

Harvest Timing in *Lolium perenne* L. Seed Crops Treated with the Growth Regulator Triapenthenol

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ABSTRACT

Following triapenthenol application, the seed yields of three *Lolium perenne* L. cultivars, Frances, Talbot and Melle (very early, intermediate and late flowering respectively) were significantly influenced by harvest timing. Maximum seed yield did not differ between treated and untreated plots. However, triapenthenol significantly increased seed yield as harvest was delayed, because crop maturity was delayed, and seed was shed from untreated plots. Seed yield increases were greater in cv. Frances and cv. Talbot than cv. Melle. The results are discussed in relation to harvest timing in experimental trials.

Additional index words: perennial ryegrass, seed production, triazole, cultivar, crop maturity.

INTRODUCTION

Triazole growth regulator effects on *Lolium perenne* seed crops are well documented, and seed yield responses have shown large variations in magnitude (Hebblethwaite, 1987). These differences are partly accounted for by different cultivars (Barrett, 1986; Wiltshire, 1988), and partly by seasonal differences (Hampton and Hebblethwaite, 1984; Hampton and Hebblethwaite, 1985; Wiltshire, Hebblethwaite, Esslemont and McGilloway, 1989). Different environmental conditions and field trial methodology may also be factors. The work reported in this paper investigates the seed yield response to time of harvesting in triazole growth regulator treated plots.

Most previous studies of triazole growth regulator effects on ryegrass seed crops have based seed yield estimates on a single harvest date. Harvest time is critical because the crop contains seed heads with a range of physiological ages which do not ripen simultaneously, and because seed is readily shed from the ear when it is mature (Hill, 1973). Harvest time must be a compromise between harvesting sufficiently early to recover the maximum number of seeds before they are shed, and late enough to allow the seeds to become sufficiently mature to resist mechanical damage during threshing. This compromise is easier to achieve by mowing at 40-45% seed moisture content (SMC) and combining after a period of drying in the field than by direct combining, which is normally done at 25%-30% SMC. Anslow (1964), Hill and Watkin (1975) and Hebblethwaite and Ahmed (1978) each found that perennial ryegrass seed yield was at a maximum when

SMC was between 40% and 50%. Simon (1987) reported that the SMC for maximum seed yield in a *Festuca pratensis* seed crop was 50%. In contrast with the above findings Hebblethwaite, Burbidge and Wright (1977) found that the seed yield of cv. S.24 perennial ryegrass was greater at 30% SMC than at 40%. Anslow (1964) reported that maximum seed germination was obtained when individual seed weight had reached a maximum, which was when SMC was about 40%. Hebblethwaite and Ahmed (1978) found that high germination percentages were obtained at a moisture content in excess of 40%, but that 1000-seed weight continued increasing as the moisture content decreased. Other measurements made over a five year period have shown that a perennial ryegrass seed crop can be threshed and yield 90% germination at a maximum SMC of 46% (NIAB, 1968), but to obtain high quality seed, the crop should not be threshed until SMC has fallen to 30%.

The optimum harvest time in a growth regulated ryegrass seed crop will be different from that in an untreated crop because triazoles cause a delay in crop maturity (Faulkner, 1981; Hampton and Hebblethwaite, 1985; Barrett, 1986) and also because the time and rate of seed shedding may be different in a crop with modified canopy structure.

The aim of this experiment was to test the hypothesis that differences in seed yield between triapenthenol (proposed common name) treated and untreated plots were independent of harvest date and of seed moisture content at harvest.

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MATERIALS AND METHODS

A field experiment was conducted on the University of Nottingham Experimental Farm, School of Agriculture, Sutton Bonington, Leicestershire (Latitude 52°5'). Details of crop management are given in Table 1. Three agricultural cultivars of *L. perenne* (Frances, Talbot, Melle) with time of heading classification (NIAB, 1985) of very early, intermediate and very late respectively, were used.

The growth regulator triapenthenol, code-named RSW0411 was used. It is a triazole with the molecular formula C₁₅H₂₅N₃O and chemical name (E)-(RS)-1-cyclohexyl-4,4-dimethyl-2-(1H-1,2,4-triazol-1-yl)pent-1-en-3-ol. Further details are given by Lurssen and Reiser (1985).

