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ANTIDOTES FOR THE PROTECTION OF FIELD BEAN (VICIA FABA L.) FROM DAMAGE BY EPTC AND OTHER HERBICIDES

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NOTE

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ANTIDOTES FOR THE PROTECTION OF FIELD BEAN (VICIA FABA L.) FROM DAMAGE BY EPTC AND OTHER HERBICIDES

A.M. Blair

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SUMMARY

The results of eleven experiments are presented in which protectants (antidotes) were tested for their potential to protect field bean (*Vicia faba* L.) against damage from EPTC. A seed dressing of 1,8-naphthalic anhydride (NA) at 0.5% (weight of protectant as percentage of weight of seed) gave some protection from EPTC applied pre-planting at 4-8 kg a.i./ha but caused marked chlorosis of the foliage. N,N-diallyl 2,2-dichloroacetamide (R25788) as a seed treatment at 0.5% (weight of protectant as percentage of weight of seed) gave comparable protection from EPTC but did not cause chlorosis. At 2%, R25788 had a severe effect alone. When R25788 was mixed in the spray tank with EPTC, protection was less good. In a single experiment R4115 gave some protection against EPTC damage but 2,2,5-trimethyl-N-dichloroacetyloxazolidine (R29148) did not. Results were very variable and the prospect of complete protection appears remote.

INTRODUCTION

Grass weeds, couch (*Agropyron repens* (L.) Beauv.) in particular, are a major problem in field beans (*Vicia faba* L.) (Wilson and Cussans, 1970) for which until the introduction of glyphosate there was no satisfactory herbicide treatment which could be sprayed prior to planting the crop (Fryer and Makepeace 1972). The only recommended pre-planting treatment was TCA. EPTC was effective in controlling grass weeds including couch but was damaging to field bean.

Many recent reports have drawn attention to the use of crop protectants (antidotes) on maize (*Zea mays* L.) to avoid herbicide damage particularly from the thiocarbamates such as EPTC (e.g. Burnside, Wicks and Fenster, 1971; Chang, Bandeen and Stephenson, 1972). The two protectants in use commercially are 1,8-naphthalic anhydride (NA) and N,N-diallyl 2,2-dichloroacetamide (R25788). NA has also been reported to protect both sorghum (*Sorghum bicolor* (Linn.) Moench.) and rice (*Oryza sativa* L.) from alachlor damage (Jordan and Jolliffe, 1971; Parker and Dean, 1976). In addition to NA and R25788, two other protectants not yet available commercially have been included in some experiments: R4115 (chemistry undisclosed) and 2,2,5-trimethyl-N-dichloro-acetyloxazolidine (R 29148).

This report describes a series of experiments to examine whether field bean could be protected against EPTC by the use of crop protectants.

MATERIALS AND METHODS

a) Materials:

Four seeds of field bean cv. Maris Bead (thiram dressed) were planted per pot (8.9 cm diameter) at 2.5 cm depth in a sandy loam soil (4.2% o.m.). John Innes base fertilizer (2.5 g/kg soil), fritted trace elements (0.25 g/kg), DDT (0.5 g/kg) and $MgSO_4$ (1.0 g/kg) were added to the soil.

Protectant formulations used were: NA as the technical (> 98% w/w a.i.); R25788 as either a wettable powder (20% w/w a.i.) or an emulsifiable concentrate (720 g a.i./l); R4115 as a water soluble powder (20% w/w a.i.) and R29148 as an emulsifiable concentrate (240 g a.i./l). The herbicide EPTC was formulated as an emulsifiable concentrate (720 g a.i./l).

b) Methods:

Protectant seed treatments were applied by shaking measured quantities of seed (already dressed with thiram) and protectant in a polythene bag to give the nominal concentration (weight of protectant expressed as a percentage of seed weight). The actual amount retained on the seed may have been lower but it proved impossible to measure this accurately because debris from the seed confused any subsequent weights after application of seed dressings. Where the protectant was applied as a tank mix the herbicide and protectant were mixed prior to spraying. In some experiments methyl cellulose was tried as a sticker (Bardner, 1958). In this case 0.15 ml of 3% methyl cellulose per 5 g seed was shaken with the seed in a glass bottle and the appropriate amount of protectant then added. The seeds were shaken and allowed to dry. EPTC, a volatile herbicide, requires incorporation and was applied to soil in tins (8 cm depth) using a sprayer fitted with an 8002E 'Teejet' fan nozzle set to pass 30 cm above the soil surface and delivering 440 l/ha at 210 kN/m^2. The herbicide was fully incorporated through the depth of the soil by shaking the treated soil in a polythene bag which was then sealed.

Pots were fully randomised within replicates in a glasshouse (10-25°C) and grown for 4-5 weeks. Pots were watered from above and given further nutrient as required. Additional illumination was provided by fluorescent lighting to give a minimum light period of 14 hours.

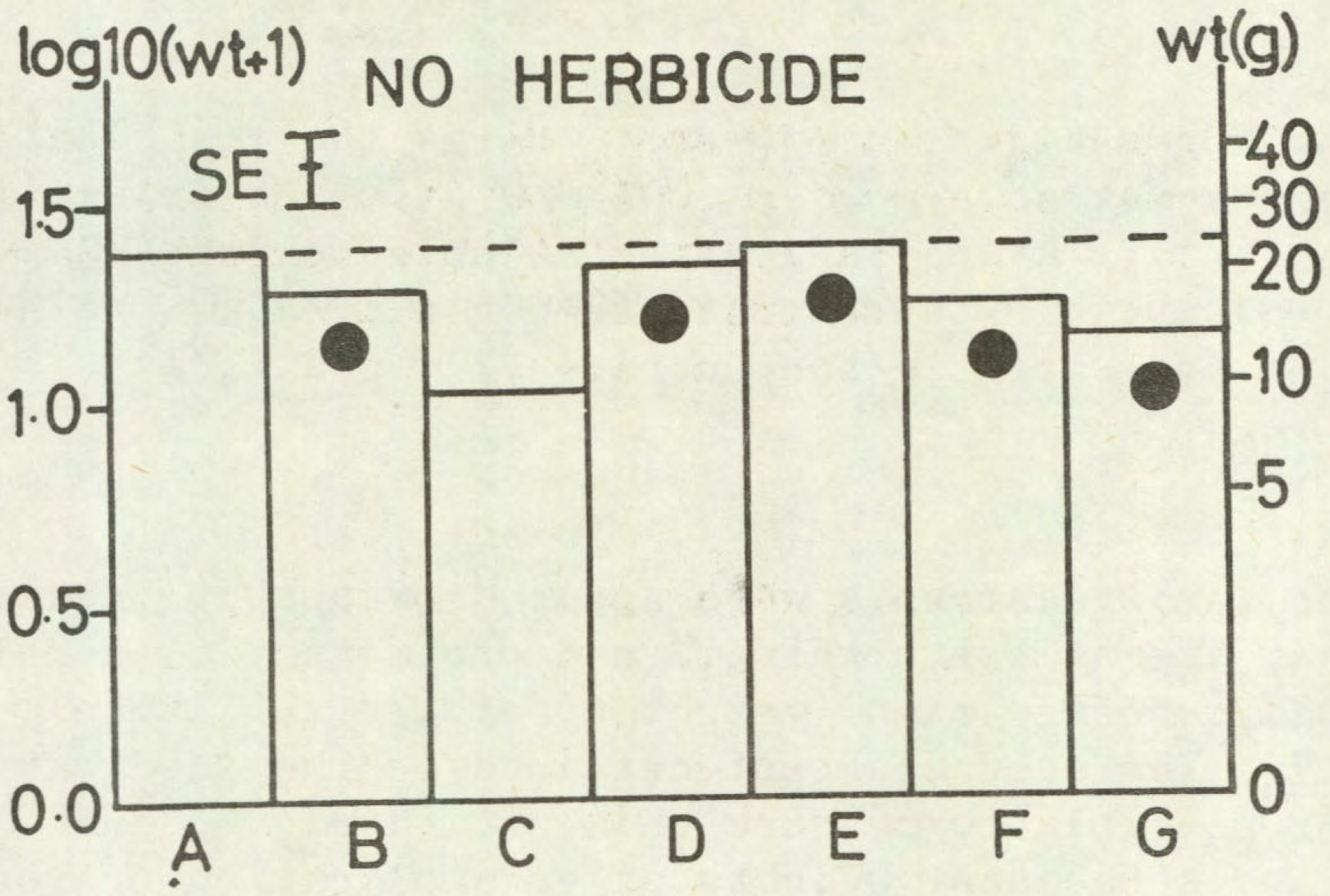
Symptoms and visual damage were recorded and the fresh weights obtained of the plants cut at the soil surface (Figs 1-10). Data have been transformed for analysis of variance to $\log_{10}$ (fresh weight + 1) and all standard errors apply to transformed data. As the histograms are mainly self-explanatory only a few comments on the results of each experiment have been made. Differences which are not significant at the 5% probability level are indicated by a black circle.

RESULTS

Bean seedlings were stunted and distorted by EPTC applied alone. In many cases the expanding leaves were unable to emerge normally but ruptured the side of the unopened first pair of leaves. Where symptoms were less severe, bean plants often developed cupped leaves with necrotic tissue around the edges. EPTC also inhibited the deposition of external foliar wax causing leaflets to adhere together.

Seed dressings:

