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THE EFFECT OF TEMPERATURE AND SOIL MOISTURE ON THE ACTIVITY OF ISOPROTURON AND CHLORTOLURON ON ALOPECURUS MYOSUROIDES AND WINTER WHEAT

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The effect of temperature and soil moisture on the activity of isoproturon and chlortoluron on Alopecurus myosuroides and winter wheat

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Summary

The effect of isoproturon and chlortoluron on wheat and A. myosuroides growing under different temperature regimes (10/6, 16/10 and 26/16°C) was investigated in controlled environment rooms. Absolute humidity deficit and light were the same in the three temperature regimes and soil moisture was maintained around field capacity. The activity of chlortoluron applied pre-emergence to wheat was not markedly affected by the temperature regime in which the plants were growing whereas A. myosuroides was least damaged in the 26/16°C day/night regime. When both of these species were treated post-emergence at the three-leaf stage, chlortoluron was less active when grown throughout the experiment in a 10/6°C regime.

The activity of isoproturon applied pre-emergence on wheat was increased by high temperatures (26/16°C), whereas susceptibility of A. myosuroides was unaffected by the temperature regime. When the wheat and A. myosuroides plants were growing before and after spraying in the same conditions, the temperature regime had little effect on isoproturon performance. When wheat plants were kept at 16/10°C until spraying at growth stage 13,20 (Zadoks, Chang & Konzak, 1974), subsequent transfer to the high compared with the low temperature regime resulted in increased phytotoxicity. A. myosuroides response to isoproturon was less affected by temperature. When seedlings of both species growing in a 10/6°C temperature regime were subjected to a short-term (24 h) exposure at 26/16°C, activity of isoproturon was not markedly altered.

Wheat seedlings treated with isoproturon were less damaged if plants were watered by sub-irrigation rather than via the soil surface. With surface watering, raising the moisture level from 50% to 100% FC increased activity. With sub-surface watering via a tube, differences between 50% FC and higher moisture contents were smaller and more erratic.

INTRODUCTION

Certain herbicides of the substituted urea group have been used to control Alopecurus myosuroides Huds. (blackgrass) selectively in winter wheat. The degree of control has sometimes been variable and this can in part be explained by soil factors and cultural regimes. For example, stubble burning and direct drilling are associated with less reliable control of grass-weeds by these herbicides (Nyffeler & Blair, 1978; Cussans, Moss, Hance, Embling, Caverley, Marks & Palmer, 1982). Climatic factors may also have some influence on the efficacy of this group of herbicides (e.g. Blair, Richardson & West, 1983). This report describes pot experiments in controlled environment chambers designed to assess the effect of temperature on the activity of isoproturon and chlortoluron on both winter wheat and A. myosuroides. One experiment investigating the effect of soil moisture is also included.

MATERIALS AND METHODS

Plant raising

5 seeds of wheat or 15 seeds of A. myosuroides were planted in 9 cm diameter pots in Begbroke North soil (coarse sand 17%, medium sand 27%, fine sand 31%, silt 10%, clay 15% and o.m. 2.2%) at 2.5 and 0.6 cm depth respectively. Seedlings for post-emergence treatment were thinned to 4 per pot after emergence. Plants were raised in controlled environments, either in

'Vötsch' rooms or 'Saxcil' cabinets with vertical air flows of approximately 0.23 m/s. Light was provided by warm white fluorescent tubes + additional tungsten lamps giving a maximum level of 95 Wm^{-2} for 14 h daylength. Temperature and relative humidity, which were controlled, changed diurnally and the detailed environmental conditions under which plants were grown are given with the results of each experiment. Soil temperatures under these conditions closely followed air temperature (Blair, 1983). The soil was kept at around field capacity (21.5 g water/100 g dry soil) by application of water to the soil surface but in 2 experiments (Fig. 2 & 4) an approximate measure of water loss was made by weighing pots at irregular intervals. In these 2 experiments some of the water was added to the foil dish in which pots were standing. In the soil moisture experiment, moisture level was controlled at 50, 100 or 150% field capacity by weighing pots (Blair, Richardson & West, 1983). Water was added either onto the soil surface or via a central tube in the pot (Blair, 1983).

Herbicide application

In the two pre-emergence experiments (Fig. 1 & 3), treatments were applied using a sprayer fitted with a single '8002E' Teejet nozzle which moved over the stationary pots at constant speed, delivering a volume of 385 l/ha at a pressure of 210 kN/m^2, this pressure being used in all experiments. In 2 of the 4 experiments in which treatments were applied post-emergence (Fig. 2 & 4) the same sprayer was used but fitted with a single '8001' Teejet nozzle delivering 175 l/ha. In the other 2 experiments a volume rate of 210 l/ha was applied either through '8003' (Fig. 6) or '8004' (Fig. 5) Teejet nozzles mounted on a boom on a trolley moving over the seedlings. In the soil moisture experiment (Fig. 7) the sprayer described by Caseley (1979) was used. It was fitted with an '8001' Teejet nozzle delivering 250 l/ha.

Both chlortoluron and isoproturon were applied as commercial flowable formulations (isoproturon as 'Hytane 500L') except in the soil moisture experiment in which for each dose of isoproturon the formulation ingredients present in the commercial product 'Hytane 500L' were added to give the concentration present when the product is used to apply 2 kg a.i./250 l/ha. This was accomplished by mixing the dose of technical isoproturon (CGA 18731) with a small volume of water, adding the requisite amount of formulation component, and finally mixing with the required volume of water. Treatments were replicated four times.

Post-spray conditions

After spraying, pots were returned to the appropriate growing condition (see Results). Plants were out of the controlled environment for as short a time as possible. Watering was carried out as in the pre-spray period, but taking care to avoid the foliage.

Assessment

Fresh weights were measured at the growth stages (Zadoks, Chang & Konzak, 1974) indicated in the results section, followed by dry weights after 48 h in an oven at 100°C. These data are presented as graphs.

