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FIELD EXPERIMENTS TO INVESTIGATE LONG-TERM EFFECTS OF REPEATED APPLICATIONS OF MCPA, TRI-ALLATE, SIMAZINE AND LINURON - EFFECTS ON THE QUALITY OF BARLEY, WHEAT, MAIZE AND CARROTS

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SUMMARY

In four long-term field experiments the following treatments have been applied annually since 1963: MCPA and tri-allate to wheat and barley, simazine to maize and linuron to carrots. Each treated plot has an adjacent untreated control. All plots have received identical management apart from the herbicide.

In tests on the produce from 1968 onwards the following properties with some minor exceptions were unaffected by the respective herbicide treatments: (i) the malting properties, nutritional value and grain constituents in barley, (ii) the milling and baking qualities in wheat, (iii) the nitrogen content estimations and grain constituents in maize, and (iv) the taste, nitrogen content and aromatic oil content of carrots. Small differences noted in produce from treated plots included:- moisture content of barley grain for malting (MCPA); the α-amylase content, bushel weight and flour grade colour in wheat (tri-allate); the texture and some nitrogen estimations in maize (simazine) and the nitrogen and carotene content in some years in carrots (linuron).

INTRODUCTION

Long-term field experiments were set up in spring 1963 at Begbroke Hill to investigate whether the repeated application of some commonly used herbicides led to any changes in the soil which might influence the growth and health of crops or yield and quality of produce. Details of the experiments and results for crop yields and persistence of the herbicide in the soil were reported by Fryer and Kirkland (1970) for the first six years, and by Fryer, Smith and Ludwig (in preparation) for the period 1969-77.

This paper reports information gathered during the course of the experiments on the quality of produce. A variety of tests were carried out by specialists at the following research institutes, who kindly agreed to cooperate in the project:-

1. Brewing Industry Research Foundation, Redhill, Surrey (malting properties of barley).

2. Lord Rank Research Centre, High Wycombe, Bucks (composition of barley and maize and the nutritional value of barley).

3. Flour Milling and Baking Research Association, Chorleywood, Herts (milling and baking qualities in wheat).

4. Food Research Institute, Norwich (taste tests on maize and carrots, nitrogen estimations in maize and carrots, and aromatic oils in carrots).

In addition, nitrogen estimations in maize and carrots and carotene content in carrots were determined by the Chemistry Group at the Weed Research Organization.

EXPERIMENTAL METHODS

The design and management of the experiments are described in detail by Fryer and Kirkland (1970). Essentially there are four experiments, each consisting of four adjacent pairs of 27.5 x 4.9m plots. One plot of each pair receives the same herbicide each year. No herbicide is applied to the other. All plots receive identical treatment apart from herbicide application. There is no crop rotation.

The crops and herbicide treatments involved in these experiments initially were:

Experiment 1 Spring barley, cv. Zephyr 1968-72, Julia 1973-75, treated at growth stage 15 (Zadoks et al, 1974) with MCPA at 1.7 kg/ha.

Experiment 2 Spring barley, cv. as in Experiment 1, treated with tri-allate at 1.7 kg/ha, applied after drilling and harrowed into the soil above the seed.

Experiment 3 Maize, cv. Inra 200 1968-70, Kelvedon 59A 1971-72 and Maris Carmine 1973-76, treated pre-emergence with simazine at 1.7 kg/ha.

Experiment 4 Carrots, cv. Autumn King, treated with linuron at 1.7 kg/ha, with half of this dose being usually applied pre-emergence and the other half at the 5-6 leaf stage of growth.

A modification in the design was made in 1969 when spring wheat (cultivars Troll 1967-70, Sirius 1971-74 and Sappo 1975-76) was introduced into Experiments 1 and 2 by dividing each plot (previously all barley) into equal areas of wheat and barley. The areas sown to each crop were selected at random and remained the same during subsequent years. A similar division was made in 1974 in Experiment 4 to include cultivar Chantenay (a canning variety) alongside the main crop variety Autumn King. Experiment 3 continued unchanged. Treated and untreated plots are managed identically apart from the application of the herbicide. After the crops are sown, weeds in all plots are destroyed as soon as possible after emergence by hand-hoeing or hand pulling. After harvest all plots are ploughed and tractor cultivated.