In all experiments, NA alone caused marked chlorosis of the foliage, which was more severe in the presence of EPTC. In most cases, plants recovered subsequently. Plants treated with all the protectants were generally slightly shorter possibly due to a shortening of internode length rather than to delayed stage of growth. There were no other effects.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A
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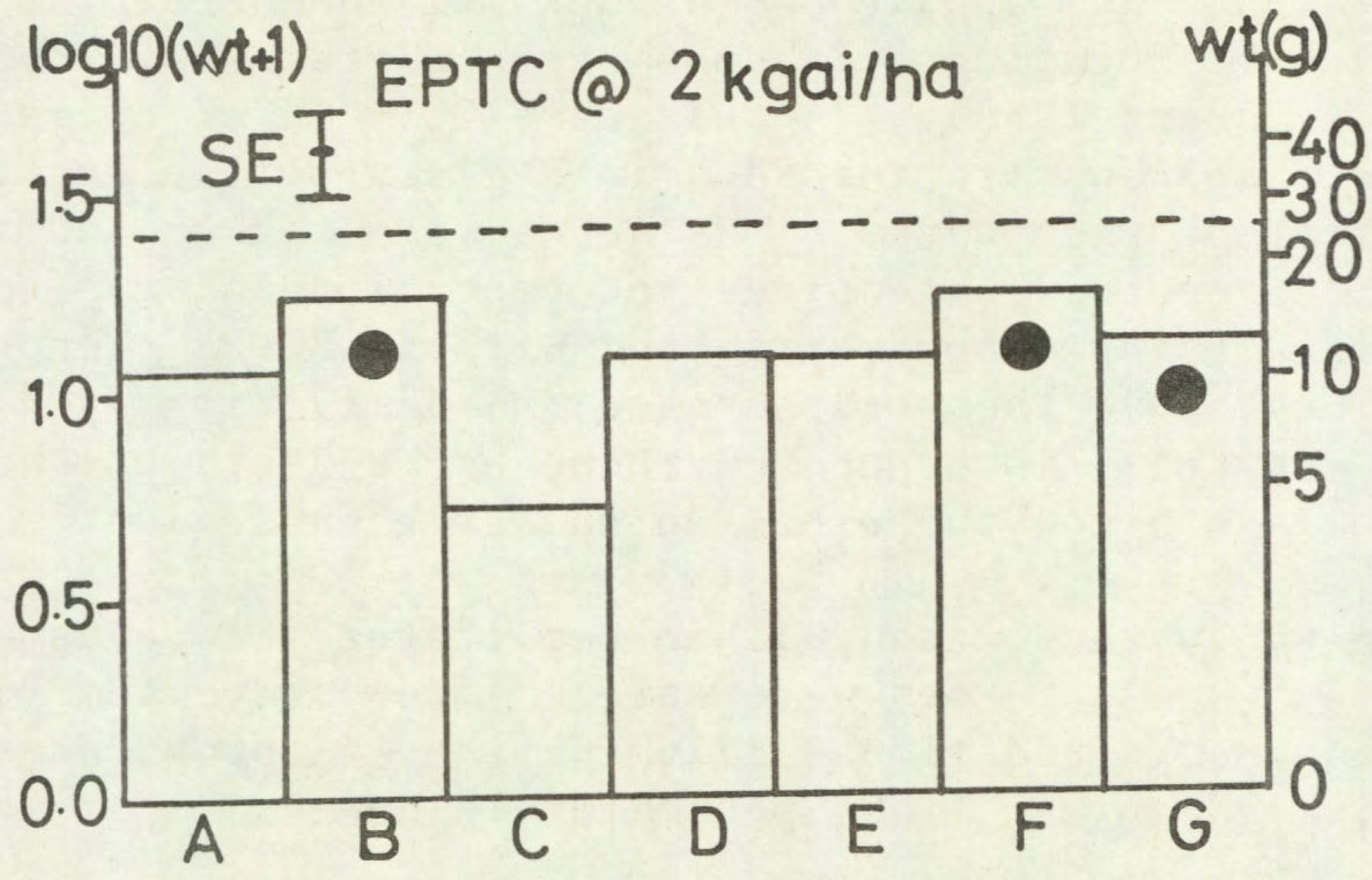
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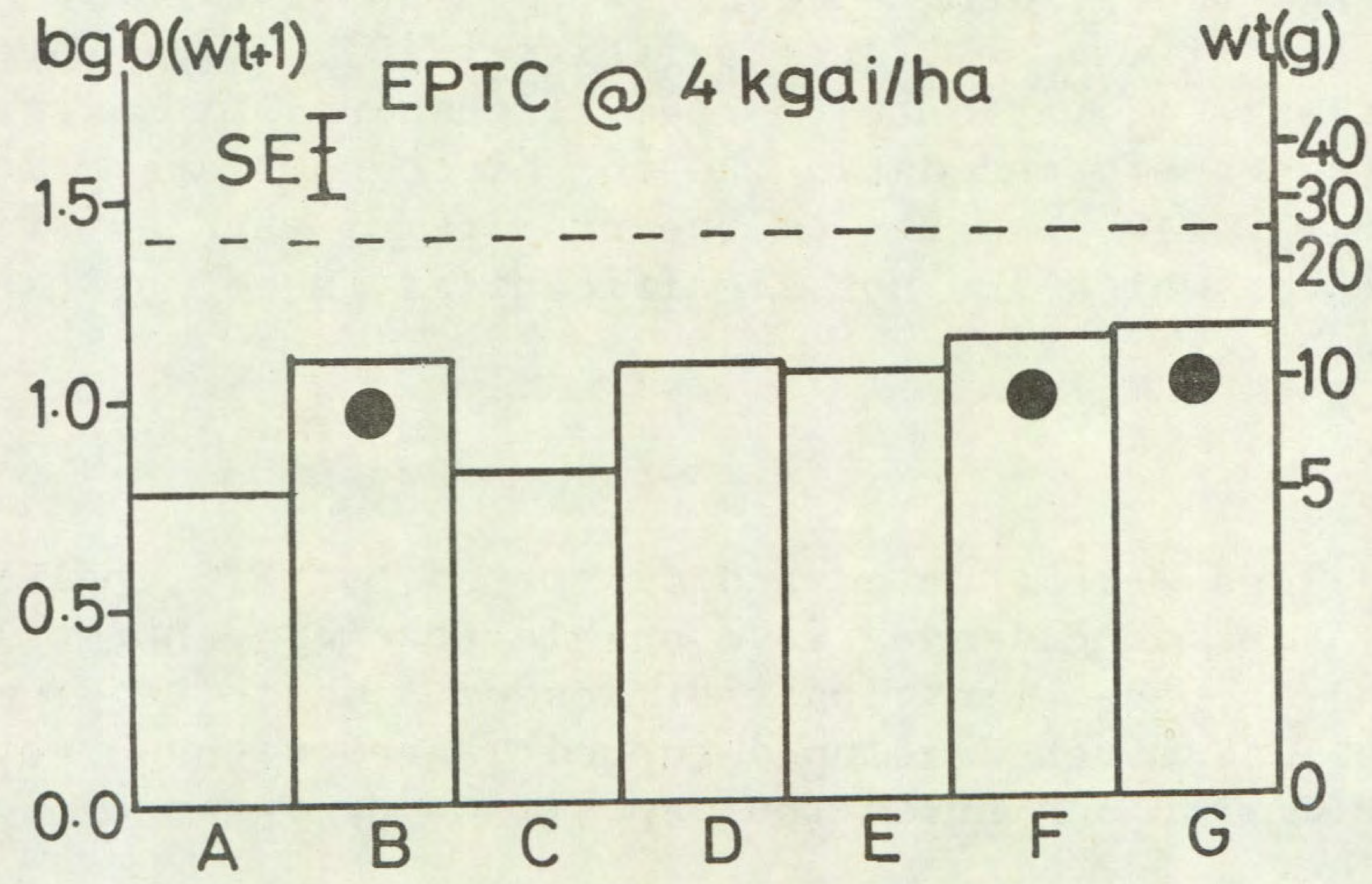
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D
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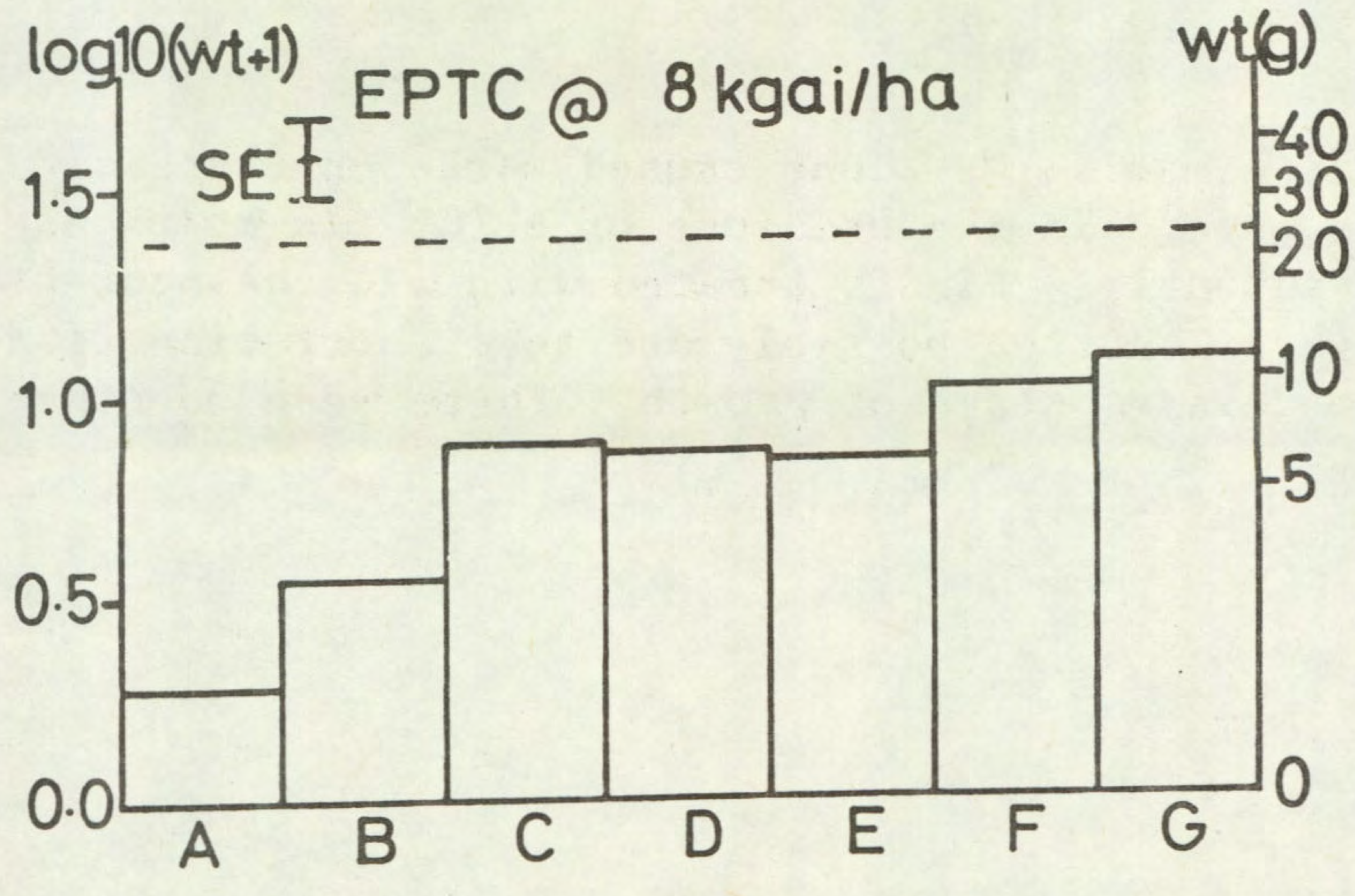
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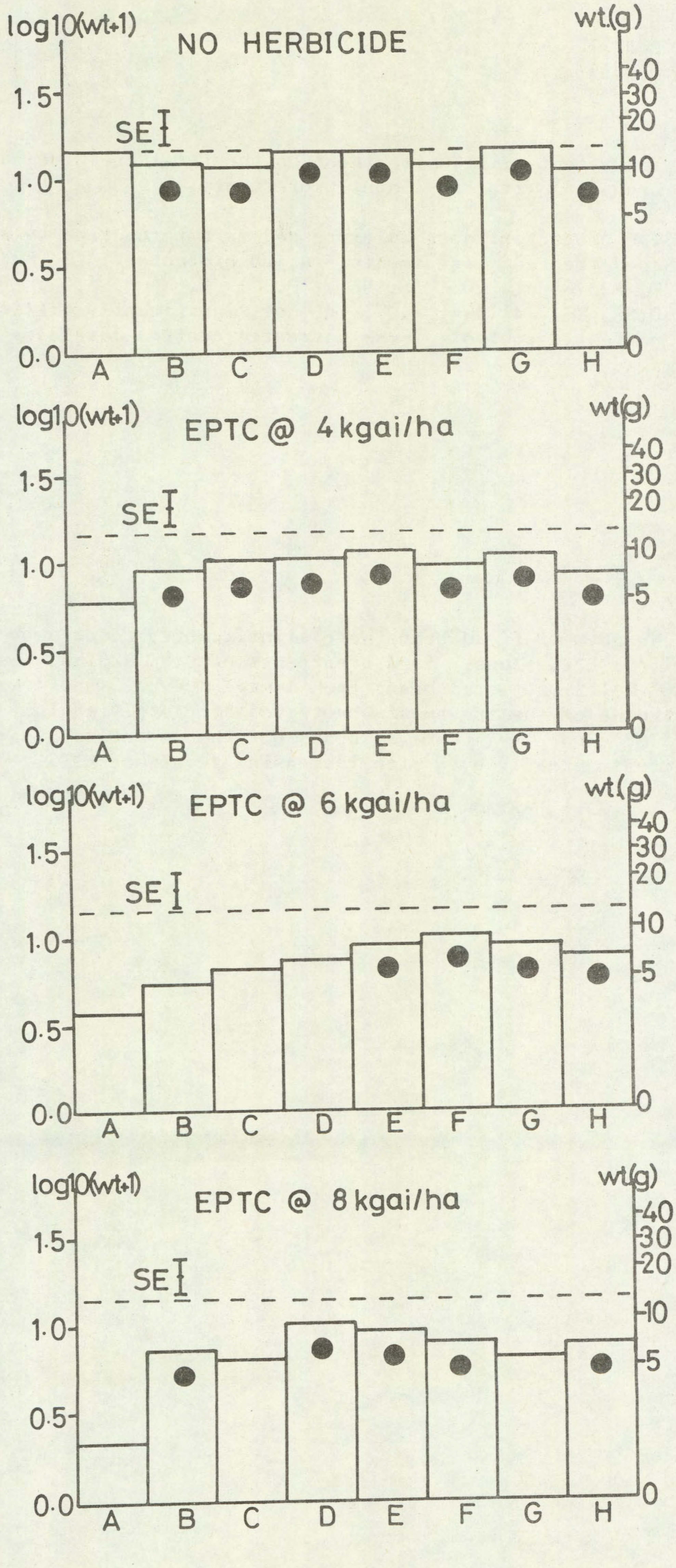
30
20
10
5
0
A
B
C
D
E
F
G

<u>Fig. 1</u> The effect of EPTC treatment on the total fresh weight of field beans (g) with or without protectants.

The protectant dose is expressed as a percentage by weight of the seed treated. Treatments: A, no protectant; B, R25788 at 0.5%; C, R25788 at 2.0%; D, NA at 0.5%; E, NA at 2.0%; F, R4115 at 0.5%; G, R4115 at 2.0%; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