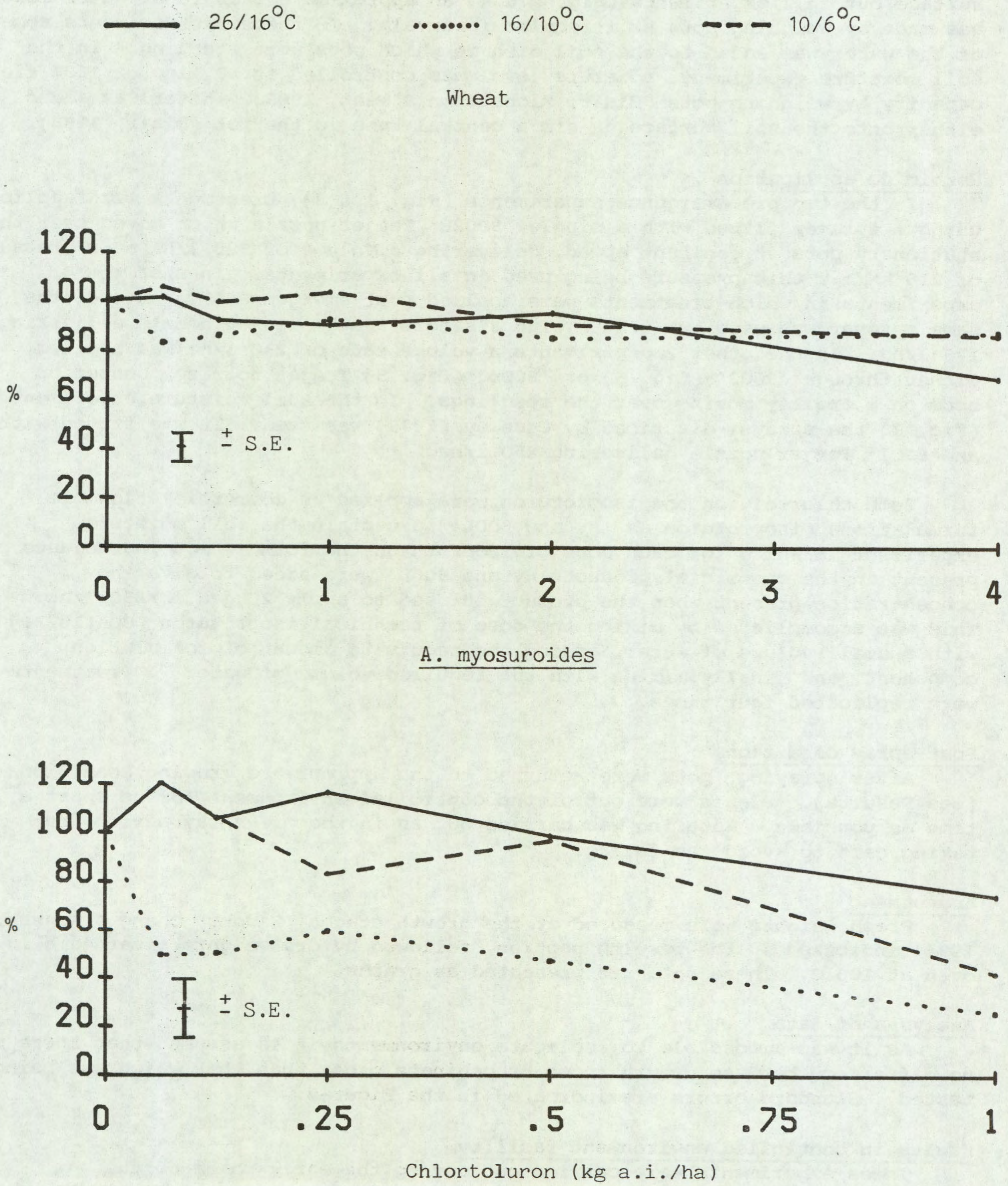
Analysis of data

As it was impossible to replicate environments it is assumed that there was no difference between growth rooms or cabinets other than that which was being tested. Standard errors are indicated in the Figures.

Faults in controlled environment facility

These experiments were carried out during the early phase of the development of a new controlled environment facility at WRO. Consequently from time to time there were malfunctions resulting in a deviation from the defined conditions. In some cases it has been possible to compare similar treatments

Fig. 1. The effect of temperature on the activity of chlortoluron applied pre-emergence to wheat and *A. myosuroides* (Dry weight as % of untreated control)



under the same conditions in different experiments and this gives confidence that any effects observed are real and not a result of changes in conditions. However, in most cases, such comparisons have not been possible and this should be remembered when considering the results.

RESULTS

The results for each experiment are given opposite the appropriate figure.

Experiment 1.

Environmental conditions: 10/6°C, 64/87% rh day/night
16/10°C, 75/86% rh day/night
26/16°C, 85/93% rh day/night