The experimental design was a split plot randomised block with four replications. A cultivar was randomly allocated to each main plot, and a treatment to each sub-plot. Triapenthenol applications were made at double ridge and spikelet initiation, i.e. 18 March and 11 April for cv. Frances, 3 April and 25 April for cv. Talbot and 5 May and 16 May for cv. Melle, at rates of 1, 2 and 3 kg active ingredient (a.i.) ha⁻¹. Timings and rates of applications were arranged factorially, giving six triapenthenol treatments and one control (no triapenthenol application).

Apical development stages were monitored at two or three day intervals during the transition of the apex from a vegetative to a reproductive state, and during early inflorescence development. Random samples of 20 tillers (ignoring tillers with no fully expanded leaves) were taken from parts of the field plots which were not to be used for subsequent growth analysis or final harvest sampling, and were dissected under a binocular microscope. The crop was defined as reaching a certain stage of apical development when 70% of a sample had reached or passed that stage. Specific development stages have been defined by Sweet, Wiltshire and Baker (1991).

Samples for seed yield determinations were taken from all plots of each cultivar on a succession of five dates (Figs 1-3). A reciprocating knife mower (Mayfield) was used to cut strips across the width of the plots. The area harvested from each plot was 1.5 m² on the first, second, fourth and fifth harvest dates for each cultivar, and 4.4 m² on the third harvest date. The cut material was put into cotton bags by hand, and was cool air dried to a seed moisture content of 9-11% before threshing and seed cleaning.

Decisions relating to the dates of seed harvests were made on the basis of results from seed moisture content measurements. Samples of ears from four replicates were taken before mowing, bulked together and hand threshed in a polythene bag, to give a seed sample of approximately

TABLE 1
Details of crop management

Year of harvest	1986	
Previous crop	Early potatoes	
Sowing date	16 August 1985	
Seed rate	12 kg ha ⁻¹	
Plot size	12 m x 1.6 m	
Row width	115 mm	
Herbicide	19 September 1985: 2,3,6-TBA, 125 g ha ⁻¹ ; diacamba, 106 g ha ⁻¹ ; mecoprop, 840 g ha ⁻¹ ; MCPA, 560 g ha ⁻¹ 7 November 1985: ethofumesate, 2 kg ha ⁻¹	
Fertilizer		
Date	12 March 1986	
Rates	N:	100 kg ha ⁻¹
	P ₂ O ₅ :	50 kg ha ⁻¹
	K ₂ O:	50 kg ha ⁻¹

30 g fresh weight. A small sub-sample was taken for an immediate moisture content determination using a N. Foss Electric 'Infra-Tester'. The remainder of the sample was weighed, then dried to a constant weight at 80°C, and reweighed to give a more accurate seed moisture content measurement. Seed moisture contents presented here were obtained by the latter method.

Cleaned seed samples were weighed, and the yield m⁻² was calculated. A sub-sample of 30-40 g of cleaned seed was weighed, dried to a constant weight at 80°C then reweighed, and the moisture content and dry seed yield m⁻² were calculated. A sub-sample of 2-4 g was taken from the cleaned seed samples, counted using an electronic seed counter, and dried to a constant weight at 80°C. The weight was recorded and 1000-seed weight and seed number m⁻² were calculated. Yields are presented at zero g kg⁻¹ moisture concentrations.

Germination tests were performed in accordance with the rules of the International Seed Testing Association (ISTA, 1985) within three months of harvest.

RESULTS

Triapenthenol treatment results are presented as means of all triapenthenol treatments within each cultivar. Significant differences between triapenthenol treatments are referred to in the text only; the magnitudes of these differences were small compared with differences between treated and control plots. Data for each individual treatment on each harvest date are presented in full by Wiltshire (1988) and these followed the same trends as the means of all triapenthenol treatments.

FIGURE 1.

Seed yield m^{-2} , seed number m^{-2} , 1000 seed weight and seed moisture content of the mean of triapenthenol treatments and controls for cv. Frances at five harvest dates.