Weights of field beans were significantly reduced by 2, 4 and 8 kg a.i./ha EPTC alone. Seed treatments of 0.5% R25788, also of 0.5 and 2.0% R4115 protected beans from damage due to 2 and 4 kg a.i./ha EPTC but none of the treatments protected completely against 8 kg a.i./ha. R25788 alone at 2% damaged beans but the amount of damage did not increase greatly even with increasing levels of EPTC.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wt(g)
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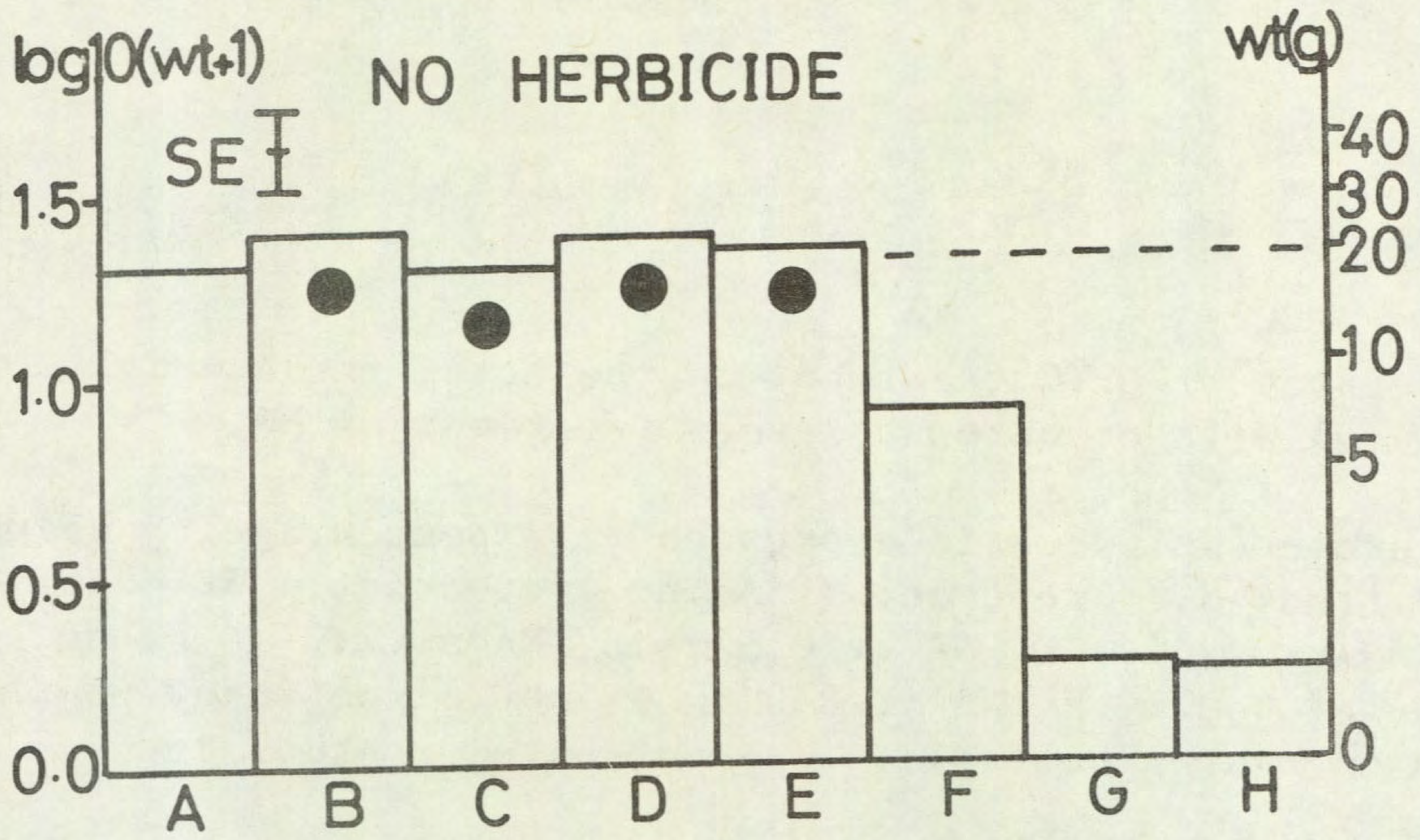
0.5
0.0
SE
40
30
20
10
5
0
A B C D E F G H
log10(wt+1)
EPTC @ 4 kgai/ha
wt(g)
A B C D E F G H
log10(wt+1)
EPTC @ 6 kgai/ha
wt(g)
A B C D E F G H
log10(wt+1)
EPTC @ 8 kgai/ha
wt(g)
A B C D E F G H

<u>Fig. 2</u> The effect of EPTC treatment on the total fresh weight of field bean (g) with or without a seed treatment of NA.

The protectant dose is expressed as a percentage by weight of the seed treated. Treatments: A, no protectant; B, NA at 0.125%; C, NA at 0.25%; D, NA at 0.5%; E, NA at 1.0%; F, NA at 2.0%; G, NA at 4.0%; H, NA at 8.0%; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

All doses of EPTC alone significantly decreased crop weight. NA at 0.125-8.0% completely protected beans from 4 kg a.i./ha EPTC. When treated with 6 or 8 kg a.i./ha EPTC most seed treatments gave significant protection.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wt(g)
SE
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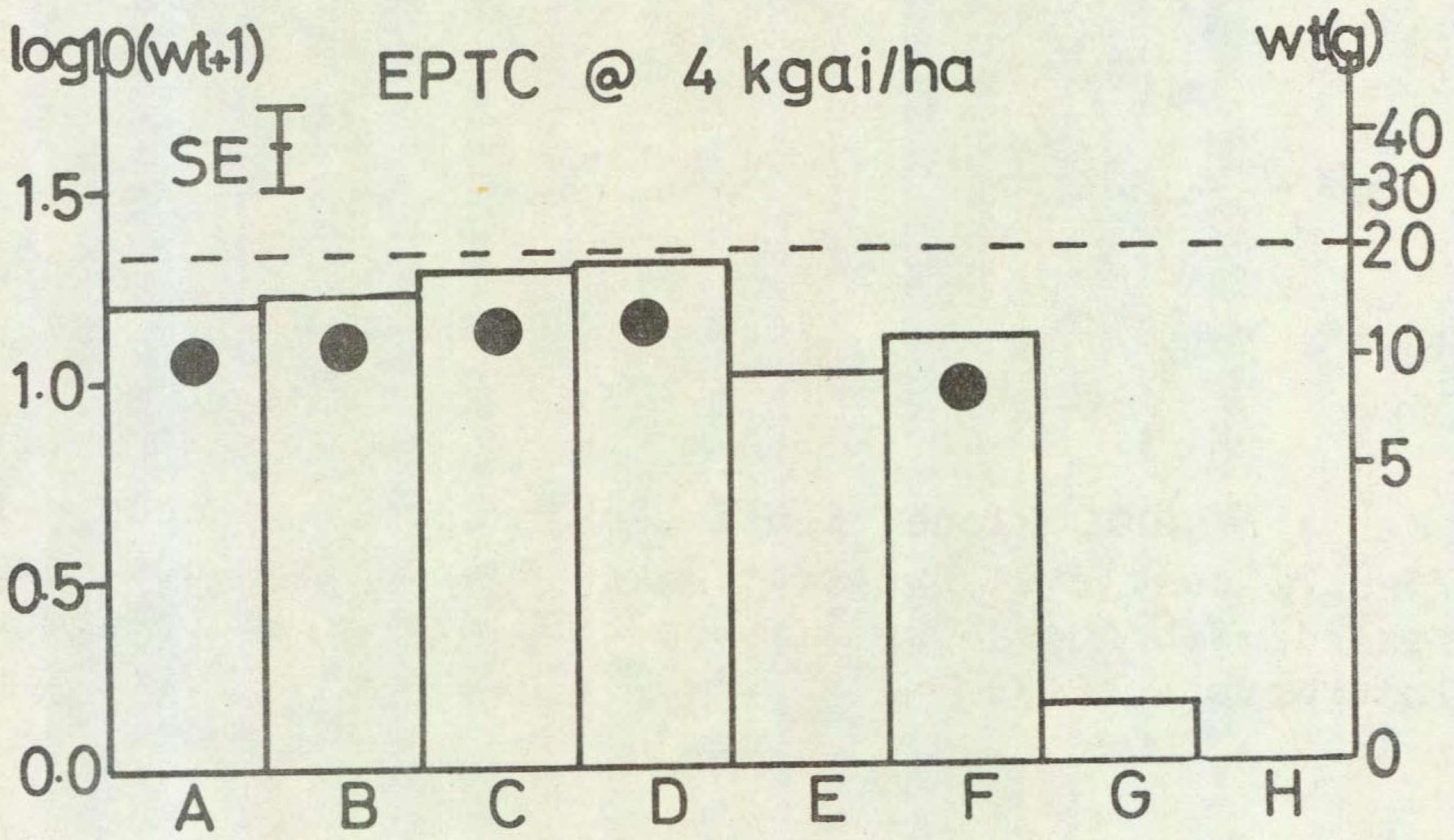
0.0
40
30
20
10
5
0
A
B
C
D
E
F
G
H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EPTC @ 4 kgai/ha
wt(g)
SE
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0.0
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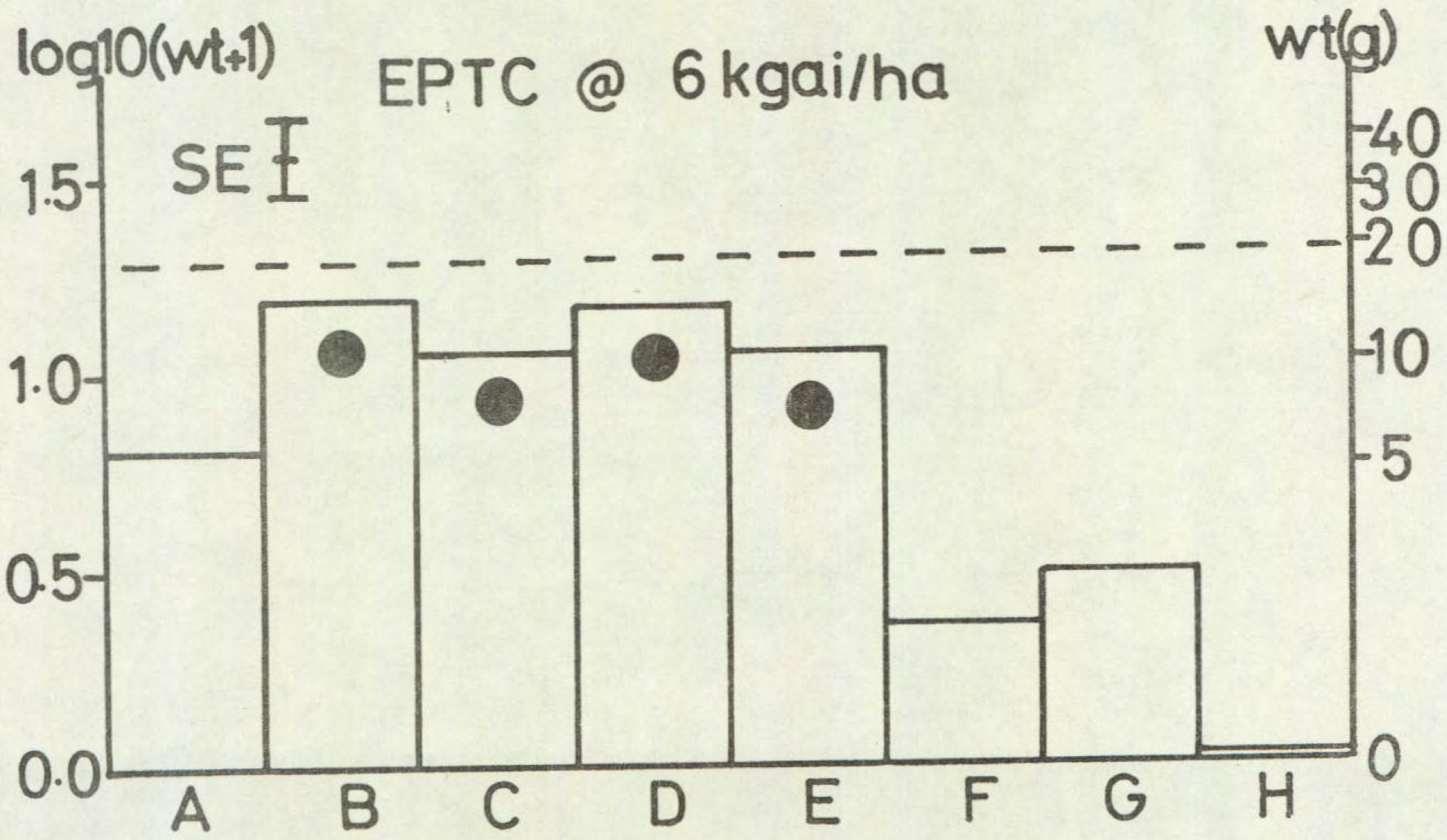
0
A
B
C
D
E
F
G
H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EPTC @ 6 kgai/ha
wt(g)
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0
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B
C
D
E
F
G
H