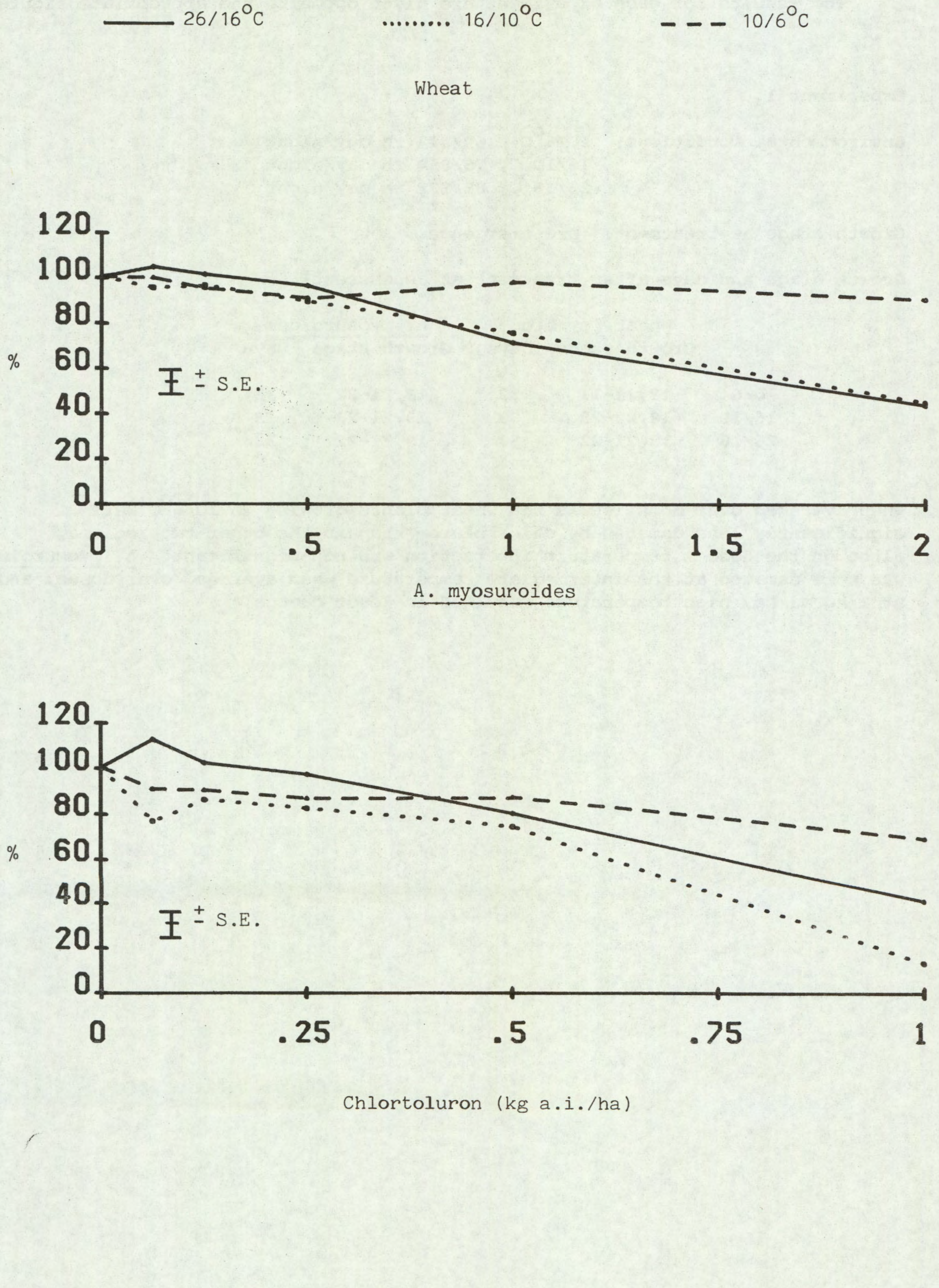
Growth stage at treatment: pre-emergence

Growth stage and days after treatment at assessment:

	Wheat (cv Atou)		A. myosuroides	
	Growth stage	Days	Growth stage	Days
10/6	13,21-11	33	13,21-22	33
16/10	13,22-23	33	13,21-23	33
26/16	13,21-22	33	13,21-22	33

When averaged over dose levels the wheat plants growing in 10/6°C were significantly less damaged by chlortoluron than in the other two regimes, although the dose x temperature interaction was non-significant. A. myosuroides was more damaged at the intermediate temperature when averaged over doses, and at 1 kg ai/ha, high temperature resulted in least damage.

Fig. 2. The effect of the same temperature pre- and post-spraying on the activity of chlortoluron applied at the 3 leaf stage of wheat and A. myosuroides (Dry weight as % of untreated control)



Experiment 2

Environmental conditions: $10/6^{o}C$, 64/87% rh day/night
$16/10^{o}C$, 75/86% rh day/night
$26/16^{o}C$, 85/93% rh day/night

Plants were grown in the same environment throughout the experiment.

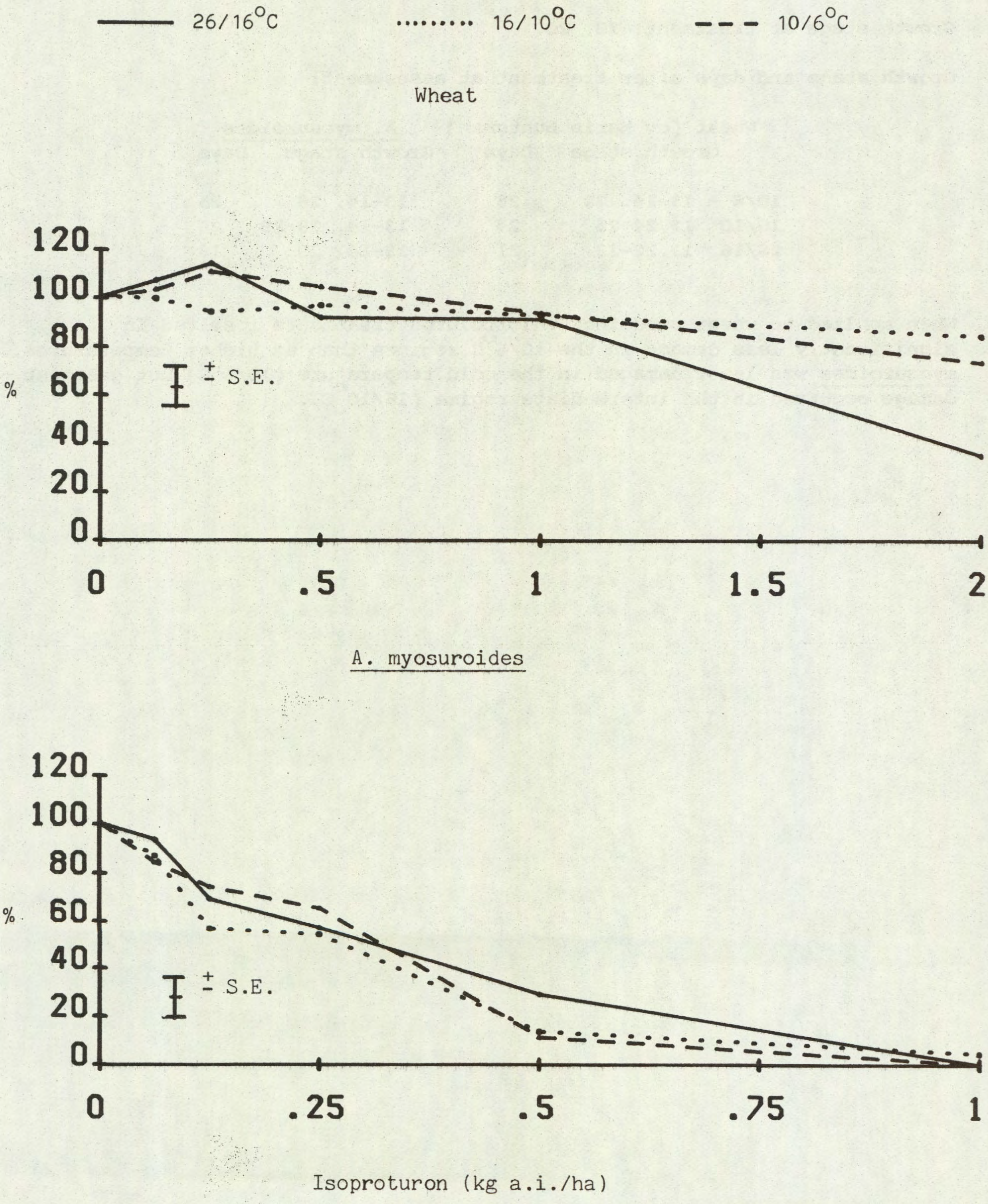
Growth stage at treatment: 13, 20.