Examination of produce

Test 1, Malting properties of barley Samples of barley grain produced in 1969 were cleaned and, after 1000 grain weight determination, were screened to separate small from large grains. The Recommended Methods of Analysis of the Institute of Brewing (1967) were then carried out on the samples as follows: barley: estimation of the % germination capacity,

% germination energy, and % water sensitivity, together with measurements of % moisture, % total nitrogen and 1000 grain weight (g); malt: % moisture, hot water extracts, cold water extract, diastatic power, total soluble nitrogen, % total nitrogen, tint, dry weight of roots, and % malting loss.

Test 2 The composition of barley grain Milled samples of barley grain, produced in 1968, were analysed for moisture, protein, ash, total carbohydrate, calcium, phosphorus, magnesium, chloride (as sodium chloride), sodium, potassium, iron, copper, zinc, mangonese and a number of amino-acids. The methods used were essentially standard tests laid down in the Fertilizers and Feeding Stuffs Regulations 1968.

Test 3 The nutritional value of barley (a) A net protein utilization value (N.P.U.) determination of 23 treatments (including feedstuff controls) was carried out using 6 rats per treatment. Barley, produced in 1968 and supplemented to bring the protein content to 10% was fed ad lib for 10 days. Then the rats were killed and the protein utilisation determined using the methods described in the Lord Rank Research Centre Report X7/P454/7. (b) Rats (6 per treatment) were fed for 30 days with a feed containing 55% of the test barley produced in 1968 and the following observations made:-

1. Live weight gain
2. Feed intakes
3. Protein efficiency ratio (P.E.R.)
4. Liver weight; body weight ratio
5. Abnormalities of organs
6. Specific observations of dissection liver and kidney tissue

Test 4 Flour milling and baking quality of wheat Samples of wheat grain harvested each year from 1971 to 1976 were milled and the dough subjected to a Hagberg falling time test to determine the α-amylase content. Additionally in the first three years a full range of milling and baking tests were undertaken. These are listed in Table 4. The determinations were carried out using the methods described by Fuller and Stewart (1970).

Test 5 The composition of maize grain Milled samples of maize grain produced in 1968 were analysed for the same constituents as the barley (Test 2) except that the maize samples were not analysed for amino-acids.

Test 6 Nitrogen content in the maize plant The nitrogen content of maize from the 1969 harvest was estimated at the Food Research Institute using a modified Kjeldahl method based on that of McKenzie and Wallace (1954). Later, in 1972 and the following three seasons, ten maize plants were collected at random from each plot at intervals during the growing season. Oven-dried samples of leaf, stem and cob from these plants were finely ground and analysed for nitrogen content. The semi-micro Kjeldahl method of digestion described by Faithfull 1969 was used followed by the automatic determination of nitrogen (Varley 1966).

Test 7 Taste test on maize Maize ears, at sweet corn stage of maturity were harvested at random in early September each year from 1969-71, following 7, 8 and 9 consecutive applications of simazine. The husk was removed, and the ears cut in half transversely, canned, and stored at

-40°C until required. The cans were allowed to thaw 5 hours prior to test. The ears were then pressure cooked for 8 minutes at 0.7 kg/sqcm pressure and the grains stripped from the cobs and thoroughly mixed. Samples were presented at 70°C as a triangle test to a trained taste panel who were asked to indicate which sample was different and why. All tests were carried out in triplicate. Results were analysed using standard tables (Arthey et al, 1968).

Test 8 Nitrogen content of carrots Representative samples of roots were collected in October each year from 1968-75. Nitrogen was determined as in maize (Test 6).

Test 9 Aromatic oils in carrots Samples were collected at random each September from 1969-71. Volatile aromatic oils were assayed using a method based on that of Buttery et al (1968).