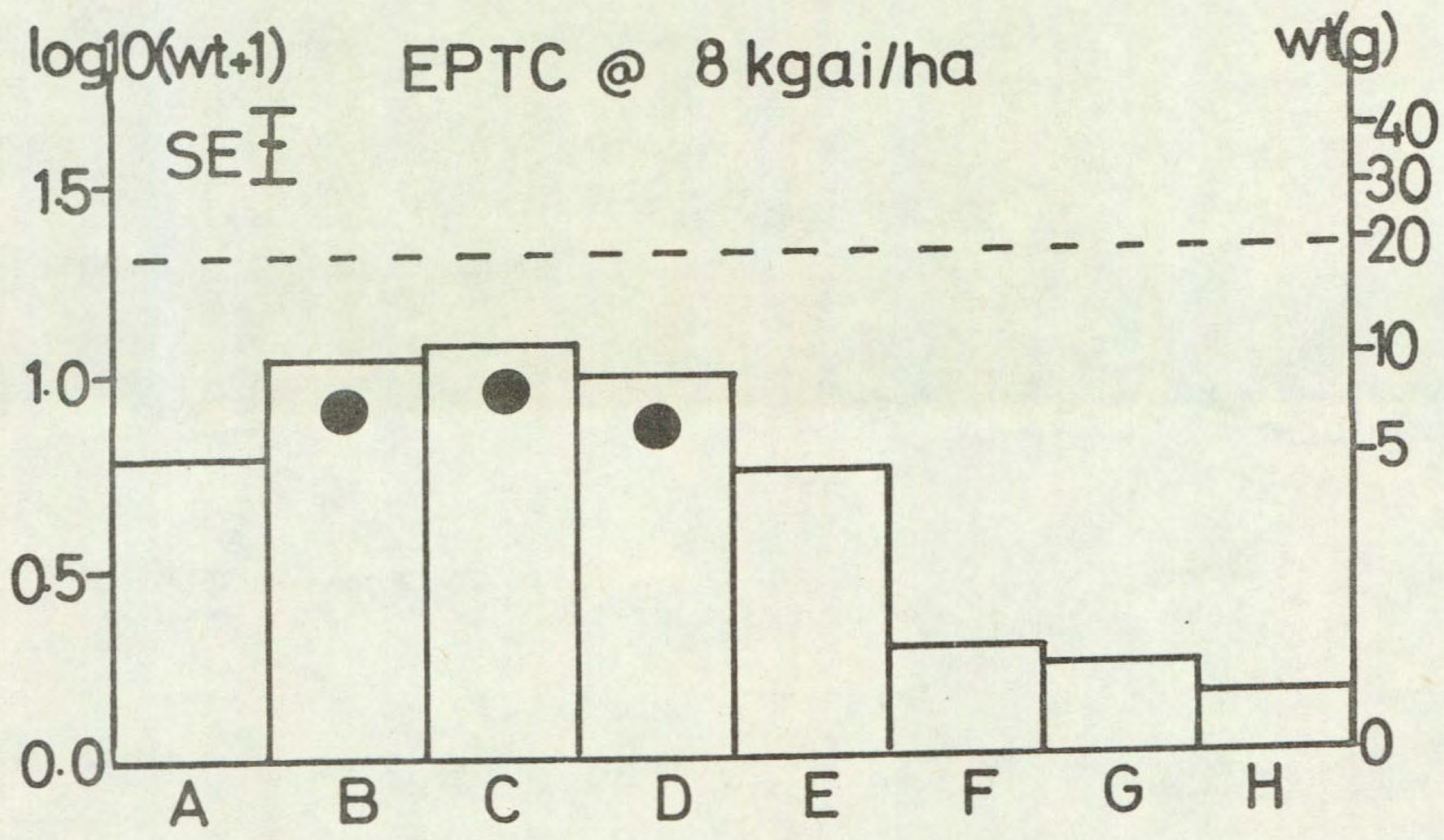
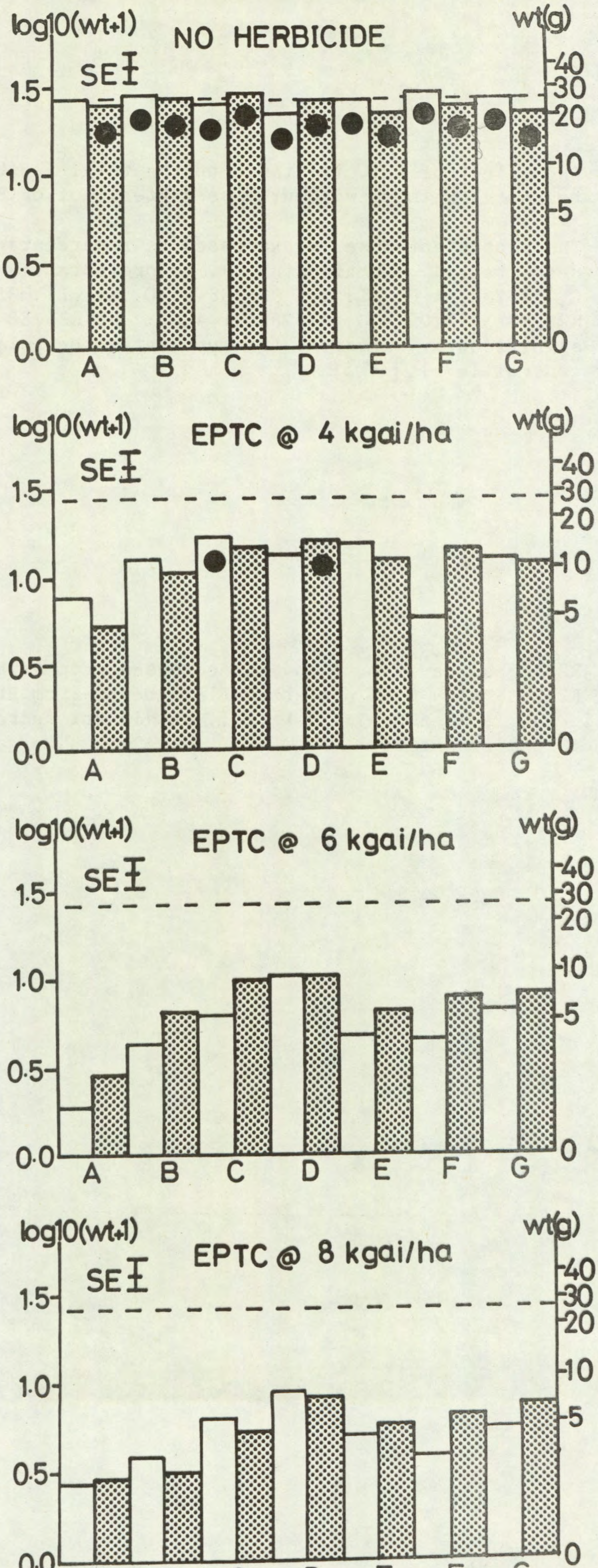

log10(wt+1)
EPTC @ 8 kgai/ha
wt(g)
SE
1.5
1.0
0.5
0.0
40
30
20
10
5
0
A
B
C
D
E
F
G
H

Fig. 3 The effect of EPTC treatment on the total fresh weight of field beans (g) with or without a seed treatment of R25788.

The protectant dose is expressed as a percentage by weight of the seed treated. Treatments: A, no protectant; B, R25788 at 0.125%; C, R25788 at 0.25%; D, R25788 at 0.5%; E, R25788 at 1.0%; F, R25788 at 2.0%; G, R25788 at 4.0%; H, R25788 at 8.0%; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

R25788 alone at 2, 4 and 8% decreased crop weight. Applications of R25788 below 0.5% protected field beans from EPTC at 6 and 8 kg a.i./ha. EPTC alone at 4 kg a.i./ha did not decrease fresh weights in this experiment.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wt(g)
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SE
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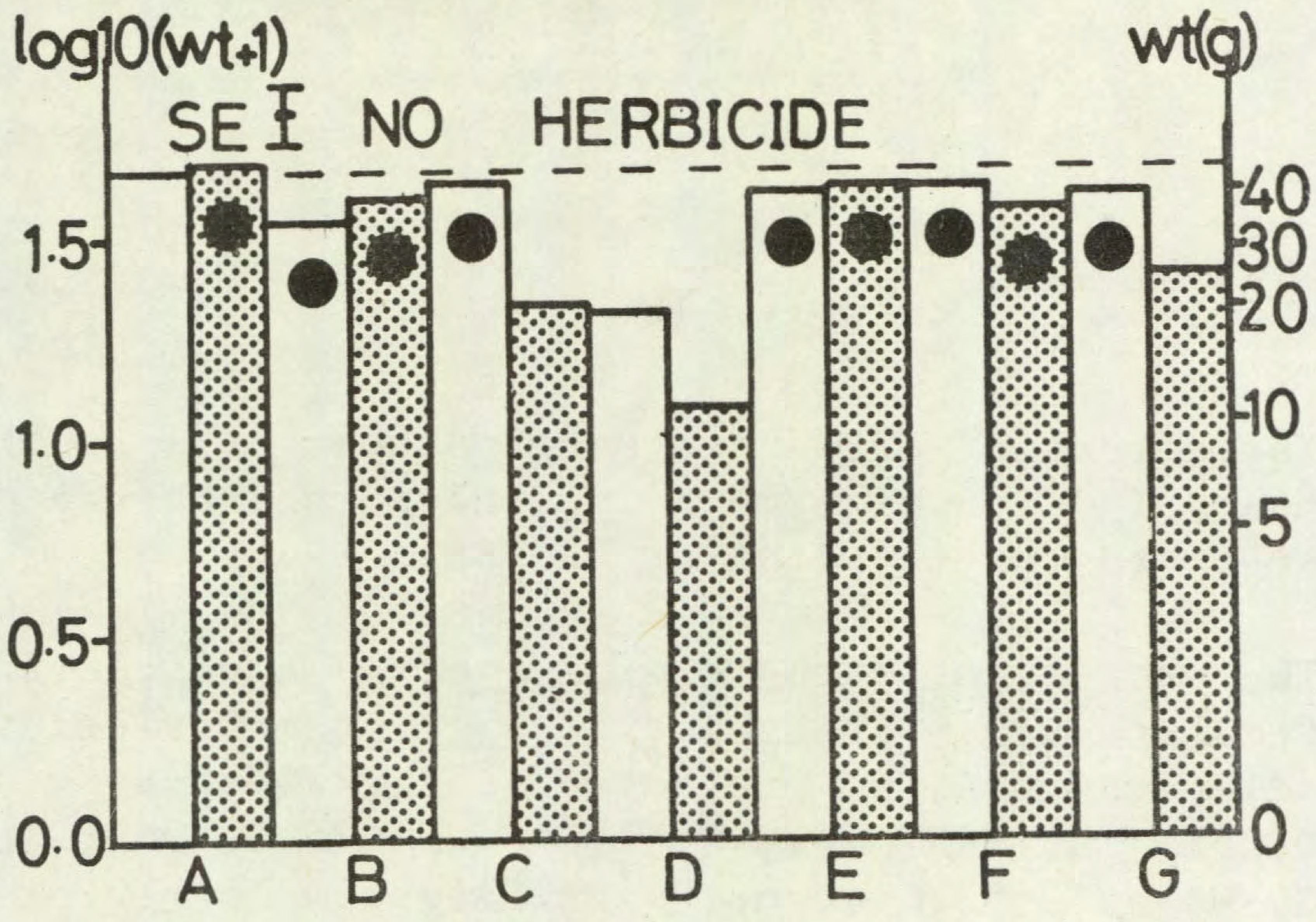
1.0
0.5
0.0
40
30
20
10
5
0
A B C D E F G
EPTC @ 4 kgai/ha
EPTC @ 6 kgai/ha
EPTC @ 8 kgai/ha

<u>Fig. 4</u> The effect of EPTC treatment on the total fresh weight of field beans (g) to which methylcellulose had been added with or without seed treatments of NA or R25788.

The protectant dose is expressed as a percentage by weight of the seed treated. Treatments: □ - no methylcellulose; ⊡ + methylcellulose; A, no protectant; B, R25788 at 0.125%; C, R25788 at 0.25%; D, R25788 at 0.5%; E, NA at 0.125%; F, NA at 0.25%; G, NA at 0.5%; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

All doses of EPTC significantly reduced field bean weights although treatments were much less active in one experiment (Fig. 4) than in another (Fig. 5). There was no particular benefit of using a sticker in either experiment and in some instances the trend was for decreased protection where methyl cellulose was used.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wt(g)
SE
NO HERBICIDE
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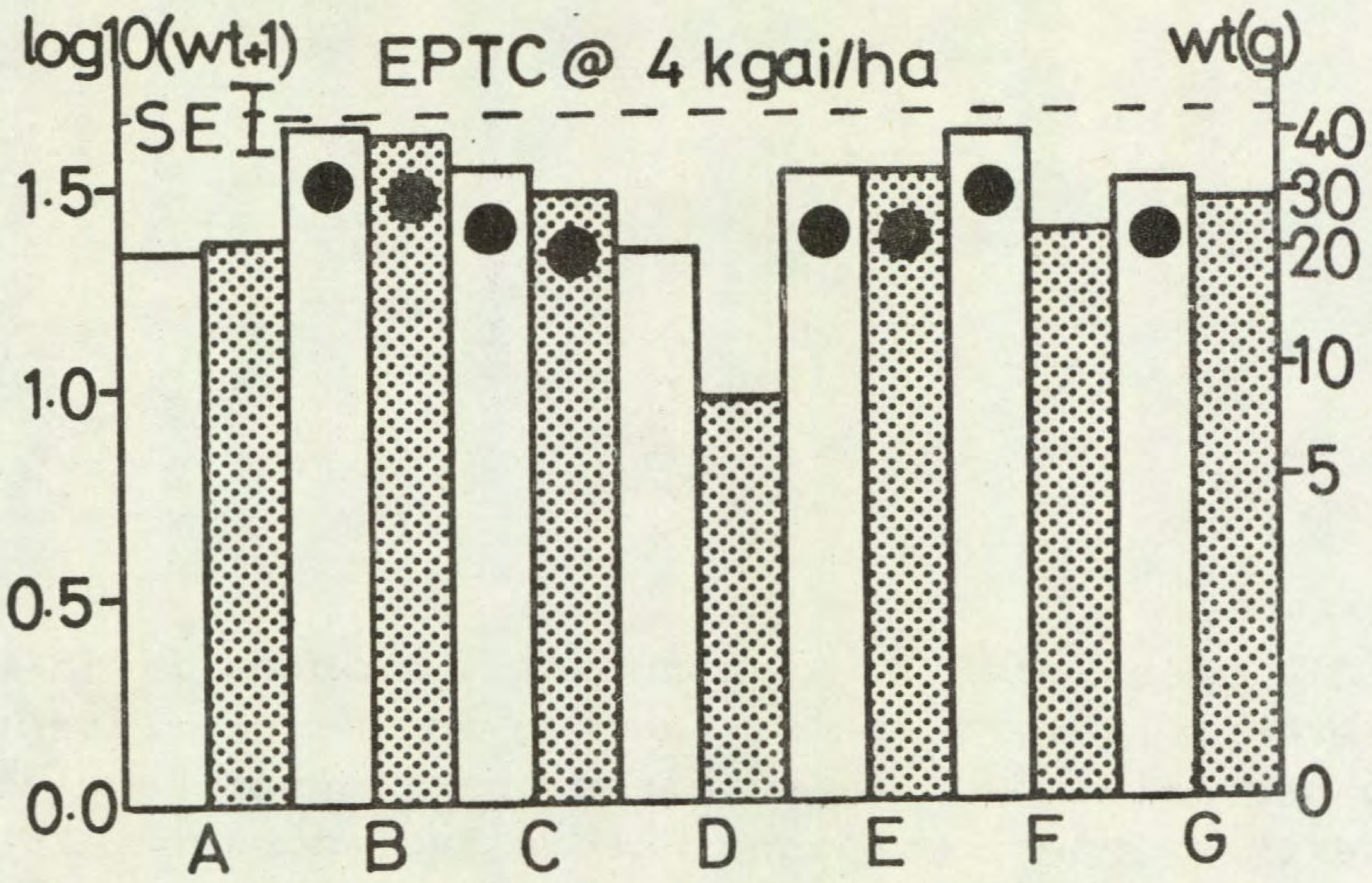
1.0
0.5
0.0
40
30
20
10
5
0
A
B
C
D
E
F
G