Growth stage and days after treatment at assessment:

	Wheat (cv Maris Huntsman)		*A. myosuroides*	
	Growth stage	Days	Growth stage	Days
10/6	13-14, 28	25	13-14, 28	25
16/10	13,24-25	24	13-14, 28-29	24
26/16	13,22-23	21	13-14, 29	18

When applied to wheat seedlings chlortoluron treatments resulted in significantly less damage in the $10/6^{o}C$ regimes than at higher temperatures. *A. myosuroides* was least damaged in the cold temperature ($10/6^{o}C$) but greatest damage occurred in the intermediate regime ($16/10^{o}C$).

Fig. 3. The effect of temperature on the activity of isoproturon applied pre-emergence to wheat and *A. myosuroides* (Dry weight as % untreated control)



Experiment 3.

Environmental conditions; 10/6°C, 64/87% rh day/night
16/10°C, 75/86% rh day/night
26/16°C, 85/93% rh day/night

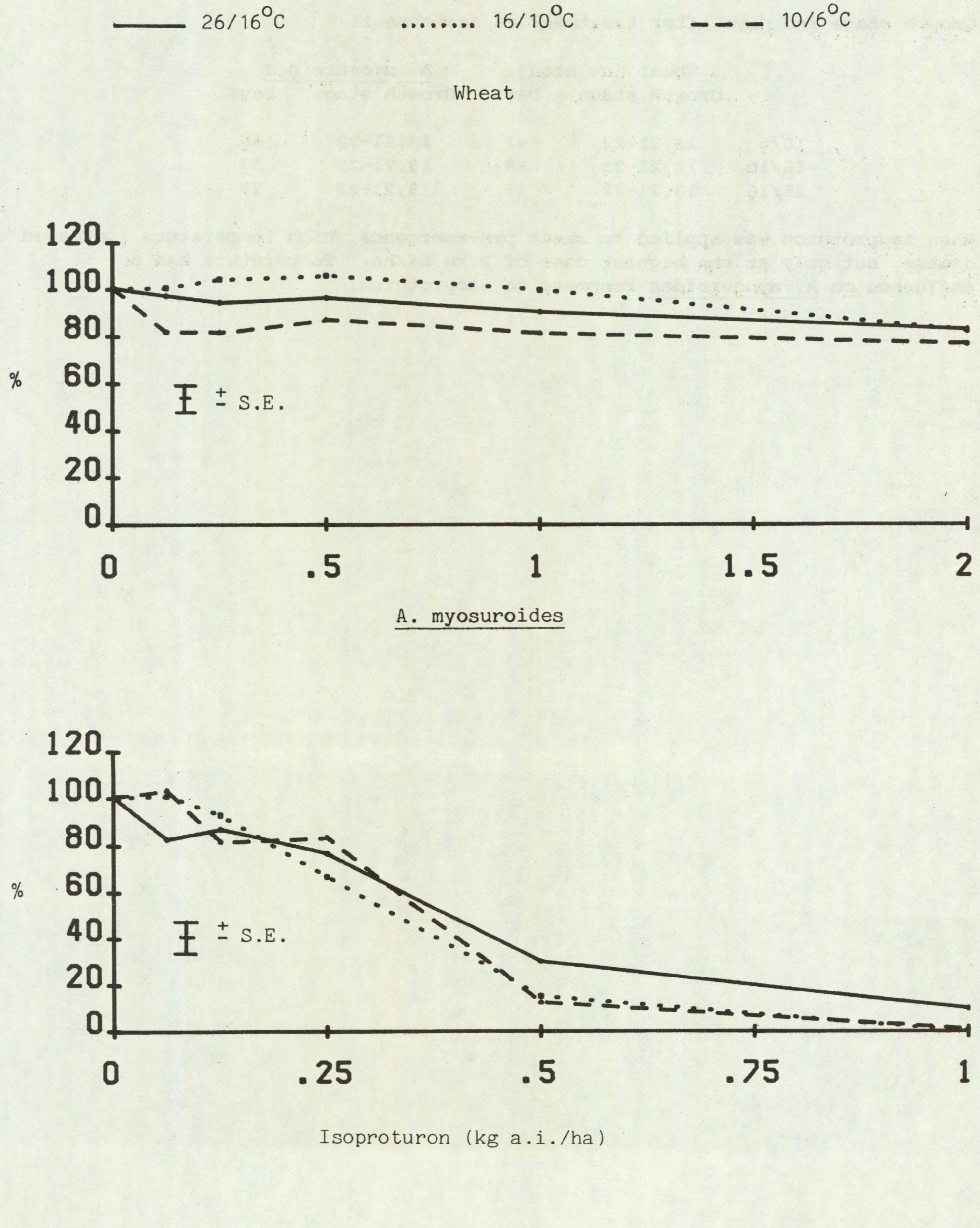
Growth stage at treatment: pre-emergence

Growth stage and days after treatment at assessment:

	Wheat (cv Atou)		*A. myosuroides*	
	Growth stage	Days	Growth stage	Days
10/6	13,21-22	42	13,21-22	50
16/10	13,21-23	33	13,21-22	33
26/16	13,21-22	29	13,21-22	29

When isoproturon was applied to wheat pre-emergence, high temperature increased damage, but only at the highest dose of 2 kg ai/ha. Temperature had no influence on A. myosuroides response to isoproturon.