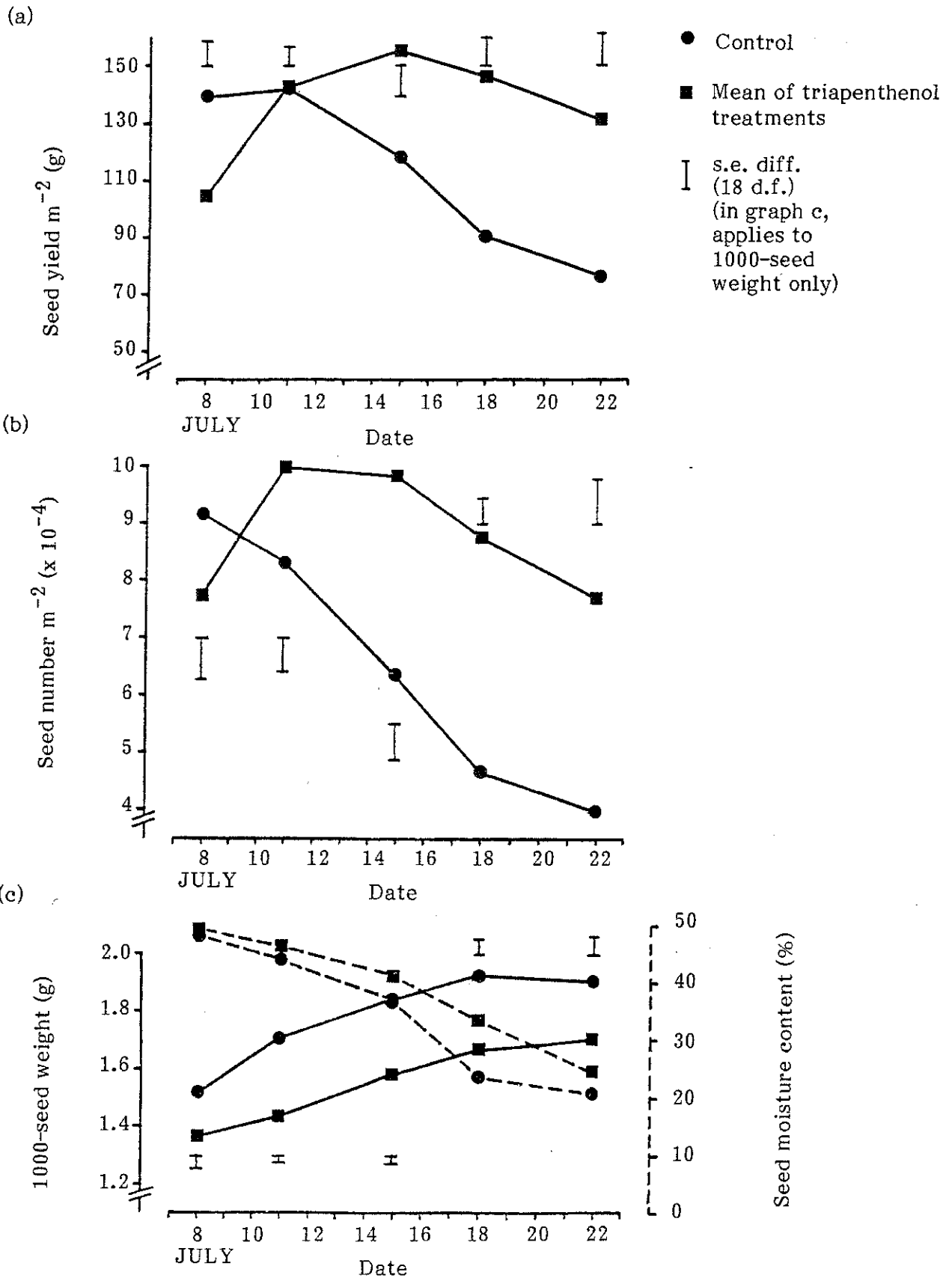


FIGURE 2.

Seed yield m^{-2} , seed number m^{-2} , 1000 seed weight and seed moisture content of the mean of triapenthenol treatments and controls for cv. Talbot at five harvest dates.