log10(wt+1)
wt(g)
EPTC @ 4 kgai/ha
SE
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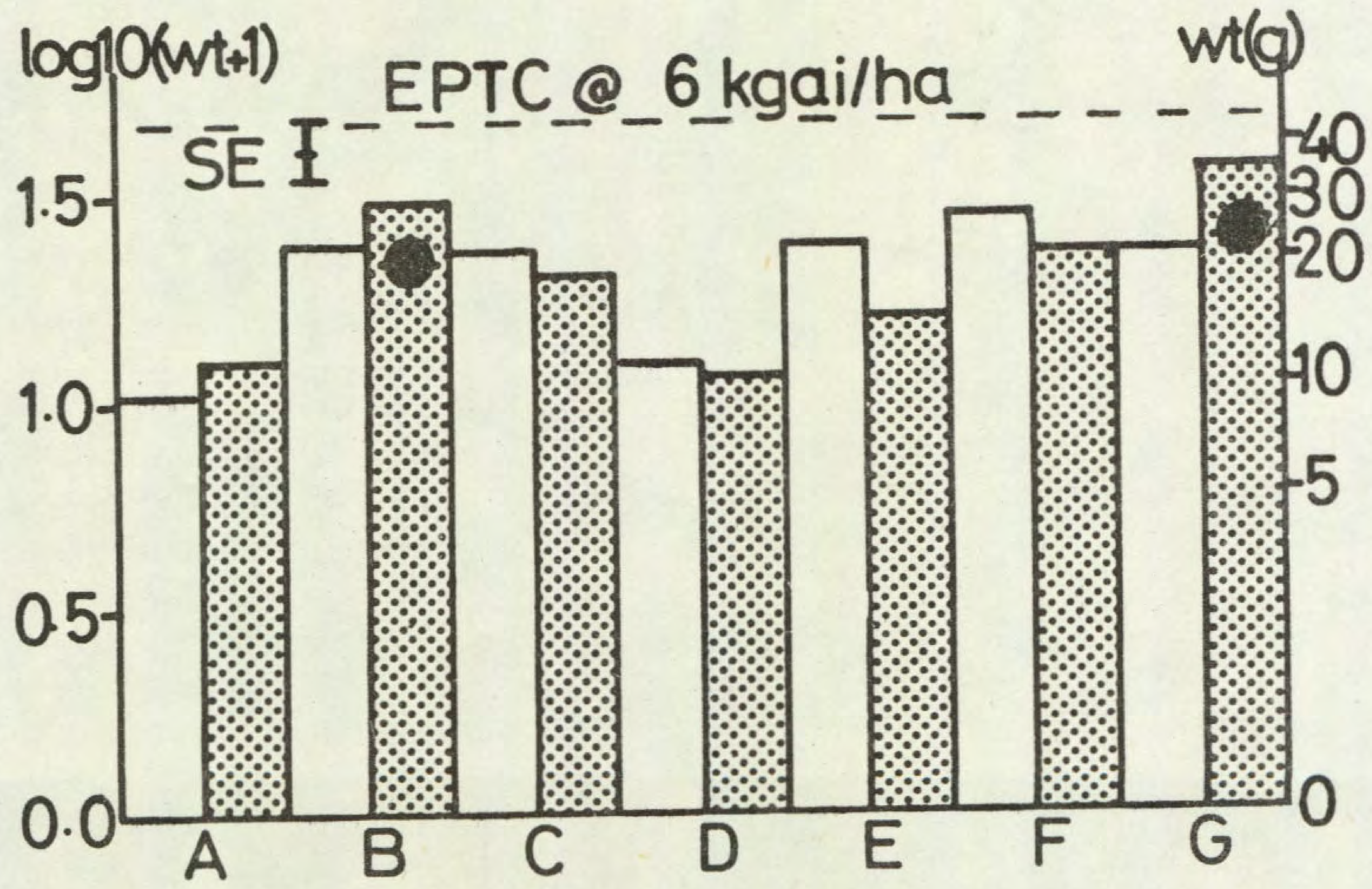
1.0
0.5
0.0
40
30
20
10
5
0
A
B
C
D
E
F
G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wt(g)
EPTC @ 6 kgai/ha
SE
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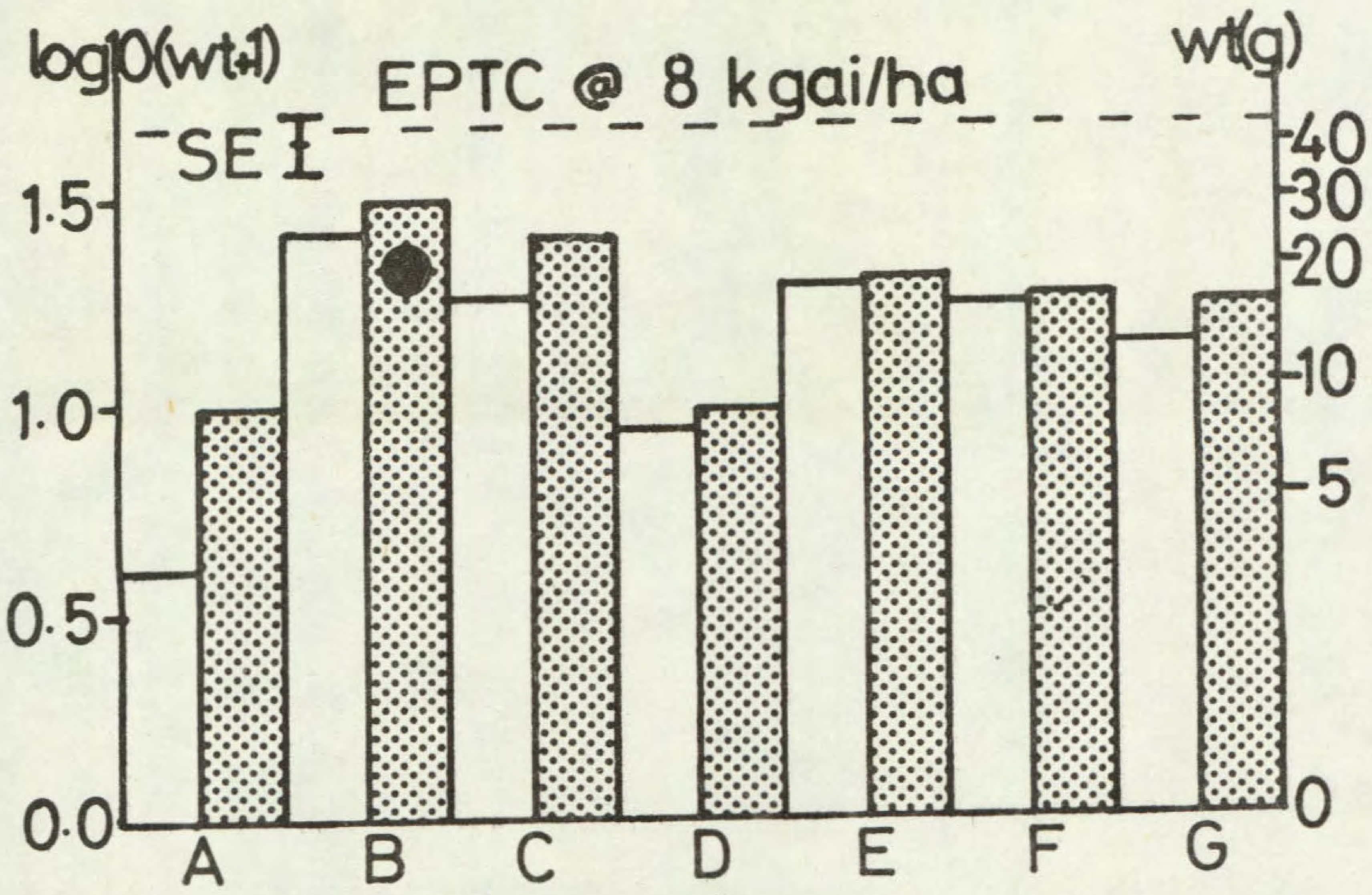
30
20
10
5
0
A
B
C
D
E
F
G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wt(g)
EPTC @ 8 kgai/ha
SE
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1.0
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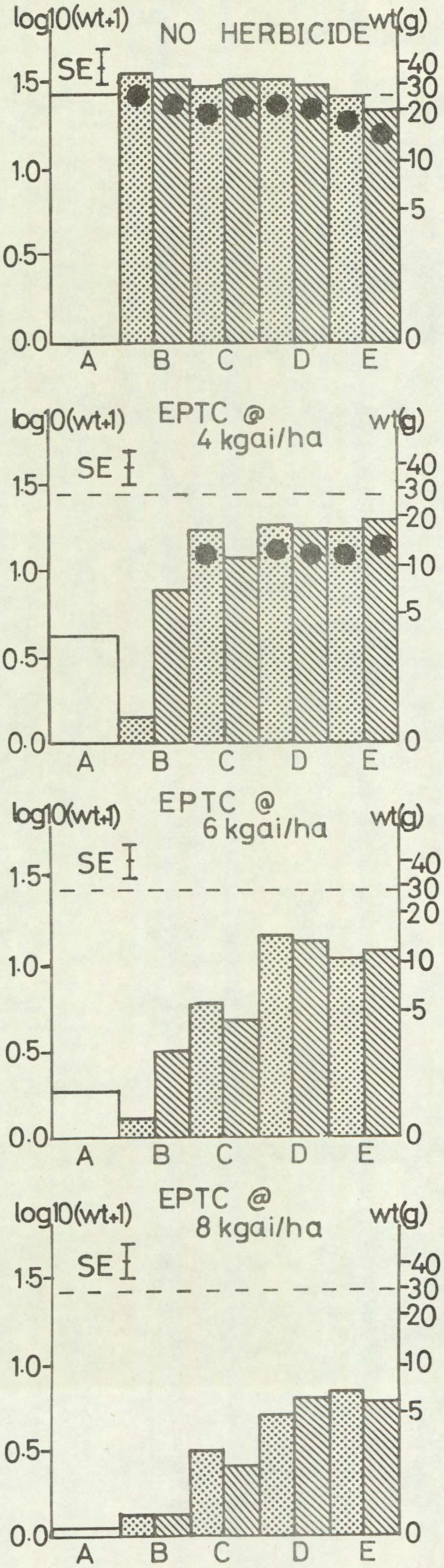
0.0
40
30
20
10
5
0
A
B
C
D
E
F
G

Fig. 5 The effect of EPTC treatment on the total fresh weight of field beans (g) to which methylcellulose had been added with or without seed treatments of NA or R25788.

The protectant dose is expressed as a percentage by weight of the seed treated. Treatments: □ - no methylcellulose; ⁙ + methylcellulose; A, no protectant; B, R25788 at 0.5%; C, R25788 at 1.0%; D, R25788 at 2.0%; E, NA at 0.5%; F, NA at 1.0%; G, NA at 2.0%; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

See notes Opposite Fig. 4.