Fig. 4. The effect of the same temperature pre- and post-spraying on the activity of isoproturon applied at the 3 leaf stage of wheat and A. myosuroides (Dry weight as % of untreated control)



Experiment 4.

Environmental conditions; 10/6°C, 64/87% rh day/night
16/10°C, 75/86% rh day/night
26/16°C, 85/93% rh day/night

Plants were grown in the same environment throughout the experiment.

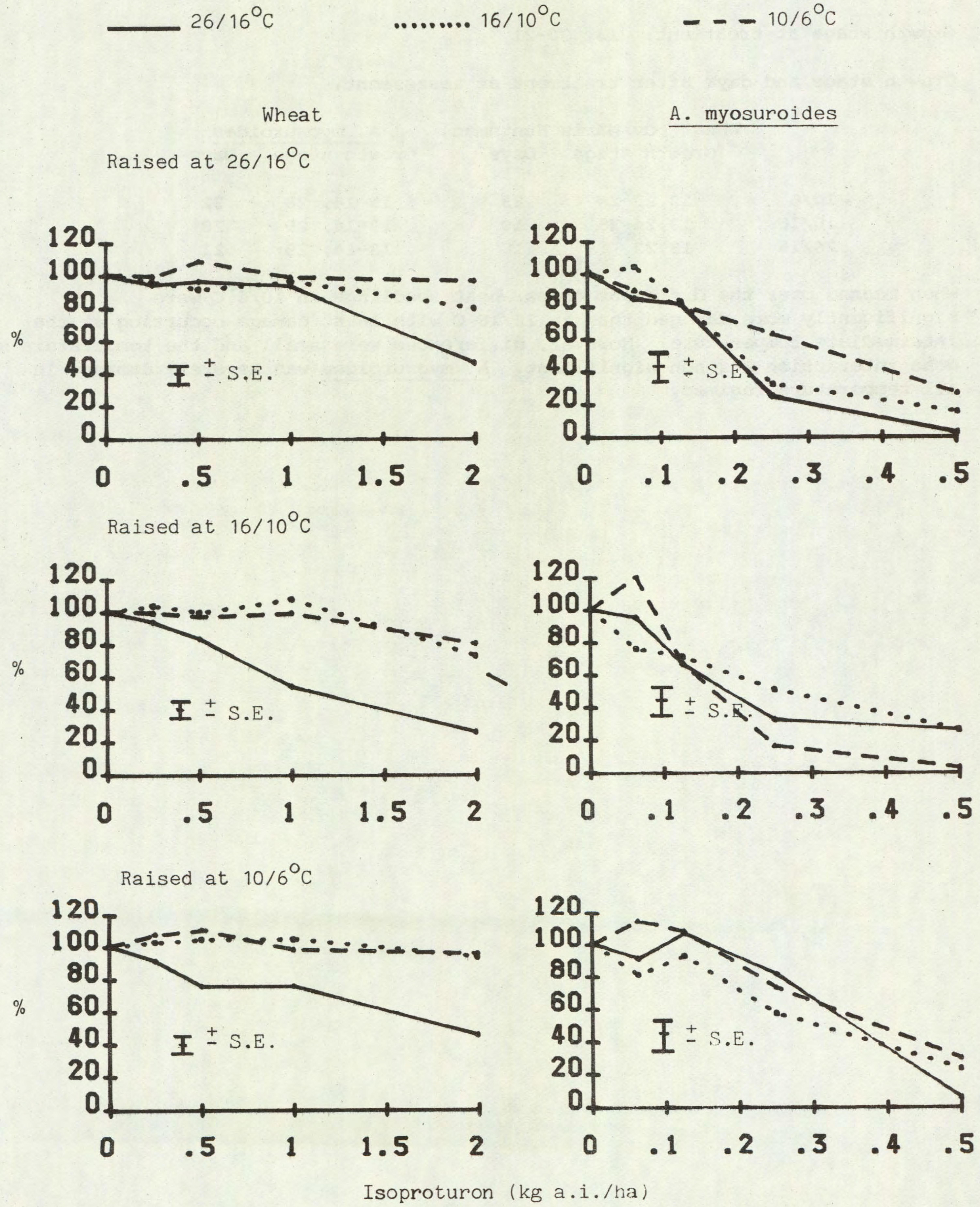
Growth stage at treatment: 13, 20-21

Growth stage and days after treatment at assessment:

	Wheat (cv Maris Huntsman)		A. myosuroides	
	Growth stage	Days	Growth stage	Days
10/6	13,23-24	23	13-14, 28	32
16/10	13,24-25	19	13-14, 29	28
26/16	13,23	18	13-14, 29	21

When meaned over the different doses wheat seedlings in 10/6°C were significantly more damaged than in 26/16°C with least damage occurring at the intermediate temperature. However, differences were small and the temperature x dose interaction was non-significant. A. myosuroides was severely damaged in all temperature regimes.

Fig. 5. The effect of pre- and post-spray temperatures on the activity of isoproturon applied at the 3 leaf stage of wheat and *A. myosuroides.* (Dry weight as % untreated control)



Experiment 5.

