PARAQUAT (057)

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EXPLANATION

Paraquat, a non-selective contact herbicide, was first evaluated in 1970 for toxicology and residues. Subsequently, it was reviewed for toxicology in 1972, 1976, 1982, 1985 and 1986, and for residues in 1972, 1976, 1978 and 1981. The 2003 JMPRMeeting reviewed paraquat toxicologically under the Periodic Review Programme and the current ADI of 0-0.005 mg paraquat cation/kg bw and acute RfD of 0.006 mg paraquat cation/kg bw were recommended. by the 2003 JMPR. The residue evaluation was postponed to the present Meeting. Currently there are 22 Codex MRLs for plant commodities, their derived products, and animal commodities.

The 32nd Session of the CCPR identified paraquat as a priority compound for Periodic Re-evaluation by the 2002 JMPR but residue evaluation was postponed to the present Meeting.

Paraquat is normally available in the form of the dichloride or bis(methyl sulfate) salt. The Meeting received data on metabolism, environmental fate, analytical methods, storage stability, supervised field trials and processing and information on use pattern.

IDENTITY

ISO common name: paraquat

Chemical name
- IUPAC: 1,1′-dimethyl-4,4′-bipyridinium
- CAS: 1,1′-dimethyl-4,4′-bipyridinium

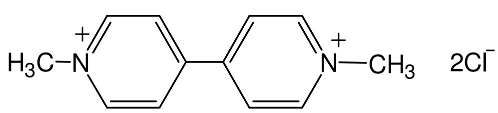
CAS Registry No.: 1910-42-5 (paraquat dichloride)
4685-14-7 (paraquat)

CIPAC No.: 56

The properties listed below refer to the dichloride

Synonyms and trade names: N,N'-dimethyl-4,4'-bi-pyridinium chloride, Gramoxone, Gramoxon, PP148, etc.

Structural formula:



Molecular formula: $C_{12}H_{14}N_2Cl_2$

Molecular weight: 257.2
(Molecular weight of paraquat ion is 186.3)

Physical and chemical properties

Pure active ingredient (Husband, 2001)

Purity:	99.5%
Appearance:	Off-white hygroscopic solid without characteristic odour
Vapour pressure:	<< 1×10^{-5} Pa at 25°C
Melting point:	No melting below 400°C; decomposition at around 340°C (613°K)
Boiling point:	Boiling point of pure paraquat dichloride not measurable; decomposition at ~340°C (613°K)
Relative density:	1.55 at 25°C
Surface tension:	73.4 mN/m at 20°C (at concentration of 0.02 M)
Henry's law constant:	4×10^{-9} Pa m^3/mol
Octanol-water partition coefficient:	Log P_{ow} -4.5 at 25°C
Solubility at 20ºC:	Water: 618 g/l at pH 5.2 620 g/l at pH 7.2 620 g/l at pH 9.2 Methanol: 143 g/l Acetone: <0.1 g/l Hexane: <0.1 g/l Dichloromethane: <0.1 g/l Toluene: <0.1 g/l Ethyl acetate: <0.01 g/l
pH at 20°C	6.4
Stability:	≥14 days at 54°C
Hydrolysis:	No hydrolysis was observed at pH 5, 7 or 9 (91 mg/l; 25 or 40°C for 30 days)
Photolysis:	In aqueous solution, photochemically decomposed by UV radiation

Technical material (Wollerton. 1987)

Purity:	Minimum 362 g/l (tested material: 529 g/l)
Appearance:	Dark red-brown clear liquid
Odour:	Earthy odour
Density:	1.13 g/cm^3 at 25°C

pH: 3.95 at approximately 20 °C

Flash point: > 90 °C

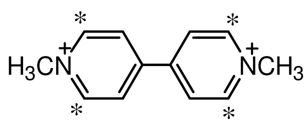
Surface tension: 58.6 mN/m at 20 °C

Storage stability: ≥2 years at 25 °C in polythene

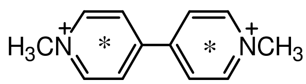
Formulations: SL (in various concentrations alone or in combination with diquat)

METABOLISM AND ENVIRONMENTAL FATE

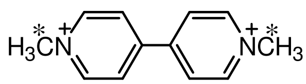
For studies of metabolism in animals and plants, [^{14}C]paraquat was labelled as shown (Figure 1). The structures of metabolites identified in these studies are shown in Figure 2.