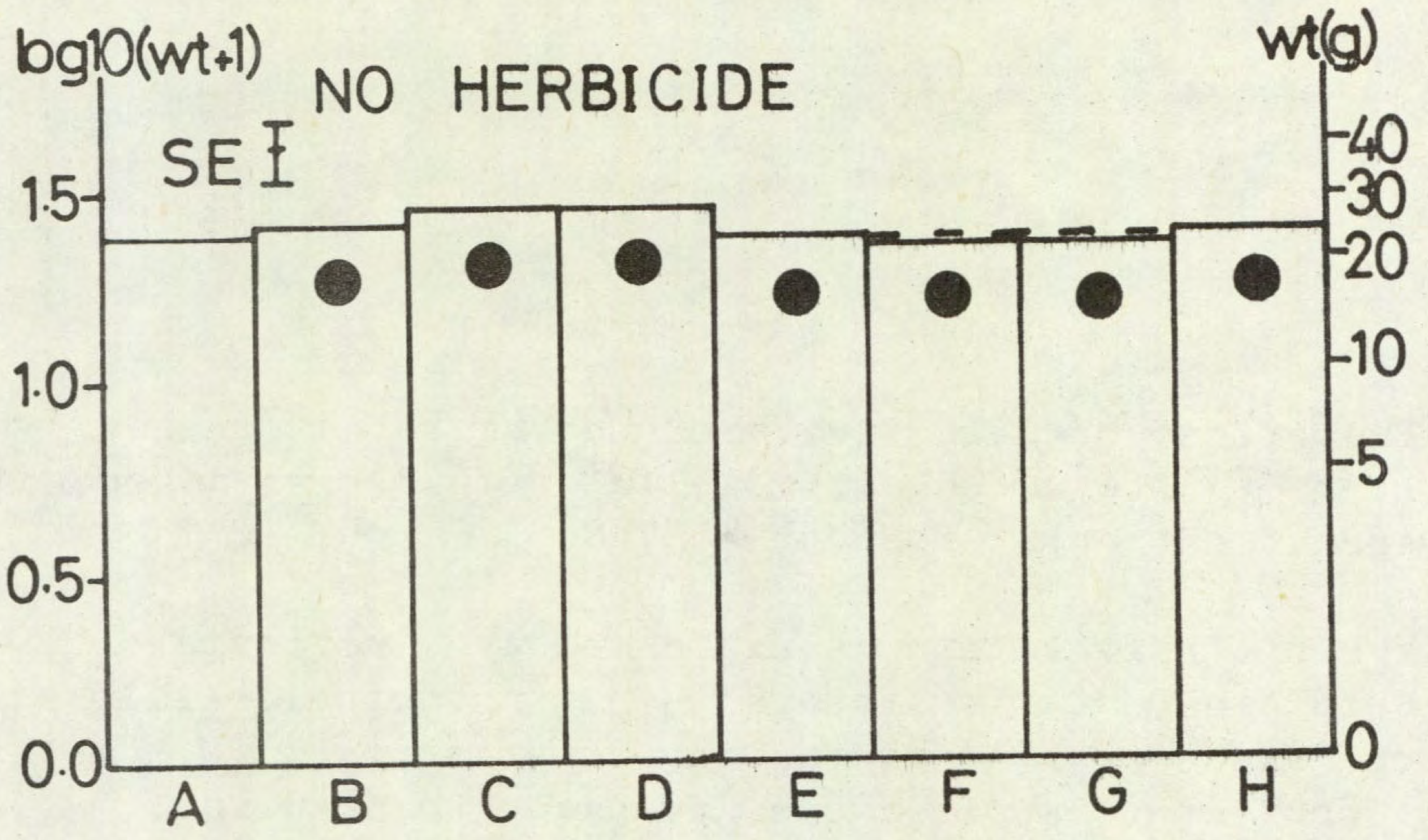


NO HERBICIDE
log10(wt+1)
wt(g)
SE
1.5
1.0
0.5
0.0
40
30
20
10
5
0
A
B
C
D
E
EPTC @ 4 kgai/ha
EPTC @ 6 kgai/ha
EPTC @ 8 kgai/ha

Fig. 6 The effect of EPTC treatment on the total fresh weight of field beans (g) to which methylcellulose had been added with or without seed treatments of NA or R25788.

The protectant dose is expressed as a percentage by weight of the seed treated. Treatments: □ - no methylcellulose; ⁙ + methylcellulose applied on the day of planting; ▧ + methylcellulose + protectant applied one day prior to planting; A, no protectant and no methylcellulose; B, methylcellulose; C, R25788 at 0.25% + methylcellulose; D, R25788 at 0.5% + methylcellulose; E, R25788 at 1.0% + methylcellulose; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

None of the treatments of methylcellulose and R25788 alone damaged the field bean plants. All doses of herbicide reduced weights. R25788 at 0.25% + methylcellulose applied one day prior to treatment with EPTC was the only treatment which did not protect from 4 kg a.i./ha. At other levels of EPTC, although there was significant protection, in no case did the seed treatment completely eliminate EPTC damage.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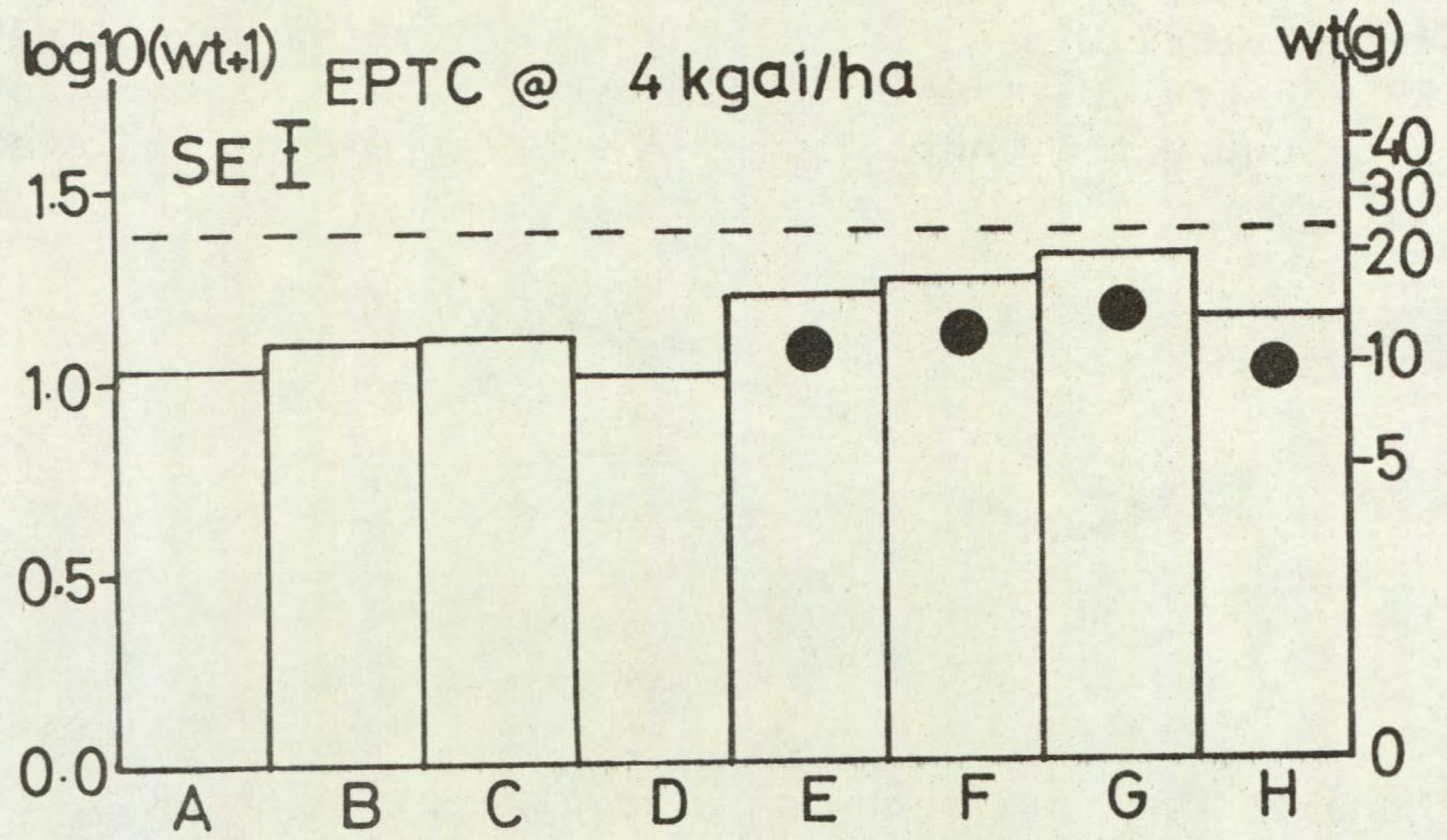
0
A B C D E F G H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EPTC @ 4 kgai/ha
wt(g)
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5
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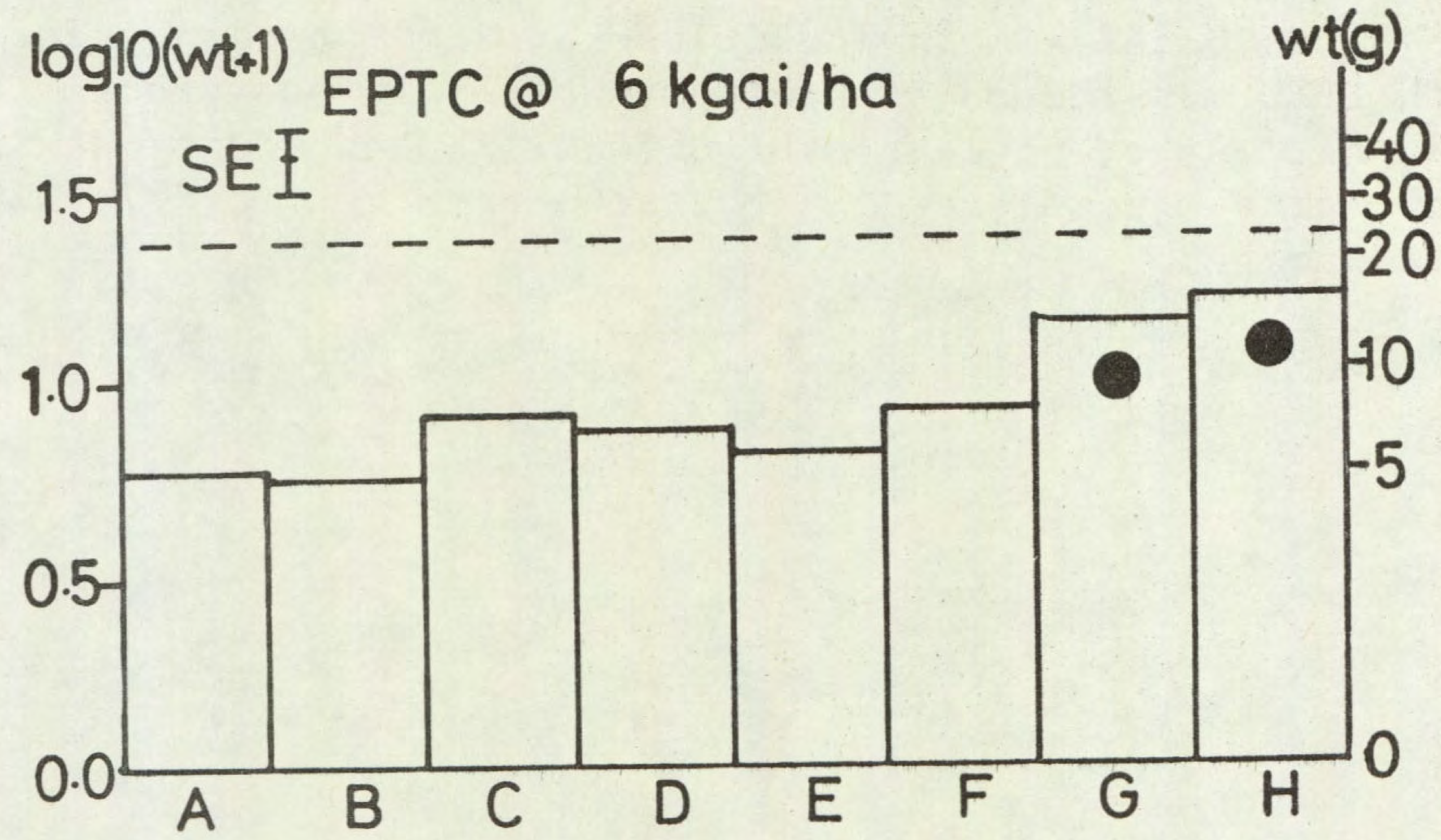
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EPTC @ 6 kgai/ha
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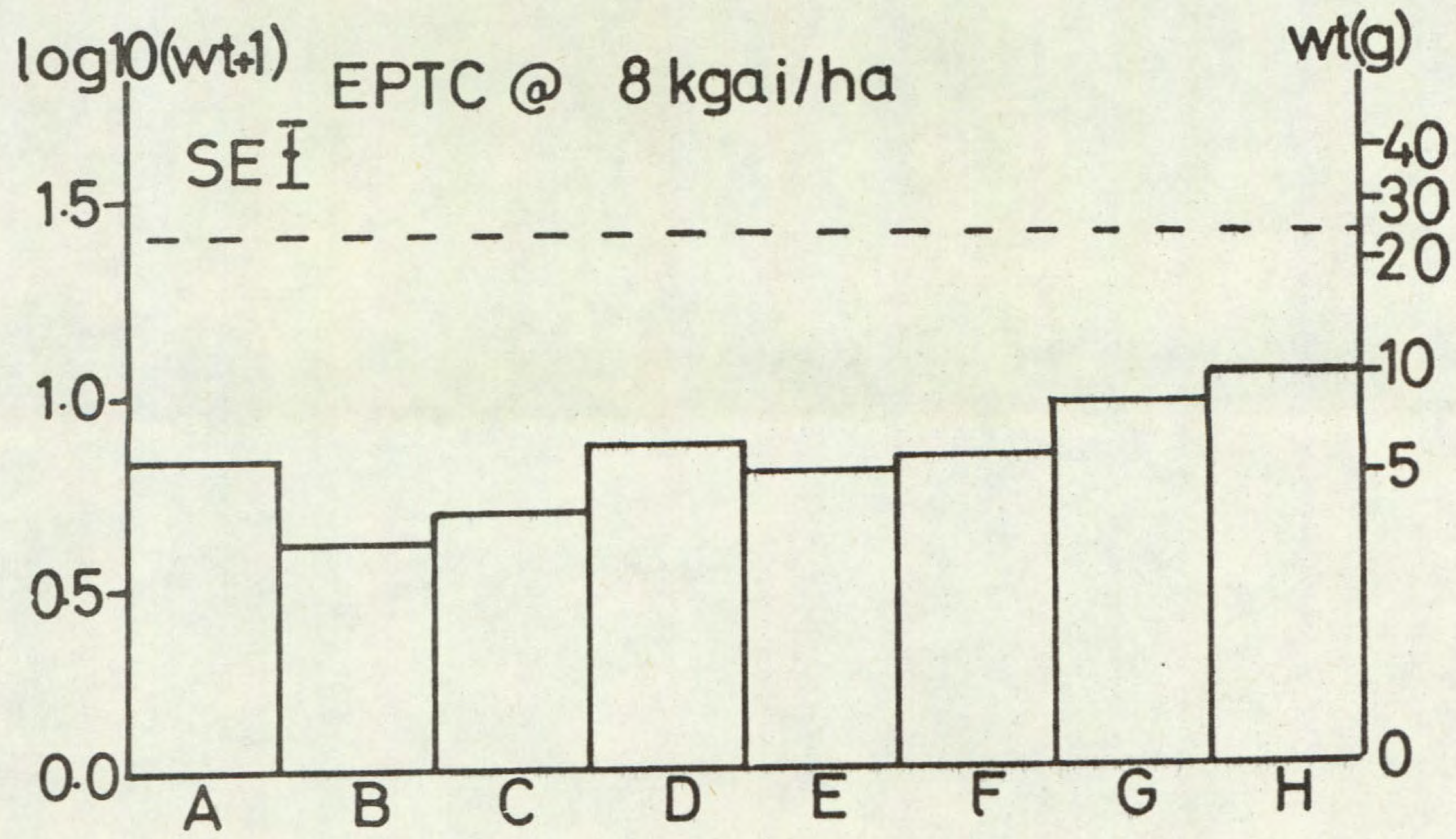
A B C D E F G H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wt(g)
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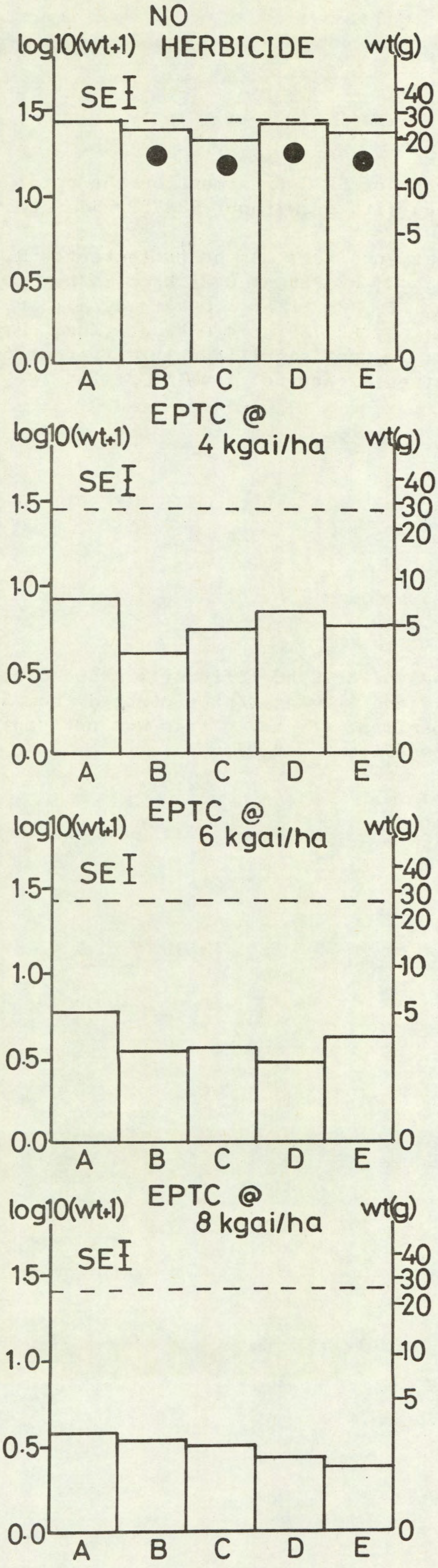
0.0
40
30
20
10
5
0
A B C D E F G H