Test 10 Carotene content in carrots Approximately 1 kg/plot samples, collected at harvest in each of the four years 1972-75, were cleaned, shredded, mixed and stored at -18°C until required for analysis when carotene was extracted and determined using the method of analysis of the Association of Official Agricultural Chemists (1960) and Sweeney and Marsh (1970).

Test 11 Taste testing of carrots Samples were collected each September from 1969 to 1971 and stored at +1°C and 95% R.H. until tested. The carrots were cleaned, sliced and pressure cooked for 8 minutes at 1.0 kg/sqcm pressure. The samples were then rapidly shredded, mixed and dispensed into warmed pots for testing. They were presented at 70°C in a triangle test to a trained panel. Ultra violet light was used to mask any colour differences. All tests were carried out at least in triplicate. The results were analysed using standard tables (Arthey etal,1968).

RESULTS

Test 1 Malting properties of barley

(a) Germination tests No significant differences were found in germinative capacity, primary dormancy or water sensitivity in produce from MCPA or tri-allate treated plots or from their respective controls.

(b) Barley analysis The nitrogen content was relatively high in all samples (approximately 2.0%) and, therefore, the malts obtained were low in extract. This was expected as the barley was not grown as a malting crop. The only significant difference between treatments was in the % moisture of barley grown on MCPA treated plots (Table 1).

(c) Malt Analysis There is no evidence of any significant treatment effects in any of the malt analysis determinations (Table 1).

Test 2 The composition of barley grain No differences were found in any of the tests carried out on the composition of barley grain but a great variation in iron content between control plots was noted (see Table 2).

Test 3 The nutritional value of barley No differences in carcass nitrogen content were evident at the end of the net protein utilization trial. Similarly, the tests carried out during and after the 30 day feeding trial also showed no differences (Table 3).

Test 4 Flour milling and baking quality of wheat In 1971 and 1972 there was an increase (Table 4) in the Hagberg falling time (which is a measure of the α-amylase content) in the case of wheat from tri-allate treated plots. Also in 1971 there was a slight decrease in the flour grade colour figure and in 1972 a decrease in grain bushel wheat for the wheat from tri-allate treated plots (Table 4). Otherwise no differences were found in any of the tests carried out. Variability from year to year and within a given year was high.

Test 5 The composition of maize grain There were no differences in grain composition in maize harvested in 1968 (Table 5).

Test 6 Nitrogen content in the maize plant No consistent differences were found between plots in the nitrogen content of each of the maize plant constituents assessed in this list. The three values found to be significantly different were maize grain at harvest 1968 (where treated maize gives a lower N_2 content than control), maize stems at harvest 1972 (treated being again lower than control) and maize leaves in 1973 (where the treated value is higher than the control). These results are shown in Table 6. All the other numerous results showed no differences in the nitrogen content between treated and control maize samples.

Test 7 Taste test of maize The results of this test are shown in Table 7. In 1969 there was no significant effect of simazine treatment. However, in both 1970 and 1971 a small but significant difference in texture was noted by the taste panel between the treated and the control samples. Although this variety is not normally grown for eating the comparison does suggest that simazine does have a small effect on the texture of maize grain.

Test 8 Nitrogen content in carrots In 1968 the N content in carrots from linuron treated plots (0.87%) was significantly less than the control (1.02%). There were no differences in the following seven seasons (Table 8).

Test 9 Aromatic oils in carrots There was a tendency for the concentrations of aromatic oils present in linuron-treated carrots to be lower than the controls (Table 9). However, the differences between treatment and control means are not statistically significant even though it was fairly consistent from year to year (mean aromatic oil ppm value for 3 years: treated carrots 128 ppm, untreated 152ppm).

Test 10 Carotene content in carrots In 1972 the carotene levels were higher for linuron-treated plots and the differences were generally significant (Table 10). They were rather more marked for β carotene than for α carotene. In the following 3 years, however, although the tendency was still present in some cases the differences were not statistically significant except in β carotene in cv. Chantenay in 1974.

Test 11 Taste test of carrots These tests showed no significant flavour difference either between control and linuron-treated samples or between control samples from different positions in the experiment (Table 11).

