 or 3.0 kg/ha on 16/2/2007 from replicate 1 for undersown dryland pastures established after forest conversion.



with 3.0 kg/ha of rape was 578 kg DM/ha or double that from the other treatments. Beyond this harvest, the rape contribution to total yield was negligible.

An indication of seasonal differences in species productivity can be seen from the spring and summer harvests. The yield and composition of the third harvest were affected by the unplanned grazing during winter. However, the early spring advantage of the perennial ryegrass and white clover, which represented 63% of the total legume yield, is illustrated in Figure 2. Equally the composition from replicate 1 of the summer harvest (Fig. 3) shows cocksfoot had the highest grass yield, and the tap rooted red clover dominated the legume and herb component. The low (<5%) weed component in all pastures reflects the annual nature of the main weed species (fathen) at this site.

The sown grasses represented ≤50% of the total DM yield at all harvests. This probably reflects the lack of available nitrogen in the system immediately after the removal of trees and the high wood content, meaning N is immobilised during decomposition due to a high C:N ratio (Condron *et al.* 2007). Typically, cultivated soils will release nitrogen that can result in establishing pastures being grass dominant. In contrast, these pastures were legume dominant, initially with white clover and then, after about 12 months, with red clover. Over time the red clover will decline as it generally only persists for 2-5 years (Brown *et al.* 2005). Pastures may then require either high fertiliser nitrogen inputs or potentially direct drilling of annual clovers to maintain productivity.

The use of perennial ryegrass may not be suitable for the shallow stony soils of ex-forestry sites as it is unlikely to persist and recover from summer drought conditions as successfully as tall fescue or cocksfoot based pastures (Charlton & Stewart 1999; Stevens & Hickey 2000). It is likely that perennial ryegrass yields would be compromised over summer months in an average year as the soil moisture deficit developed (Korte & Chu 1983). Due to the spring sowing, annual clovers were not included in pastures but this may be an alternative option for weed suppression in autumn sown pastures established after the removal of forests. Regardless, this experiment has shown that when a slow establishing species is selected to ensure long term pasture productivity it is important to use a cover crop to reduce competition from weed species.

Conclusions

- Total DM production was similar in all pastures at the first two harvests and the inclusion of rape at ≥1.5 kg/ha reduced weed content during pasture establishment while maintaining total yield.
- Brassica yield at the first harvest was similar for pastures which included rape at 1.5 and 3.0 kg/ha.

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