Fig. 7 The effect of EPTC treatment on the total fresh weight of field beans (g) with or without R25788 added to the spray solution.

The treatments are: A, no protectant; B, R25788 at 0.125 kg a.i./ha; C, R25788 at 0.25 kg a.i./ha; D, R25788 at 0.5 kg a.i./ha; E, R25788 at 1.0 kg a.i./ha; F, R25788 at 2.0 kg a.i./ha; G, R25788 at 4.0 kg a.i./ha; H, R25788 at 8.0 kg a.i./ha; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

All doses of EPTC significantly reduced crop weight. Although R25788 at 4 and 8 kg a.i./ha protected from EPTC at 4 and 6 kg a.i./ha in one experiment (Fig. 7), this was not confirmed in two subsequent experiments (Figs 8 and 9).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wt(g)
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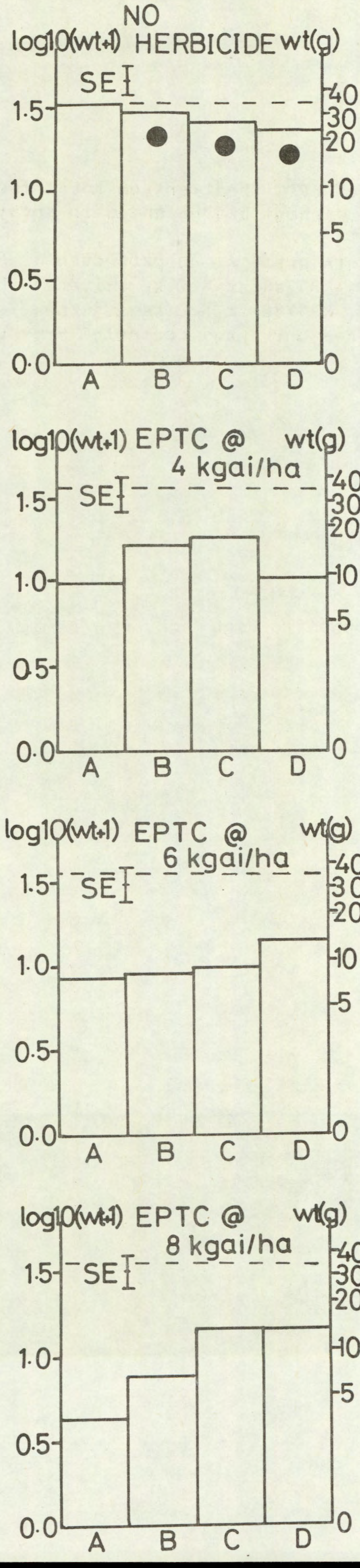
30
20
10
5
0
A
B
C
D
E
EPTC @ 4 kgai/ha
EPTC @ 6 kgai/ha
EPTC @ 8 kgai/ha

<u>Fig. 8</u> The effect of EPTC treatment on total fresh weight of field beans (g) with or without R25788 added to spray solution.

The treatments are: A, no protectant; B, R25788 at 2.0 kg a.i./ha; C, R25788 at 4.0 kg a.i./ha; D, R25788 at 6.0 kg a.i./ha; E, R25788 at 8.0 kg a.i./ha; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

See notes opposite Fig. 7.



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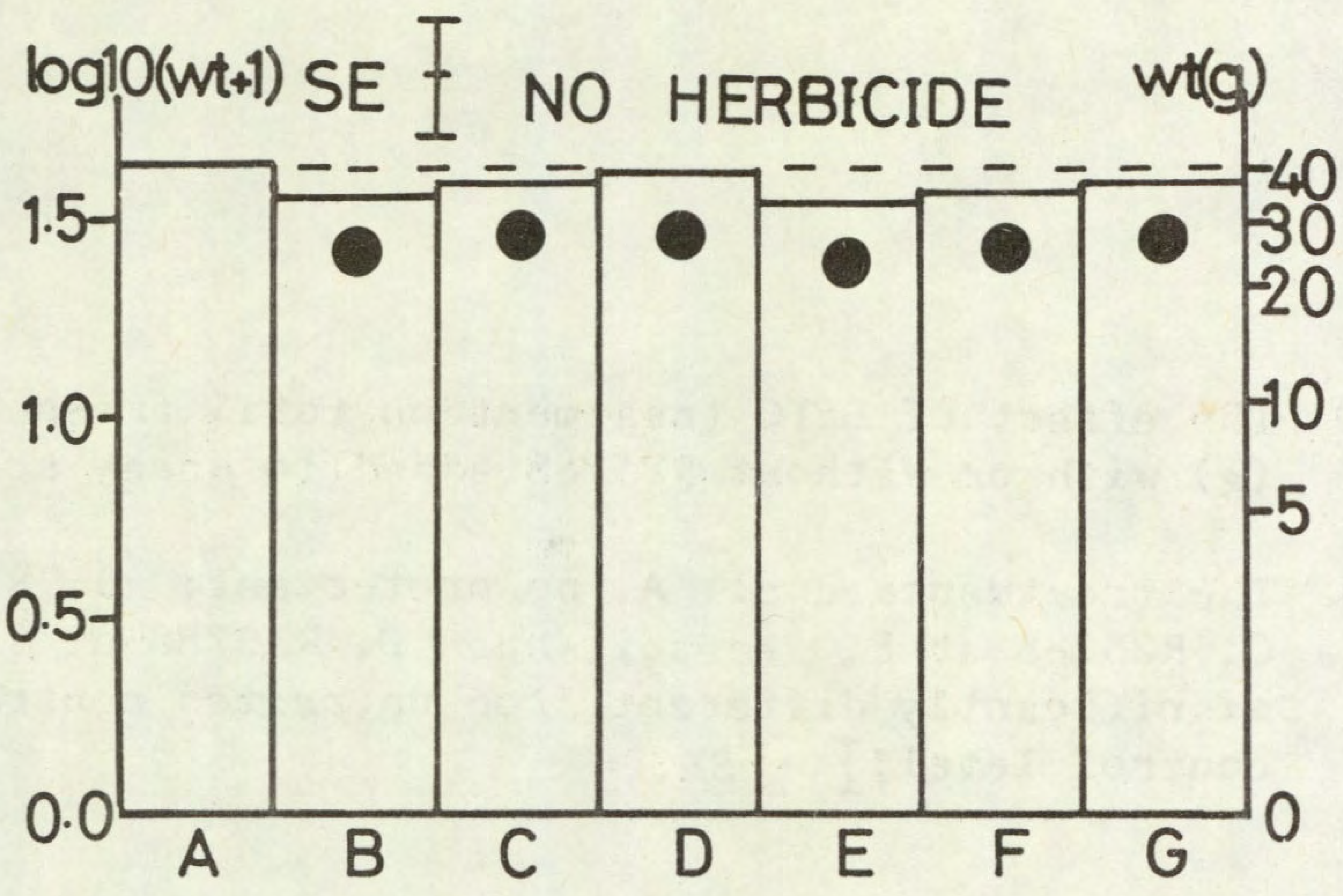
wt(g)
SE
1.5
1.0
0.5
0.0
40
30
20
10
5
0
A
B
C
D
EPTC @ 4 kgai/ha
EPTC @ 6 kgai/ha
EPTC @ 8 kgai/ha

<u>Fig. 9</u> The effect of EPTC treatment on total fresh weight of field beans (g) with or without R25788 added to spray solution.

The treatments are: A, no protectant; B, R25788 at 4.0 kg a.i./ha; C, R25788 at 8.0 kg a.i./ha; D, R25788 at 16.0 kg a.i./ha; ●, not significantly different from untreated control; ---- untreated control level; I ± SE.