DISCUSSIONS AND CONCLUSIONS

As already noted no effect on the malting quality of barley was found. Karpin and Ivantson (1971) using MCPA in mixtures found that 0.34 kg/ha MCPA + 0.02 kg/ha dicamba had no effect on malting quality but found a reduction in yield and starch content and an increase in protein content when 0.98 kg/ha MCPA was used with 0.07 kg/ha dicamba. Kohout (1971) using solution culture and Engström (1974) working in the field both report an increase in % protein content in barley where MCPA was used at a similar level to that used in our experiment. The protein increase did not occur in samples from our plots.

Although there were four significant results from wheat grown on tri-allate treated plots in 1971 and 1972 the results in subsequent years suggest that these differences are not of regular occurrence for the cultivars Sirius and Sappo. However, these effects may be different with other varieties.

Contrary to the results of Tweedy and Ries (1967), Frieske (1971) and many others no increase in total nitrogen was found in simazine-treated maize in any year in which this test was carried out.

In the 44 determinations of nitrogen contents in maize, only in three instances were there significant effects and in each case from different constituents and in different years. None of these results was repeated within a year or in any other year, and so little importance can be attached to these isolated results.

Small differences were found between treated and untreated samples in the taste tests of maize grain. The taste panel's comments showed that the differences were in texture rather than in flavour, but there was no agreement from person to person, panel to panel, or year to year, suggesting that although perceived a significant number of times, the difference was too small to be clearly defined.

The nitrogen content of carrots from linuron-treated plots was lower than from the controls in 1968 (a very wet season), but this tendency was not repeated during the following seven seasons. Zechalko et al (1971) reported an increase in nitrogen content on linuron-treated plots.

Although the concentrations of aromatic oils present in linuron-treated carrots tended to be lower than in control carrots the difference was never statistically significant in the years the test was carried out. Combining the three years' results into one statistical analysis confirmed the consistent treatment difference but again did not reach statistical significance.

Sweeney and Marsh (1971) and Zechalko et al (1971) reported increased carotene content in carrots following linuron treatment. The results obtained in the first year of our tests (1972) and those obtained with β carotene in Chantenay in 1974 were similar but the remaining tests showed no effect. The weather condtions in 1972 were dry but significant results were not obtained in 1975 which was also dry. Also, there was no indication of short-term herbicide damage in 1972.

The results of the taste test for carrots confirmed the preliminary findings of Arthey (1969) who also found no taint or taste differences when linuron was used in carrots.

Certain limitations to this experiment must be emphasised. The experiment was carried out on one soil type only (i.e. the coarse sandy loam soil of Deal Field at the Weed Research Organization) and so it is not certain that the same results would be obtained elsewhere. In addition some tests were carried out on cultivars not normally grown for the property being tested (e.g. a fodder maize variety was used in a sweet corn taste test). However, the results are nonetheless encouraging in that no evidence of major effects on the quality of produce have emerged as a consequence of repeated herbicide treatment.

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Table 1 Brewing properties of barley

Property examined	MCPA EXPERIMENT			TRI-ALLATE EXPERIMENT		
	Untreated	MCPA treated	S.E. of means ±	Untreated	Tri-allate treated	S.E. of means ±
Germination						
% germinative capacity	97.2	97.5	0.60	97.5	97.2	0.53
% germinative energy	97.2	96.5	0.53	96.5	97.5	1.0
% water sensitivity	94.0	91.2	1.3	94.0	95.5	0.61
Barley analysis						
% moisture	13.6	13.8*	0.04	13.6	13.6	0.32
% total nitrogen	2.0	2.0	0.02	2.0	2.0	0.02
1000 grain wt (unscreened sample) (g)	33.4	33.8	0.40	34.5	33.8	0.64
Malt analysis						
% moisture	4.2	4.1	0.11	4.0	3.8	0.14
Hot water extract (%)	94.5	94.1	0.29	94.8	93.8	0.59
Cold water extract (%)	60.0	58.5	2.8	59.3	46.4	6.1
Diastatic power, °Lintner	102.5	105.2	1.1	95.0	91.5	2.8
Total soluble nitrogen (mg/100 ml)	0.56	0.57	0.003	0.56	0.56	0.002
% total nitrogen	1.9	2.0	0.02	1.9	1.9	0.04
Tint (European Brewery Convention)	2.0	2.0	+	2.0	2.0	+
Roots, dry wt (g)	8.0	7.8	0.28	8.0	8.1	0.13
% malting loss	5.3	5.2	0.11	5.1	4.9	0.23