[2,2′,6,6′-^{14}C]paraquat



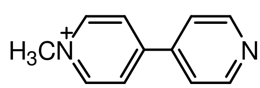
[U-^{14}C-dipyridyl]paraquat



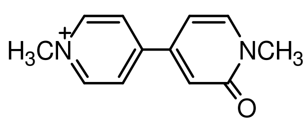
[1,1′-^{14}C-dimethyl]paraquat

(*position of ^{14}C label)

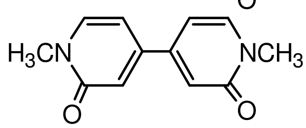
Figure 1. Radiolabelled paraquat used in metabolism studies.



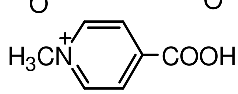
Monoquat



Paraquat monopyridone (MP)



Paraquat dipyridone (DP)



4-carboxy-1-methylpyridinium ion
(*N*-methyl isonicotinic acid (MINA))

Figure 2. Structures of metabolites identified in metabolism studies.

Animal metabolism

The Meeting received information on the fate of orally-dosed paraquat in rats, sheep, pigs, a lactating cow and goat, and laying hens.

Rats. The excretion balance of paraquat in male and female Alpk:ApfSD rats which were given a single dose (at either 1 mg/kg bw or 50 mg/kg bw of [1,1′-^{14}C-dimethyl]paraquat dichloride) or repeated doses (1 mg/kg bw of radiolabelled paraquat dichloride following 14 daily doses of 1 mg/kg unlabelled compound) (Lythgoe & Howard, 1995 a-c, reported in Macpharson, 1995) was evaluated by the WHO Core Assessment Group of the 2003 JMPR. It concluded that paraquat was not well absorbed when administered orally. After oral administration of radiolabelled paraquat to rats, more than half the dose (60-70%) appeared in the faeces and a small proportion (10-20%) in the urine. Excretion was rapid: about 90% within 72 h.

The biotransformation of paraquat was studied by Macpherson (1995) who analysed urine and tissue samples of rats administered the same doses of radiolabelled paraquat as above by TLC and HPLC. This was also reviewed by the WHO Core Assessment Group of the 2003 JMPR together with other rat metabolism and toxicity studies. It was concluded that paraquat is largely eliminated unchanged - approximately 90-95% of radiolabelled paraquat in the urine was excreted as the parent. In some studies no metabolites were identified after oral administration of paraquat, while in others a small degree of metabolism probably occurring in the gut as a result of microbial metabolism was observed. Paraquat was not found in the bile.

Sheep. In a study by Hemmingway *et al.* (1972) on two sheep [1,1′-^{14}C-dimethyl]paraquat dichloride was administered via a rumen fistula to one sheep weighing 73.5 kg (7.14 mg of radiolabelled+1.7035 g unlabelled paraquat in 30 ml of water) and to another weighing 60.5 kg via subcutaneous injection (0.87 mg of radiolabelled+54.5 mg unlabelled paraquat in 4 ml of water). Urine and faeces from these sheep were collected for 10 days. For spectrophotometric determination of paraquat, 100 g of faeces were boiled with 500 ml of 2N H_2SO_2 for three hours, the digest was filtered, and the filtrate diluted with an equal volume of water. An aliquot of urine or an aliquot of faeces sample processed as above was percolated separately through a column of cation-exchange resin. The column was washed with 2.5% ammonium chloride solution and the paraquat eluted with saturated ammonium chloride solution. A portion of the column effluent was treated with sodium dithionite in an alkali solution, which reduces paraquat to a free radical whose absorption was measured photometrically at 396 nm with background correction.