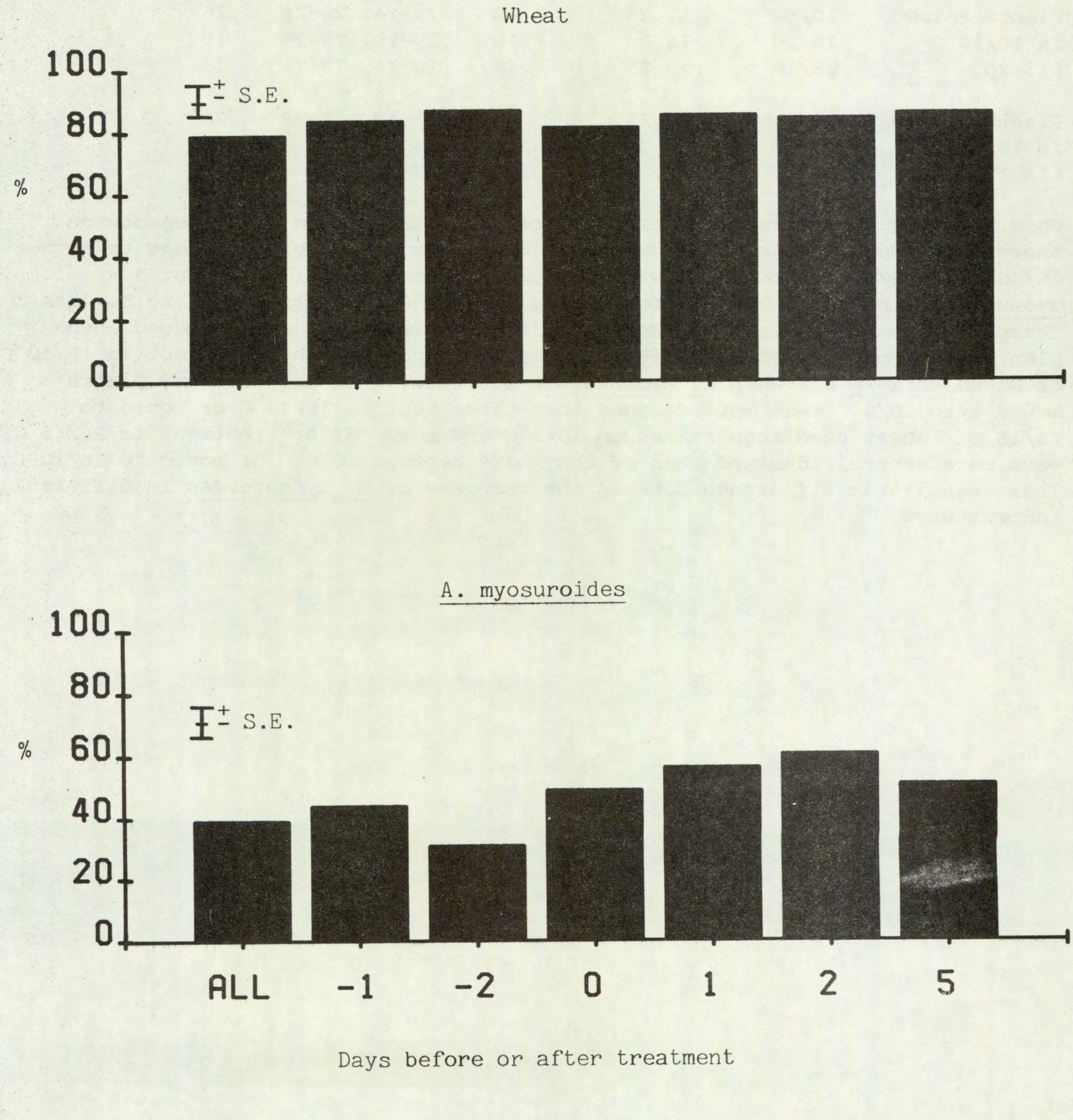
Environmental conditions: 10/6°C, 64/87% rh day/night
16/10°C, 75/86% rh day/night
26/16°C, 85/93% rh day/night

Growth stage and days after treatment at assessment:

		Wheat (cv Maris Huntsman)		*A. myosuroides*	
		Growth stage	Days	Growth stage	Days
Plants raised	10/6	13,25	17	13-14, 27-28	22
in 26/16°C	16/10	13,25	17	13-14, 29	21
(13,20)	26/16	13,23	14	13-14, 28	17
Plants raised	10/6	13,24	19	13-14, 26-29	26
in 16/10°C	16/10	13,24	19	13-14, 26-29	19
(13,20)	26/16	13,25	15	13-14, 28-29	14
Plants raised	10/6	13,25	19	13-14, 26-29	29
in 10/6°C	16/10	13,24	16	13-14, 29	16
(13,20)	26/16	13,25	16	13-14, 29	16

When seedling wheat, raised in 26/16°C regime, was sprayed with isoproturon there was a decrease in damage when plants were moved after treatment to either 16/10°C or 10/6°C as compared with plants remaining in 26/16°C. For *A. myosuroides* there was a trend for plants in 10/6°C after treatment to be less damaged. Wheat seedlings, raised in 16/10°C regime, were more damaged when plants were moved to 26/16°C after treatment compared with those kept in 16/10°C or moved to 10/6°C. When *A. myosuroides* was treated in the same way plants moved into 10/6°C were more damaged than those kept in 16/10°C or moved to 26/16°C. Wheat seedlings raised in 10/6°C and moved after treatment to 26/16°C were more severely damaged than if they were kept in 10/6°C or moved to 16/10°C. There was little difference between the response of *A. myosuroides* in different temperatures.

Fig. 6. The effect of a 24h exposure to 26/16°C around the time of treatment on isoproturon activity (mean of 1 and 2 kg a.i./ha) on plants growing at 10/6°C (Dry weight as % untreated control)



Experiment 6.

Environmental conditions: 10/6°C, 64/87% rh day/night
26/16°C, 85/93% rh day/night

Plants grown in 10/6°C regime (labelled ALL in Fig. 6) but moved for short-term stress to 26/16°C and then returned to initial temperatures.