* significant when $P < 0.05$
\+ all values identical

Table 2 Composition of barley grain

Constituent	MCPA Experiment			TRI-ALLATE Experiment		
	Control	Treated	S.E.	Control	Treated	S.E.
Moisture %	12.4	12.6	0.39	12.90	12.4	0.35
Oil	1.7	1.7	0.03	1.74	1.7	0.03
Protein (6.25)%	8.7	8.8	0.23	8.6	8.4	0.10
Fibre %	5.1	5.0	0.48	4.8	4.0	0.51
Ash %	2.2	2.2	0.04	2.31	2.4	0.08
Total Carbohydrate %	65.00	64.50	1.3	52.25	64.80	4.6
Calcium %	0.02	0.02	+	0.02	0.02	0.01
Phosphorus %	0.34	0.35	0.01	0.34	0.33	0.01
Magnesium %	0.10	0.10	0.01	0.10	0.09	0.01
Salt %	0.12	0.14	0.02	0.12	0.15	0.01
Sodium %	-	-	-	<0.01	<0.01	-
Potassium %	0.42	0.53	0.07	0.46	0.44	0.01
Iron (ppm)	98.3	78.5	5.3	167	354	103.2
Copper (ppm)	5.8	5.2	0.38	9.62	9.4	0.18
Manganese (ppm)	15.0	14.7	0.62	15.70	18.7	1.9
Zinc (ppm)	35.0	27.6	5.2	22.0	21.7	0.18
		NS			NS	

+ all values identical

Table 3 Animal feed value of barley

	MCPA Experiment			TRI-ALLATE Experiment		
	Control	Treated	S.E.	Control	Treated	S.E.
NPU assay						
Net protein utilization of barley by rats (%)	67.8	65.4	0.72	68.5	65.5	0.92
30 day feeding trial						
Liveweight gain (g/day)	5.8	5.7	+	5.8	6.0	+
Feed intake (g/day)	14.4	14.6	+	14.4	14.5	+
PER (protein efficiency ratio)	2.5	2.4	+	2.5	2.5	+
Liveweight: bodyweight ratio	6.0	6.1	+	6.0	5.8	+
		NS			NS	

NB Joint control used in 30 day feeding trial

+ S.E.s not provided by collaborator

Table 4 Milling and baking properties of spring wheat

Parameter	Year	Variety	MCPA Experiment Control	MCPA Experiment Treated	MCPA Experiment S.E.	TRI-ALLATE Experiment Control	TRI-ALLATE Experiment Treated	TRI-ALLATE Experiment S.E.
Wheat bushel weight (kg)	1971	Sirius	27.7	27.7	0.04	27.7	27.5	0.09
	1972	"	27.7	27.3	0.24	27.2	26.9*	0.07
	1973	"	28.4	28.4	0.11	28.6	28.4	0.14
Flour yield %	1971	"	70.7	71.3	0.24	70.1	68.3	0.68
	1972	"	72.7	72.9	0.21	72.1	72.2	0.53
	1973	"	74.0	73.7	0.08	73.2	73.6	0.54
Flour grade Colour Figure	1971	"	2.2	2.1	0.06	2.4	2.1*	0.03
	1972	"	2.0	2.6	0.18	2.8	2.8	0.07
	1973	"	2.4	2.7	0.20	3.0	3.3	0.18
Water absorption %	1971	"	53.9	54.3	0.18	54.1	54.2	0.71
	1972	"	55.8	55.5	0.39	54.8	54.1	0.26
	1973	"	16.8	17.0	0.10	16.7	16.9	0.06
Extensiometer resistance	1971	"	909	834	21.8	772	782	44.0
	1972	"	482	501	12.3	554	641	30.7
	1973	"	573	569.0	17.2	609.5	562.5	21.1
Extensiometer extensibility	1971	"	19.0	19.7	0.29	20.2	19.2	0.39
	1972	"	20.5	21.3	0.78	19.8	18.6	0.70
	1973	"	22.0	21.2	0.78	21.6	21.9	0.55
Loaf score (Max 50)	1971	"	39.8	42.0	0.78	41.25	41.5	1.0
	1972	"	38.2	38.8	1.17	34.5	32.2	2.2
	1973	"	45.5	46.0	0.46	45.8	45.0	0.60
% Flour Protein @ 13.5% moisture	1971	"	11.8	12.1	0.12	11.5	11.60	0.07
	1972	"	11.3	11.3	0.18	11.3	11.45	0.23
	1973	"	12.7	12.8	0.11	12.6	12.85	0.18
Flour Hagberg Falling time (secs)	1971	"	222.3	213.3	4.9	208.5	223.3**	1.8
	1972	"	148.3	141.3	6.1	163.8	172.0*	1.7
	1973	"	191.8	184.5	4.0	171.5	177.8	3.2
	1974	"	321.8	317.8	5.6	341.0	336.0	5.0
	1975	Sappo	316.0	323.8	4.3	343.2	343.5	4.2
	1976	"	389	406	15.2	413	412	6.4