It appeared that via rumen fistula, all administered radioactivity was recovered within 10 days in urine and faeces: approximately 4% from the urine and the remainder from the faeces (Table 1). Most of the radioactivity was excreted in the faeces on days 2-5. These results indicate that residues of paraquat do not remain or accumulate in the tissues of sheep when the dose is administered orally.

Table 1. Residues in the urine and faeces of sheep given radiolabelled paraquat via rumen fistula (Hemmingway *et al.*, 1972).

Day	% of administered radioactivity		% of paraquat in excreted radioactivity*		% of radioactivity on paper chromatogram (faeces)	
	Urine	Faeces	Urine	Faeces	Paraquat	Other bands**
1	1.66	0.8	74 (83)	81 (93)	-	-
2	1.13	22	87 (95)	89 (90)	99	1
3	0.68	22	78 (88)	85 (101)	99	1
4	0.20	27	77 (80)	86 (89)	99	1
5	0.12	15	72 (80)	94 (103)	98	2
6	0.057	7.5	69 (78)	79 (97)	97	3
7	0.034	4.3	80 (82)	84 (88)	-	-
8	0.029	1.3	76 (87)	59 (87)	-	-
9	0.020	0.53	66 (79)	55 (77)	-	-

Day	% of administered radioactivity		% of paraquat in excreted radioactivity*		% of radioactivity on paper chromatogram (faeces)	
	Urine	Faeces	Urine	Faeces	Paraquat	Other bands**
10	0.016	0.23	78 (95)	47 (70)	-	-
Total	3.9	100.7	-	-	-	-

* Percentage of paraquat in the saturated ammonium chloride eluate from a cation-exchange column in parentheses.
** MP + MINA + DP + solvent front area + origin area (solvent system: iso-propanol:ethanol:NH_4Cl 3:3:2)

The urine and faeces samples, after fractionation on a cation-exchange column, were analysed by paper chromatography (solvent system: iso-propanol:ethanol:NH_4Cl 3:3:2; and n-butanol:acetic acid:water 4:1:2). The chromatograms showed that most of the radioactivity in these samples was unchanged paraquat, and about 2-3% MP. A trace (<1%) can be accounted for as MINA and DP in the iso-propanol:ethanol:NH_4Cl solvent system, and monoquat in the n-butanol:acetic acid:water solvent system. The results of paper chromatography (solvent system of iso-propanol:ethanol:NH_4Cl 3:3:2) of the faecal samples are also shown in Table 1.

Subcutaneously administered paraquat was also excreted very rapidly. Over 80% of the administered radioactivity was excreted in the urine; 69% one day after the treatment. Unchanged paraquat accounted for most of the radioactivity, MP for 2-3%, and monoquat was a trace metabolite. This pattern is virtually identical to that seen in urine after administration via the rumen fistula.

Pigs. In a trial in 1976 Leahey *et al.* dosed one pig weighing about 40 kg twice daily with [1,1′-^{14}C-dimethyl]paraquat ion in the diet at a rate of about 100 mg a day, equivalent to 50 mg/kg in the diet for 7 days. Another pig was used as a control. After the first dose, blood was sampled at hourly intervals and the radioactivity measured to determine when peak levels were reached. On subsequent days, a blood sample was taken after the morning dose after an interval corresponding to the time taken to reach the maximum blood level. The faeces and urine were collected from the day before the first administration and the pig was slaughtered two hours after the morning dose on the seventh day and, after bleeding, samples of liver, kidney, muscle, fat, heart, blood, lung and brain were taken. The content of paraquat in the tissues was determined by reverse-isotope dilution.

The radioactivity levels in blood samples increased after the morning dose on the first day, reaching a maximum within two hours of dosing, and then decreased very slowly. The radioactivity in blood did not increase significantly after the second day.

At the time of slaughter 69% of the administered radioactivity had been excreted in the faeces and 3.4% in the urine, and 13.4% was found in the stomach contents and viscera.