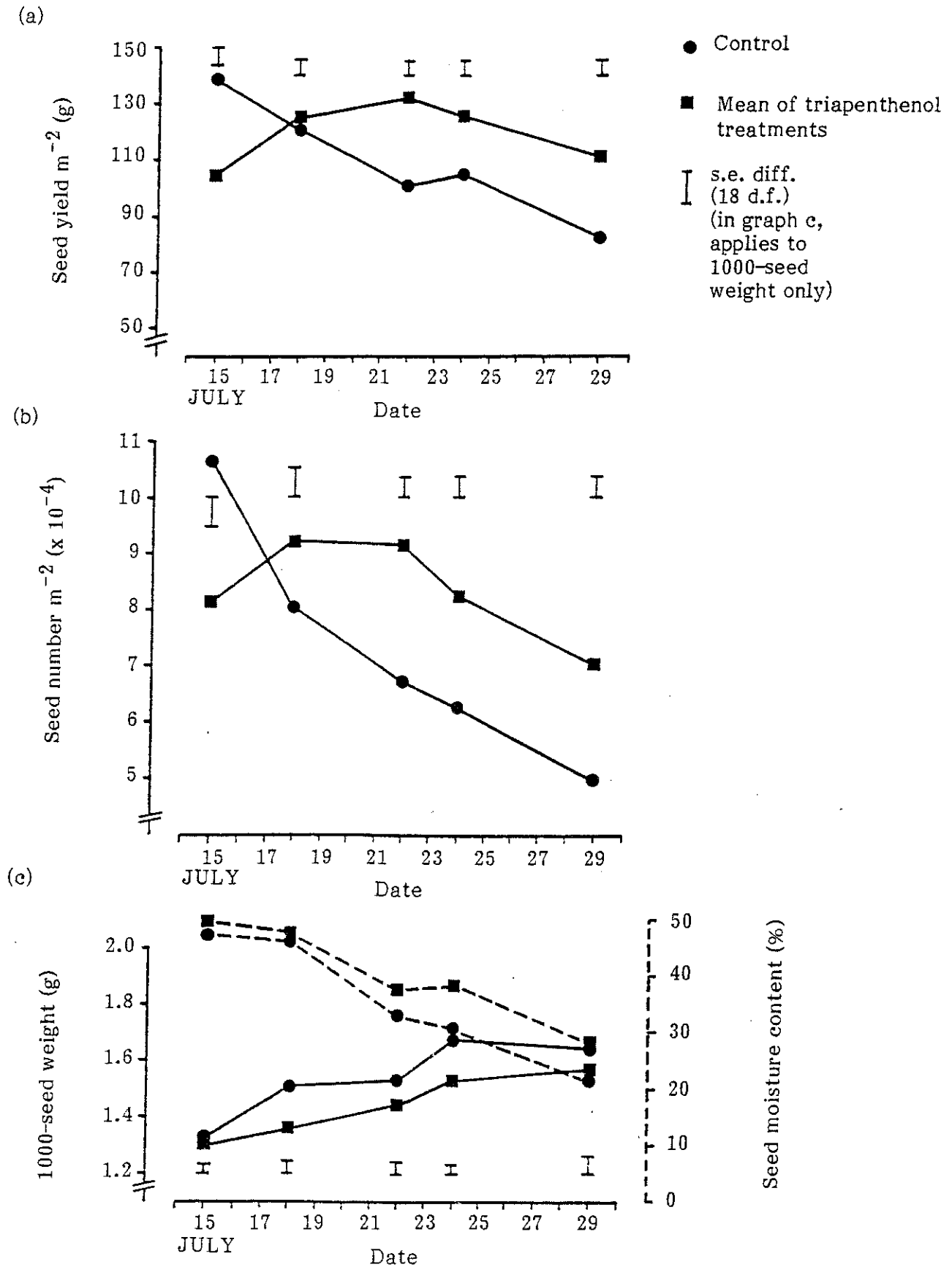