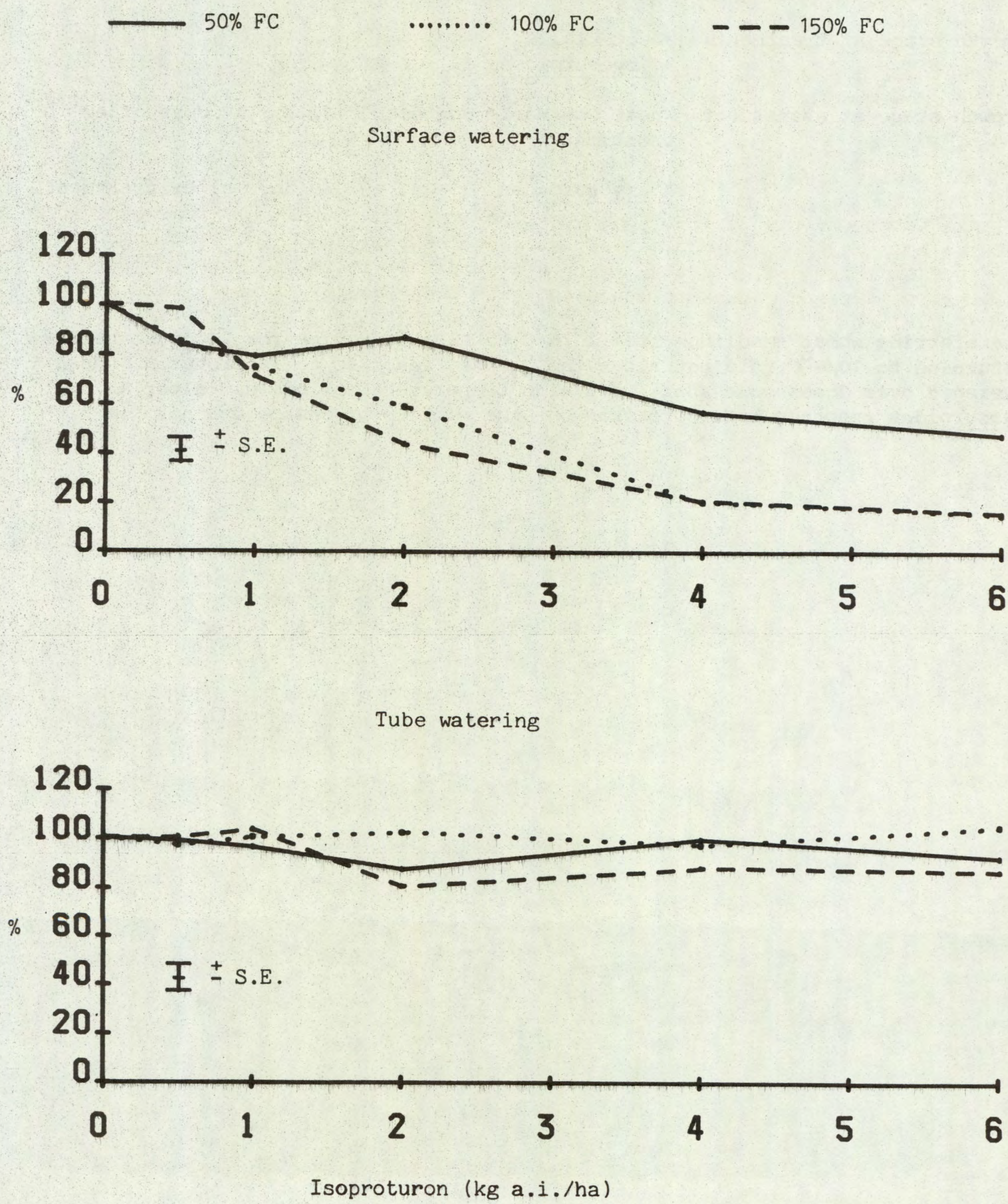
Growth stage at treatment: Wheat 13,20
<u>A. myosuroides</u> 13, 20-22

Growth stage at assessment: Wheat (cv Maris Huntsman) 13, 25; 17 days after treatment

<u>A. myosuroides</u> 13-14, 29; 19 days after treatment.

Transferring wheat seedlings from 10/6°C to 26/16°C regime for 24 hours before returning to 10/6°C, did not alter the plants' response to isoproturon. When averaged over doses some short term high temperature periods did alter <u>A. myosuroides</u> response to isoproturon but the pattern of change was not clear.

Fig. 7. The effect of soil moisture regime on the activity of isoproturon applied at the 3 leaf stage of wheat growing in 16/10°C (Dry weight as % untreated control)



Experiment 7.

Environmental conditions: $16/10^{\circ}C$, 75/86% rh day/night
100% FC = 21.5 g water/100 g dry soil

Plants grown in the same environment before and after treatment.

Growth stage at treatment: 13, 20.

Growth stage of wheat (cv Maris Huntsman) at assessment: 13-14, 26-28 except for 50% surface water plants which were at 13, 24-25 stage: all assessed 21 days after treatment.

Plants watered via a central tube were less damaged than those receiving water to the soil surface. With surface watering, raising the moisture level from 50% to 100% FC increased activity. With sub-surface watering by tube, differences between 50% FC and higher moisture contents were smaller and more erratic.

DISCUSSION

Other studies have shown both chlortoluron and isoproturon to be active largely as a result of herbicide uptake from the soil (Richardson, Dean & Parker, 1977; Richardson & Parker, 1978; Blair, 1978). When plants were sprayed post-emergence some herbicide was retained on the foliage but, as the seedlings were still relatively small, more than 90% fell onto the soil surface. It is assumed that the ratio of soil to foliar uptake is unaltered by pre-spraying temperature regime although this has not been checked experimentally.

Rates of germination, establishment and development of the seedling and the water status of the plant are all influenced by temperature. Herbicide degradation in the soil and metabolism in the plant are also temperature dependent. Hence the relationship between herbicide availability and uptake into the plant with movement and metabolism within the plant will determine the degree of activity.