The distribution of radioactivity in the tissues All the radioactivity found in all tissues except the liver could be accounted for as paraquat. In the liver about 70% was determined as paraquat, 7% as the monoquat ion and a trace (c.0.6%) of MP ion.

Table 2. Distribution of radioactivity in the tissues of a pig dosed with [1,1′-^{14}C-dimethyl]paraquat for 7 days (Leahey *et al.*, 1976).

Sample	Radioactivity as paraquat ion equivalents mg/kg	% of radioactivity as paraquat
Hindquarter muscle	0.03	94
Forequarter muscle	0.06	106
Subcutaneous fat	0.02	115
Peritoneal fat	0.06	102

Sample	Radioactivity as paraquat ion equivalents mg/kg	% of radioactivity as paraquat
Liver	0.20	73
Kidney	0.46	109
Heart	0.12	104
Lung	0.12	105
Brain	0.02	108
Blood	0.07	104

Spinks *et al.* in 1976 conducted a similar study except that [2,2′,6,6′-^{14}C]paraquat was used instead of [1,1′-^{14}C-dimethyl]paraquat ion. At slaughter, 72.5% of the administered radioactivity had been excreted in the faeces and 2.8% in the urine.

The distribution of radioactivity in the tissues at the time of slaughter is shown in Table 3. There was no significant metabolism of paraquat in most of the tissues. In the liver, approximately 70% of the radioactivity was accounted for as paraquat with 4% as monoquat.

Table 3. Distribution of radioactivity in tissues of pig dosed with [2,2′,6,6′-^{14}C]paraquat ion for 7 days (Spinks *et al.*, 1976).

Sample	Radioactivity as paraquat ion equivalents mg/kg	% of radioactivity as paraquat
Hindquarter muscle	0.05	93
Forequarter muscle	0.05	95
Subcutaneous fat	0.01	105
Peritoneal fat	0.01	106
Liver	0.10	70
Kidney	0.38	101
Heart	0.08	81
Lung	0.10	94
Brain	0.03	62
Blood	0.06	71

Lactating cow. In a study by Leahey *et al.* (1972), [1,1′-^{14}C-dimethyl]paraquat dichloride was administered using a balling gun to a Friesian cow (475 kg) in a single dose equivalent to approximately 8 mg/kg paraquat ion. The faeces and urine were thereafter collected for nine days, and the milk collected each day in the morning and afternoon (each day of the experiment started at afternoon milking). Faeces and urine samples were processed as in the study on sheep above for spectrophotometric analysis. For the milk samples, five g of cation-exchange resin were added to two l of day-2 pm milk in a polythene bottle which was placed on mechanical rollers for 2.75 hours. After removal of the milk, the resin was transferred to a burette with glass wool above the stopcock. The resin was washed with 150 ml of 2.5% aqueous ammonium chloride and then eluted with 50 ml of saturated ammonium chloride. The first 25 ml eluate was analysed spectrophotometrically in the same manner as used for the urine samples. This eluate contained 70% of the radioactivity adsorbed onto the resin from the milk.

Virtually all the administered radioactivity was excreted within nine days: a total of 95.6% was excreted in the faeces (Table 4). In the first three days a total of 89% was excreted. A small amount (0.7%) was excreted in the urine and 0.56% (80% of that excreted in the urine) was excreted in the first two days. Only 0.0032% of the administered radioactivity was recovered from the milk.

Table 4. Excretion of administered paraquat in the faeces, urine and milk of a cow dosed orally with radiolabelled paraquat (Leahey, 1972).

Day	% of administered radioactivity		
	Faeces	Urine	Milk
1	25.9	0.31	0.0009
2	49.5	0.26	0.001
3	14.0	0.08	0.0005
4	3.3	0.03	0.0003
5	2.1	0.01	0.0002
6	0.6	0.005	0.0001
7	0.14	0.004	0.0001
8	0.03	0.006	0.00007
9	<0.01	0.002	0.00005
Total	95.6	0.7	0.0032

Paper chromatography (solvent system iso-propanol:ethanol:NH_4Cl, 3:3:2) of faecal extracts showed that paraquat was the main radioactive compound in the faeces. It accounted for 97-99% of the radioactivity recovered in day 1-4 samples (Table 5) and was the only radioactive component detected in the faeces from days 5 and 6.