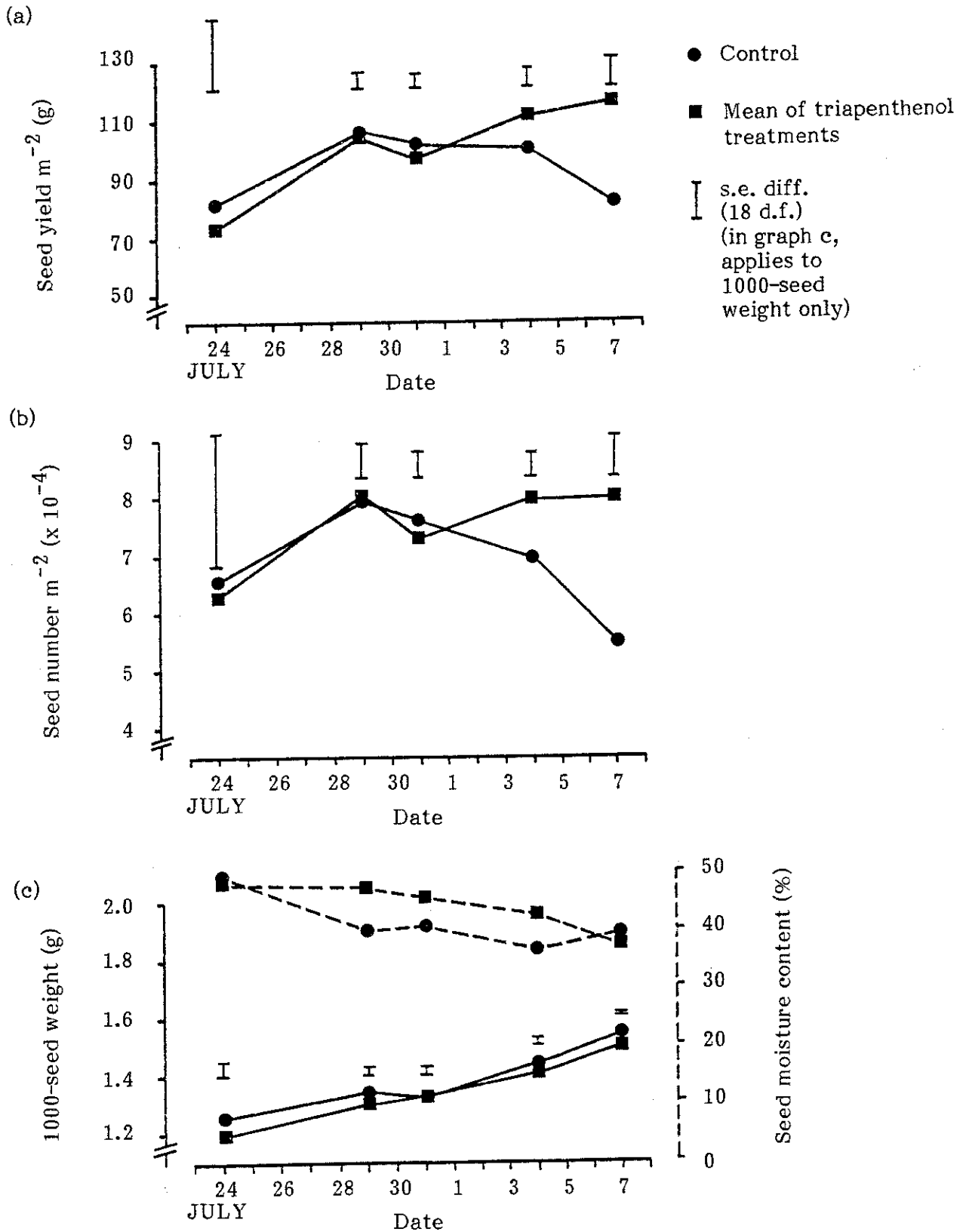