* difference significant when $P < 0.05$

** difference significant when $P < 0.01$

Table 5 Composition of maize grain

Constituent	Control	Simazine treated	S.E.
Moisture %	19.6	22.3	0.90
Oil %	2.7	1.5	0.39
Protein %	9.7	9.5	0.15
Fibre %	1.3	1.4	0.09
Ash %	1.4	1.4	0.03
Total Carbohydrate %	65.2	56.2	3.5
Phosphorus %	0.32	0.32	0.01
Magnesium %	0.11	0.12	0.01
Salt %	0.11	0.04	0.02
Sodium %	-	-	-
Potassium %	0.37	0.36	0.01
Iron (ppm)	34.5	33.5	1.2
Copper (ppm)	4.6	4.6	0.10
Manganese (ppm)	7.9	7.7	0.14
Zinc (ppm)	23.5	24.1	0.74

NS

Table 6 Nitrogen content of the maize plant (as % total N on dry weight basis)

		1972			1973			1974			1975		
		Control	Simazine treated	S.E.	Control	Simazine treated	S.E.	Control	Simazine treated	S.E.	Control	Simazine treated	S.E.
1st assessment date		31.7.72			1.8.73			5.8.74			1.8.75		
	leaves	3.9	4.0	0.05	2.8	3.0	0.07	3.2	3.2	0.06	2.9	3.1	0.09
2nd assessment date		1.9.72			29.8.73			5.9.74			7.9.75		
	leaves	3.1	3.4	0.18	2.3	2.7*	0.06	2.6	2.6	0.13	1.9	1.9	0.03
	stems	1.3	1.4	0.04	0.6	0.72	0.03	0.80	0.75	0.03	0.76	0.78	0.05
	immature ears	2.0	2.0	0.04	1.6	1.6	0.03	1.4	1.4	0.02	1.4	1.4	0.02
3rd assessment date		13.10.72			25.9.73			2.10.74			30.9.75		
	leaves	2.4	2.5	0.07	1.7	1.6	0.03	2.3	2.4	0.11	1.6	1.6	0.08
	stems	0.97	1.1	0.06	0.68	0.64	0.06	0.64	0.69	0.05	0.74	0.96	0.07
	immature ears	1.5	1.6	0.03	1.4	1.3	0.02	1.4	1.3	0.03	1.6	1.6	0.07
4th (harvest) assessment date		13.11.72			24.10.73			21.10.74			30.10.75		
	leaves	1.8	1.8	0.10	1.3	1.3	0.02)			(	1.5	1.6	0.04
							)	stover 4.7	4.9	0.16(			
	stems	1.2	1.1*	0.02	0.47	0.49	0.03)			(	0.80	0.93	0.06
	whole ears	1.5	1.7	0.06	0.55	0.53	0.02	2.6	2.7	0.08	1.5	1.6	0.06
	grain	2.1	2.2	0.04	1.6	1.6	0.03				1.8	1.8	0.02
harvest	grain	1.0	1968 (F.R.I.)										
			0.87*	0.03									
harvest	grain	2.3	1969 (F.R.I.)										
			2.2	0.10									