See notes opposite Fig. 7.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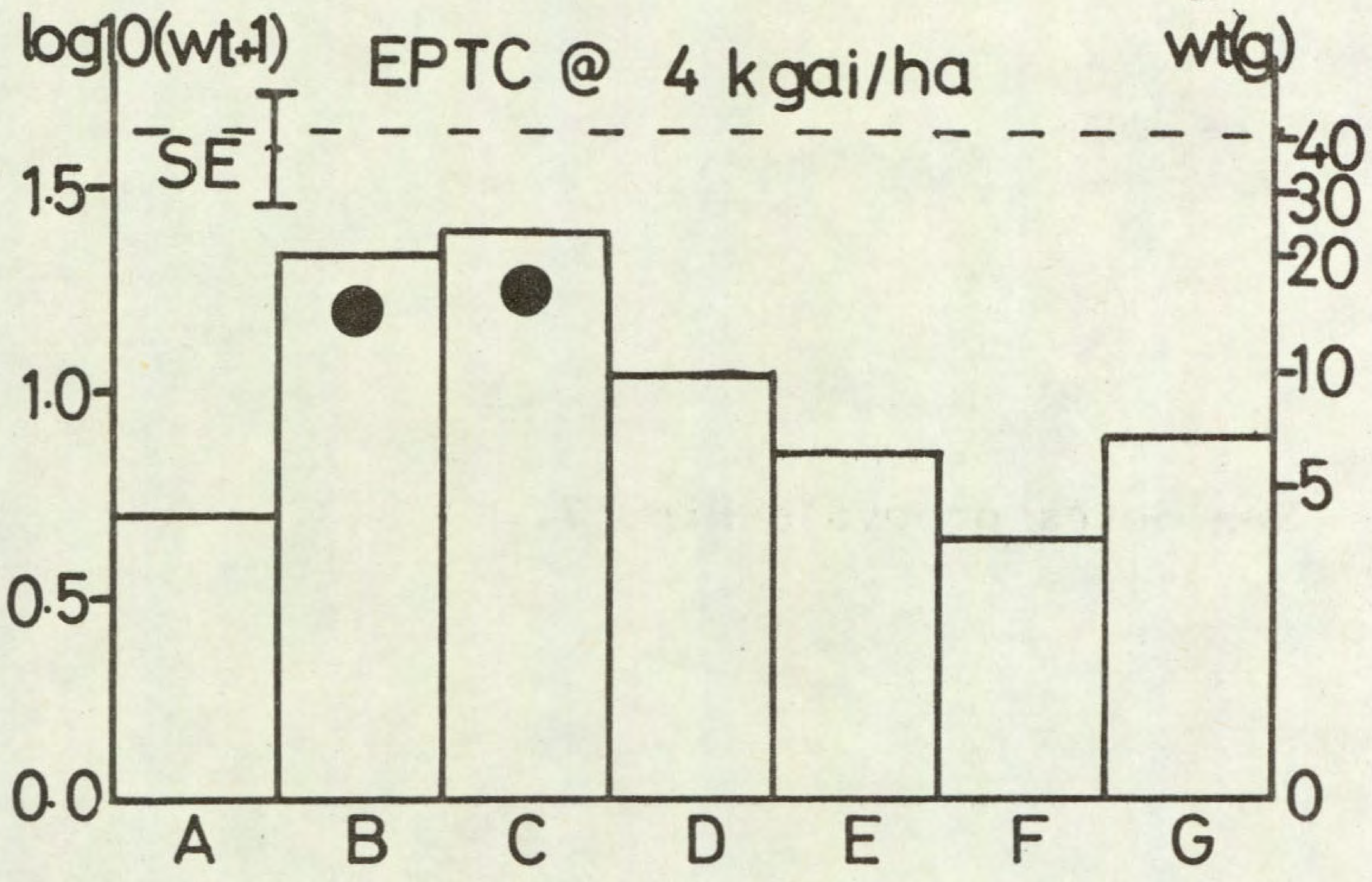
A
B
C
D
E
F
G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EPTC @ 4 kgai/ha
wt(g)
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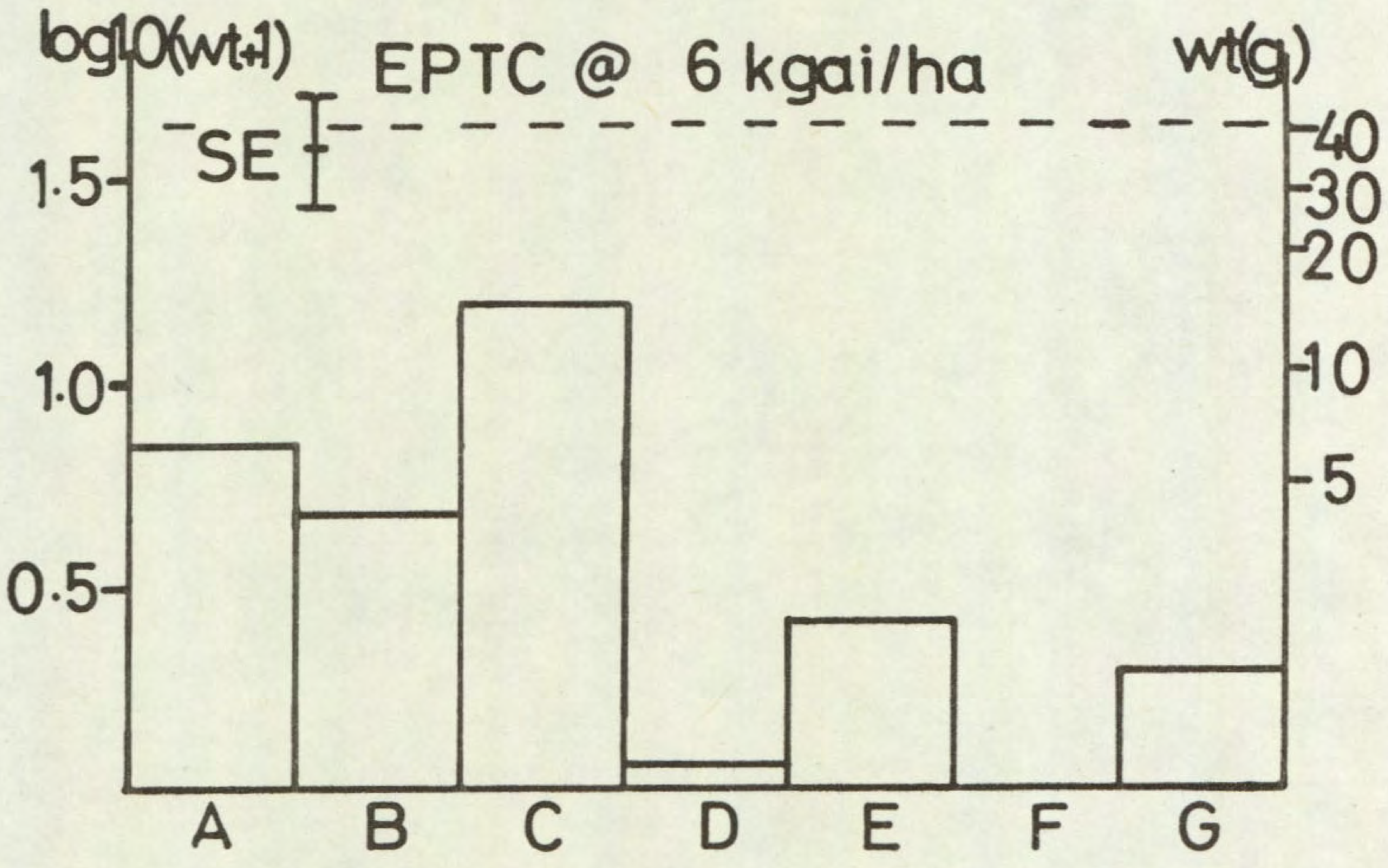
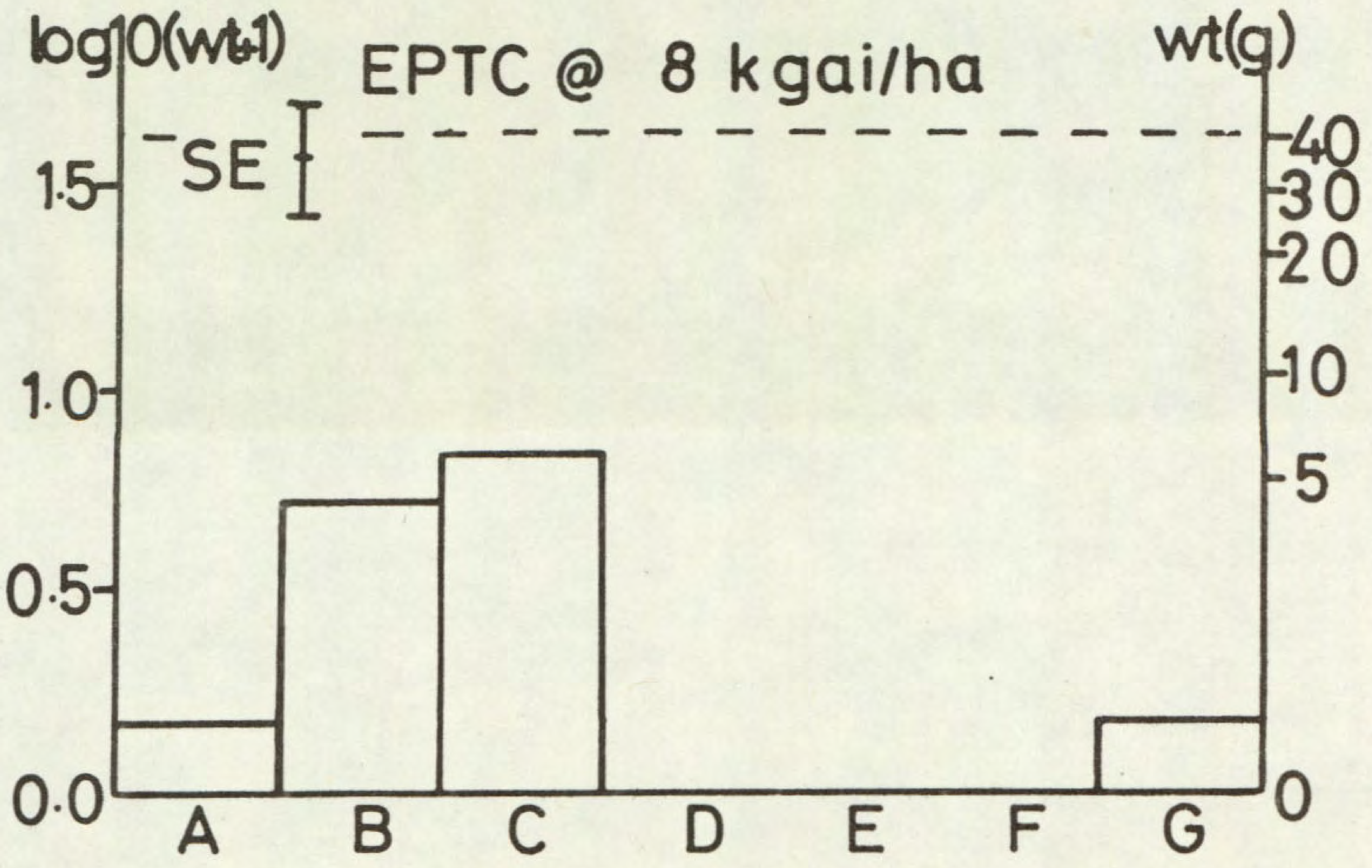
1.0
0.5
0.0
40
30
20
10
5
0
A
B
C
D
E
F
G


log10(wt+1)
EPTC @ 6 kgai/ha
wt(g)
SE
1.5
1.0
0.5
40
30
20
10
5
A
B
C
D
E
F
G


log10(wt+1)
EPTC @ 8 kgai/ha
wt(g)
SE
1.5
1.0
0.5
0.0
40
30
20
10
5
0
A
B
C
D
E
F
G

<u>Fig. 10</u> The effect of EPTC treatment on total fresh weight of field beans (g) with or without R29148 added to spray solution or seed treatments of NA or R25788.

The treatments are: A, no protectant; B, R25788 at 0.5%; C, NA at 0.5%; D, R29148 at 0.5 kg a.i./ha; E, R29148 at 1.0 kg a.i./ha; F, R29148 at 2.0 kg a.i./ha; G, R29148 at 4.0 kg a.i./ha; ●, not significantly different from untreated control; ---- untreated control level; I $\pm$ SE.

Doses of 0.5, 1, 2 and 4 kg a.i./ha R29148 mixed with herbicide in the spray tank provided no protection.

The effect of TCA and dalapon on field beans with and without a seed treatment of NA or R25788, or added R25788 in the spray solution (data not presented)

Both TCA and dalapon at doses up to 16 kg a.i./ha were applied as a surface pre-planting treatment to field beans and there was no indication of any protection by NA at 0.5 and 2.0% or R25788 at 0.5 and 2.0%. The addition of R25788 at 0.5, 2.0 and 8.0 kg a.i./ha to the spray solution also gave no protection from TCA or dalapon.

DISCUSSION

This series of experiments in the glasshouse demonstrated that it was possible to alleviate EPTC damage symptoms in field beans by using crop protectants. In some cases protection from EPTC was complete. Although a protectant which could be mixed in the spray tank would have many advantages compared to seed treatment, in these experiments tank mixtures of EPTC and R25788 were not generally effective (Fig. 8, 9) except in one experiment (Fig. 7) in which there was some indication of protection. This protection was not confirmed in one field experiment (results not presented).

In the case of a seed treatment the protectant is being applied at or near the site of herbicide uptake and therefore one could expect a greater chance of protection. R25788 at 0.5% in most cases gave good protection from 4.0 kg a.i./ha EPTC (Fig. 1, 3, 5), but did not always eliminate all visual symptoms of herbicide damage. Plant numbers were reduced by 2% R25788. NA at 0.5% also gave good protection from 4.0 kg a.i./ha EPTC (Fig. 2, 5), but the marked chlorosis caused by NA particularly in presence of EPTC would probably make this treatment unacceptable. This chlorosis could possibly increase plant susceptibility to other factors e.g. pathogens or adverse climatic conditions.

At 0.5%, most of R25788 was taken up on the seed but at higher levels there was excess. In contrast NA could be applied at much higher concentrations because the powder contained much greater quantities of active ingredient (> 98%) than R25788 (20%).

The main point illustrated by these experiments is the unreliability of such protection particularly at the higher doses of EPTC. If protection is to be worthwhile a greater margin of safety is required. Without understanding how these protectants function it is difficult to explain this unreliability. Lay, Hubbell & Casida (1975) suggest that R25788 is effective by stimulating the glutathione-s-transferase enzyme system responsible for the metabolism of EPTC. Similar suggestions for the activity of NA have been made but not specifying particular enzyme systems (Güneyli, 1971). An alternative possibility is that protectants interfere with the action of the herbicide on lipid metabolism. Wilkinson and Smith (1975) show that EPTC, NA and R25788 all interfere with the incorporation of ^{14}C labelled acetate into fatty acids. In the case of the experiments discussed in this paper it could be that the protectant is not getting to the site of entry in sufficient amounts. However, the use of methyl cellulose as a 'sticker' had no consistent effect suggesting that better and longer contact between the seed and seed treatment did not improve protection. It is also possible that there is a critical threshold amount which must reach a specific site within the seed or young seedling to give consistent protection. A 'sticker' could, however, have practical benefits in limiting the amount of surplus powder which could come off the seed when drilling thereby blocking the machine.

Of other protectants not available commercially R4115 looked promising but was only included in one experiment, and R29148 did not seem to give any protection.

Until there is a greater understanding of the mode of action of these protectants it makes prediction of other potential uses difficult: it is however still an interesting prospect for the future.

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*	^oC
degree centigrade	^oC
degree Fahrenheit*	^oF
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: $\times 10^{-9}$)	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: $\times 10^{-12}$)	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.
<u>varietas</u>	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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