FIGURE 3.

Seed yield m^{-2} , seed number m^{-2} , 1000 seed weight and seed moisture content of the mean of triapenthenol treatments and controls for cv. Melle at five harvest dates.



Frances: Triapenthenol treated plots had a lower seed yield on the first harvest date ($P < 0.001$), and a significantly higher seed yield than control plots on the third, fourth and fifth harvest dates (Figure 1.a) ($P < 0.01$, $P < 0.001$ and $P < 0.001$ respectively). The maximum mean seed yield for control plots was obtained on the second harvest date (11 July) at 44.2% SMC, and the maximum for the mean of treated plots was obtained on the third harvest date (15 July) at 41.5% SMC (Fig. 1.a, 1.c). No differences in maximum seed yields between treated and untreated plots, and no effects of triapenthenol application timings or rates were found.

Triapenthenol treated plots had a greater seed number m^{-2} than untreated plots on the second, third, fourth and fifth harvest dates (Fig. 1.b) ($P < 0.025$, $P < 0.001$, $P < 0.001$ and $P < 0.001$ respectively). The maximum harvested seed number was obtained at 44% SMC (Fig. 1.b, 1.c) earlier than the maximum seed yield. The increase in 1000-seed weight with time (Fig. 1.c) initially compensated for falling seed numbers. Seed from control plots had a significantly greater 1000-seed weight than that from treated plots at all harvest dates ($P < 0.025$).

On the fourth harvest date (18 July), plots treated with 3 kg a.i. ha^{-1} had a higher mean seed yield than other treated plot ($P < 0.05$); on the fifth harvest date (22 July), there was a consistent trend towards higher seed yields with higher rates of triapenthenol application ($P < 0.025$). This same trend was observed in seed numbers m^{-2} on 18 July, and was also statistically significant ($P < 0.01$).

Talbot: Triapenthenol treated plots had a lower seed yield on the first harvest date ($P < 0.001$), and significantly outyielded control plots on the third, fourth and fifth harvest dates (Fig. 2.a) ($P < 0.001$, $P < 0.01$ and $P < 0.001$ respectively). The maximum mean seed yield from control plots was obtained on the first harvest date (15 July) at 47% SMC, while the maximum seed yield for the mean of treated plots was obtained on the third harvest date (22 July) at 37% SMC. Analysis of variance of maximum seed yields obtained for each treatment showed no differences between the means of treated and untreated plots. There was, however, a significant effect of application timing: plots treated at spikelet initiation had a greater seed yield than those treated at double ridge ($P < 0.05$).

Seed number m^{-2} was decreased by triapenthenol treatment on the first harvest date ($P < 0.001$), but increased on the following four harvest dates (Fig. 2.b) ($P < 0.05$, $P < 0.001$, $P < 0.001$ and $P < 0.001$ respectively). Seed from treated plots had a consistently lower 1000-seed weight than that from control plots, and this difference was significant on the second and fourth harvest dates (Fig. 2.c) ($P < 0.025$ and $P < 0.001$ respectively).

Melle: Triapenthenol treated plots outyielded the control only on the fifth harvest date (Fig. 3.a) ($P < 0.01$), while seed number was increased on the fourth and fifth harvest dates (Fig. 3.b) ($P < 0.05$ and $P < 0.01$ respectively). The maximum seed yield and seed number m^{-2} for control plots was obtained on the second harvest date (29 July) at 40% SMC, while the maximum seed yield for the mean of treated plots was obtained on the fifth harvest date (7 August) at 37.5% SMC. Differences between the second, fourth and fifth harvest dates in seed number m^{-2} of treated plots were small (Fig 3.b), and seed numbers were greater than on the first and third harvest dates. There were no significant differences between maximum mean seed yields of treated and untreated plots, nor between maximum seed yields of triapenthenol treatments. 1000-seed weight increased as harvest was delayed, but no differences between control and triapenthenol treated plots were recorded (Fig. 3.c).

On the third and following harvest dates, wet weather made accurate seed moisture content measurements different (Fig. 3.c). Excessive moisture retained within the floral bracts and on the surface of the caryopsis may have resulted in elevated measurements, despite attempts to remove this moisture. It is probable that this effect was greatest in control plots, which were more densely lodged than treated plots (Wiltshire, 1988), and in which the canopy dried out more slowly.

The rate of triapenthenol application had a significant effect on seed yield and seed number m^{-2} on the second and fourth harvest dates, when treatment with 2 kg a.i. ha^{-1} gave increases over other treatments ($P < 0.05$).

Germination: In all three cultivars and for all five harvests there were no significant differences between germination of seed from the control plots and plots treated at spikelet initiation with 3 kg a.i. ha^{-1} triapenthenol.