* significantly different when P <0.05

Table 7 Flavour and texture of maize grain

Year	Samples compared	Triangle Tests			
		No. of tests	No. correct	No. no difference	Significance of difference
1969	Control I v Treated I	27	7	7	N.S.
	Control III v Treated III	27	8	6	N.S.
	Treated II v Treated IV (field effect)	27	9	3	N.S.
1970	Control III v Treated III	36	28	1	***
	Control IV v Treated IV	36	20	1	**
	Control I v Control III (field effect)	36	10	4	N.S.
1971	Control II v Treated II	27	18	0	**
	Control III v Treated III	27	12	3	N.S.
	Control I v Control II (field effect)	36	13	1	N.S.

** $P < 0.01$

*** $P < 0.001$

Significance determined by the method for the evaluation of results for sequential triangle test given by Arthye et al (1968)

Table 8 Nitrogen content of carrot roots (as % total N on dry wt. basis)

Year & cultivars	Control	Linuron treated	S.E. of mean
1968 **Autumn King**	1.02	0.87*	0.03
1969 **Autumn King**	1.07	1.23	0.04
1970 **Autumn King**	0.78	0.78	0.02
1971 **Autumn King**	1.06	1.07	0.04
1972 Autumn King	0.84	0.84	0.01
1973 **Autumn King**	1.01	0.98	0.06
1974 **Autumn King**	0.96	1.04	0.03
Chanteney	1.12	1.14	0.04
1975 **Autumn King**	1.17	1.08	0.03
Chanteney	1.06	1.16	0.03

* significant difference $P < 0.05$

Table 9 Total volatile constituents in carrots (as ppm on wet weight basis)

Year	Control	Linuron treated	S.E. of mean
1969	124.8	106.5	12.1
1970	198.8	161.8	10.6
1971	131.8	114.5	8.2

Table 10 Carotene content (mg/100g)

Year	Pigment	WET			DRY		
		Untreated	Linuron treated	S.E. means	Untreated	Linuron treated	S.E. of means
1972	α	1.56	1.76*	0.03	10.86	11.86	0.35
Autumn King	β	5.20	6.38**	0.13	36.14	43.89*	1.31
1973	α	2.06	2.17	0.14	17.94	18.32	1.08
Autumn King	β	5.89	5.90	0.19	51.38	49.76	1.01
1974	α	2.03	1.54	0.28	17.03	13.20	2.62
Autumn King	β	6.12	5.98	0.12	50.90	51.53	1.39
Chanteney	α	1.38	2.30	0.25	12.44	20.63	2.30
	β	5.57	8.38*	0.49	50.47	75.49*	4.90
1975	α	2.58	2.48	0.22	NOT TAKEN		
Autumn King	β	6.20	6.25	0.40			
Chanteney	α	1.72	1.95	0.16			
	β	5.70	6.15	0.16			

* P <0.05
** P <0.01

Table 11 Flavour and texture of carrots

Year	Samples compared	No. of tests	No. Correct	No. No difference	Significance of difference
1969	Control I v Treated I	27	6	4	N.S.
	Control II v Treated II	36	14	6	N.S.
	Control I v Control IV (field effect)	36	10	4	N.S.
1970	Control II v Treated II	27	8	3	N.S.
	Control IV v Treated IV	27	9	1	N.S.
	Control II v Control IV (field effect)	45	16	1	N.S.
1971	Control II v Treated II	27	6	1	N.S.
	Control IV v Treated IV	27	8	1	N.S.
	Control II v Control IV (field effect)	27	8	0	N.S.

Significance determined by the method for the evaluation of results for the sequential triangle test given by Arthey et al (1968)

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*	±
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*	√
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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