As low temperatures (4-5°C) have been shown to increase the half-life in soil of chlortoluron (Kibler, 1979) and isoproturon (Mudd, Hance & Wright, 1983), it seems probable that in the experiments reported above there would be less herbicide breakdown in the soil in 10/6°C as compared with 16/10°C as compared with 26/16°C regimes. Since both herbicides were most active when temperatures were high after spraying, this implies that herbicide entry into and movement through the plant occurred more quickly than breakdown in the soil and plant. Plants of Bromus sterilis kept in 26/16°C transpired at least twice the volume of water of those in 10/6°C (Blair, Richardson & West, 1983). Therefore since both chlortoluron and isoproturon are transported in the apoplast it seems probable that accumulation of the herbicide in the aerial part of both wheat and A. myosuroides will be quicker under high temperatures.

When the herbicides were applied pre-emergence temperature affected the rate of seedling emergence (3-4 days in 26/16°C and 14 days in 10/6°C). Hence the relative stage of development of the seedling could vary in relation to the location of herbicide in the soil profile under the different temperature regimes. As for post-emergence treatments, the ultimate activity will depend upon the balance between herbicide degradation in soil and the entry, movement and metabolism within the plant.

Two pathways for the degradation in soil and metabolism in plants have been proposed for chlortoluron (Ryan, Gross, Owen & Laanio, 1981) and in the soil for isoproturon (Mudd, Hance & Wright, 1983). It is not known whether the balance between these two pathways is influenced by temperature.

Comparing treatments where seedlings were grown constantly in 26/16°C in Fig. 4 with those in Fig. 5 shows that there was greater damage in the second experiment (Fig. 5). It may be that such differences reflect the importance of soil moisture levels and the way the water is applied as is illustrated by the data in Fig. 7 and elsewhere (Blair, 1983).

The main facts emerging from this series of experiments are:- 1) that it is important to define and use a method of watering which can be repeated, and 2) that increased damage to wheat seemed often to be associated with higher temperature particularly post-treatment. However, in practice in the field temperatures will rarely be as high in the UK at the times of year when isoproturon or chlortoluron are being used and would be of very short duration should they ever occur. Although Fig. 6 demonstrated that short duration (24 h) high temperatures did not affect plant response to isoproturon, slightly longer exposures (2-4 days) may be worth further study.

The relevance of these studies to the situation where these herbicides are used in warmer climates, e.g. India and South America, needs further consideration.

ACKNOWLEDGEMENTS

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ABBREVIATIONS

ångström	Å
Abstract	Abs.
acid equivalent*	a.e.
acre	ac
active ingredient*	a.i.
approximately equal to*	$\simeq$
aqueous concentrate	a.c.
bibliography	bibl.
boiling point	b.p.
bushel	bu
centigrade	C
centimetre*	cm
concentrated	concd
concentration	concn
concentration x time product	ct
concentration required to kill 50% test animals	LC50
cubic centimetre*	cm^3
cubic foot*	ft^3
cubic inch*	in^3
cubic metre*	m^3
cubic yard*	yd^3
cultivar(s)	cv.
curie*	Ci
degree Celsius*	^{o}C
degree centigrade	^{o}C
degree Fahrenheit*	^{o}F
diameter	diam.
diameter at breast height	d.b.h.
divided by*	÷ or /
dry matter	d.m.
emulsifiable concentrate	e.c.
equal to*	=
fluid	fl.
foot	ft
freezing point	f.p.
from summary	F.s.
gallon	gal
gallons per hour	gal/h
gallons per acre	gal/ac
gas liquid chromatography	GLC
gramme	g
hectare	ha
hectokilogram	hkg
high volume	HV
horse power	hp
hour	h
hundredweight*	cwt
hydrogen ion concentration*	pH
inch	in.
infra red	i.r.
kilogramme	kg
kilo ($x10^3$)	k
less than	<
litre	l.
low volume	LV
maximum	max.
median lethal dose	LD50
medium volume	MV
melting point	m.p.
metre	m
micro ($x10^{-6}$)	µ
microgramme*	µg
micromicro (pico: $x10^{-12}$)*	µµ
micrometre (micron)*	µm (or µ)
micron (micrometre)* †	µm (or µ)
miles per hour*	mile/h
milli ($x10^{-3}$)	m
milliequivalent*	m.equiv.
milligramme	mg
millilitre	ml

† The name micrometre is preferred to micron and µm is preferred to µ.

millimetre*	mm
millimicro* (nano: $x10^{-9}$)	n or mμ
minimum	min.
minus	-
minute	min
molar concentration*	M (small cap)
molecule, molecular	mol.
more than	>
multiplied by*	x
normal concentration*	N (small cap)
not dated	n.d.
oil miscible concentrate	o.m.c. (tables only)
organic matter	o.m.
ounce	oz
ounces per gallon	oz/gal
page	p.
pages	pp.
parts per million	ppm
parts per million by volume	ppmv
parts per million by weight	ppmw
percent(age)	%
pico (micromicro: $x10^{-12}$)	p or μμ
pint	pint
pints per acre	pints/ac
plus or minus*	$\pm$
post-emergence	post-em
pound	lb
pound per acre*	lb/ac
pounds per minute	lb/min
pound per square inch*	lb/in^2
powder for dry application	p. (tables only)
power take off	p.t.o.
precipitate (noun)	ppt.

pre-emergence	pre-em.
quart	quart
relative humidity	r.h.
revolution per minute*	rev/min
second	s
soluble concentrate	s.c.
soluble powder	s.p.
solution	soln
species (singular)	sp.
species (plural)	spp.
specific gravity	sp. gr.
square foot*	ft^2
square inch	in^2
square metre*	m^2
square root of*	$\sqrt{\ }$
sub-species*	ssp.
summary	s.
temperature	temp.
ton	ton
tonne	t
ultra-low volume	ULV
ultra violet	u.v.
vapour density	v.d.
vapour pressure	v.p.
varietas	var.
volt	V
volume	vol.
volume per volume	v/v
water soluble powder	w.s.p. (tables only)
watt	W
weight	wt
weight per volume*	w/v
weight per weight*	w/w
wettable powder	w.p.
yard	yd
yards per minute	yd/min

* Those marked * should normally be used in the text as well as in tables etc.

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