DISCUSSION

In the United Kingdom, direct combining of perennial ryegrass at 25-30% SMC is the preferred harvest method (MAFF, 1981). However, in untreated plots, maximum seed yield for all three cultivars was recorded between 40-47% SMC (Table 2), a result which agrees with data presented by Anslow (1964), Hill and Watkin (1975) and Hebblethwaite and Ahmed (1978). Waiting to direct combine at 25-30% SMC would have resulted in a seed yield loss of around 50 g m^{-2} and 40 g m^{-2} for cultivars Frances and Talbot respectively, while cv. Melle did not reach 30% SMC during the duration of the experiment, but had already lost around 25 g seed m^{-2} in drying down to 40% SMC. These seed yield losses resulted from

TABLE 2
Dates and seed moisture contents at which maximum seed yields were obtained in cultivars Frances, Talbot and Melle, treated and untreated with triapenthenol.

	Control		Mean of triapenthenol treatments	
	Moisture content (%)	Date	Moisture content (%)	Date
Frances	44.2	11 July	41.5	15 July
Talbot	47.1	15 July	37.2	22 July
Melle	40.0	29 July	37.5	7 August
Mean	43.8	—	38.7	—

shedding of the earliest maturing seeds (Hill, 1973). Attempts to direct combine at higher seed moisture contents can lead to seed damage during threshing as the endosperm is still soft (Hill, 1973), and to practical difficulties in passing a large quantity of fresh green material through a combine.

In *Lolium* species, endosperm maturation is able to proceed in caryopses after the culm has been severed at an immature stage (Stoddart, 1965), and in other countries, mowing and combine harvesting after a period of field drying is preferred. For example, in New Zealand, perennial ryegrass is cut at around 42% SMC, and field dried to 25% SMC if drying facilities are available or to 14% SMC if they are not, before combining (J.G. Hampton, pers. comm.). This method of course, depends on an environment which allows field drying to occur relatively quickly.

Plots in this trial were harvested by a modified mowing and threshing system which produced seed yields much higher than those that would have been obtained from direct combining at a lower seed moisture content, in line with commercial practice. Similarly, seed yield differences between treated and untreated plots were smaller when each was harvested at the time of maximum seed yield, than if all plots had been direct combined on the same day. For example, in cv. Frances, triapenthenol treatments outyielded the control by 71% at around 25% SMC, whereas maximum seed yield (at 41-44% SMC) differed by only 10% (Fig. 1).

Treatment with triapenthenol caused a delay in crop maturity, so that maximum seed yield was delayed 4, 7 and 9 days for cultivars Frances, Talbot and Melle respectively (Table 2). Similar delays in maturity have been reported with paclobutrazol (Hampton and Hebblethwaite, 1985) and triapenthenol (Wiltshire *et al.*, 1989). These results emphasise the point that to accurately record treatment effects, seed should be harvested at a common moisture content and not necessarily a common harvest date. This should be taken into consideration when looking at results reported in previous work with triazole growth regulators, where seed yield assessments are mostly from a single harvest date. On the other hand, at the final harvest date for both cv. Frances and cv. Talbot, when SMC of all plots was between 21-28%, triapenthenol treatments outyielded the control because less seed had been shed. These data therefore provide a realistic assessment of growth regulator effects for growers who direct combine, even though yields were not maximal at the time of harvest. Harvest times for the late heading cv. Melle were too early, and therefore direct comparisons with the other two cultivars cannot be made.

CONCLUSIONS

From this work the following can be concluded:

1. The hypothesis, that differences in seed yields between triapenthenol treated and untreated plots are independent of harvest date and of seed

moisture content at harvest, can be rejected.

2. Waiting to direct combine at 25-30% SMC may reduce seed yield by up to one-third in early-mid heading cultivars because of seed shedding.
3. Because of maturity delays, triapenthenol treated plots outyielded the control when harvested at 25-30% SMC, because less seed was shed.
4. Previously reported seed yield responses to triazole plant growth regulators (PGRs) may have reflected seed maturity/harvest timing differences, rather than solely PGR responses, as maximum seed yields for the mean of triapenthenol and for control plots did not differ significantly. However, the ability of PGRs to delay seed shedding needs to be further investigated.
5. For direct comparisons of PGR effects on seed yield, treated and control plots should be harvested at the same seed moisture content, which means that harvest may not necessarily be on the same day.
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