Table 5. Analysis of faecal extracts by paper chromatography (Leahey, 1972).

Day	% of radioactivity in paraquat band	% radioactivity in remainder of chromatogram
1	99	1
2	98	2
3	97	3
4	97	3

Paraquat accounted for 90, 70 and 62% of the radioactivity in the urine from days 1, 3 and 5, respectively. The remaining activity was accounted for as MP and monoquat.

The traces of radioactivity in the milk (a maximum of 0.005 mg paraquat ion equivalent/l in day-2 a.m. milk and decreasing thereafter) were mainly accounted for as paraquat and MP, and as naturally incorporated radioactivity. The latter appears to be radioactive lactose in the milk (Table 6). The residue of any single compound was not above 0.002 mg/kg.

Table 6. Radioactive residues in milk (Leahey, 1972).

Day	% of total radioactivity after paper chromatography			
	Paraquat	Monoquat[1]	MP	Lactose[2]
1	15	15	3	27.5
	(0.5 µg/l)	(0.9 µg/l)	(0.1 µg/l)	
2 a.m.	17.5	17.5	18	27.5
	(0.6 µg/l)	(1 µg/l)	(0.6 µg/l)	
3 a.m.	9	25	10	28
	(0.2 µg/kg)	(0.8 µg/kg)	(0.2 µg/kg)	

[1] Since monoquat has lost one of the two radioactive carbons of diquat, the residue in µg/l will be double that for paraquat, when the two compounds are present at the same % of the total activity.

[2] These results based on milk containing 4% lactose, a normal lactose content.

Lactating goat. In a metabolism study (Hendley, 1976a), a lactating goat was dosed with [2,2′,6,6′-^{14}C]paraquat dichloride twice daily at each milking for 7 days at a total daily rate of 206.6 mg in the normal diet, approximately equivalent to 100 ppm in the diet. A second lactating goat was used as a control. Both goats were killed four hours after the final dose and, after bleeding, samples of liver, kidney, hindquarter and forequarter muscle, peritoneal and subcutaneous fat, heart, lung, brain and blood were taken. The faeces and urine were collected from two days before the first dose and throughout the study, and milk too was collected in the morning and afternoon two days before dosing until the animals were slaughtered.

At slaughter 50.3 and 2.4 of the administered radioactivity had been excreted in the faeces and urine and 33.2% was in the stomach contents.

The total radioactivity as paraquat ion equivalents in the collected milk increased over the experimental period reaching the highest level of 0.0092 mg/kg (equivalent to 0.003% of the daily dose) four hours before slaughter (Table 7). Analysis of milk by reverse-isotope dilution indicated that 75.7% of this radioactivity was attributable to paraquat. 15.8% of the radioactivity was not adsorbed onto the cation exchange resin.

Table 7. Total radioactivity in milk expressed in paraquat ion equivalents (Hendley, 1976a).

Day/time	Total radioactivity mg-paraquat ion equivalents/kg
1 evening	0
1 morning	<0.001
2 evening	0.0010
2 morning	0.0013
3 evening	0.0018
3 morning	0.0026
4 evening	0.0030
4 morning	0.0038
5 evening	0.0048
5 morning	0.0051
6 evening	0.0064
6 morning	0.0064
7 evening	0.0083
7 morning	0.0092

[1] an experimental day starts at 10 am and ends at 10 am. As a result evening milk precedes morning milk

The distribution of radioactivity in goat tissues at the time of slaughter is shown in Table 8.

Table 8. Distribution of radioactivity in the tissues of goat given [2,2′,6,6′-^{14}C]paraquat ion (Hendley, 1976a).

Sample	Radioactivity as paraquat ion equivalents mg/kg	% of radioactivity as		
		Paraquat	MP	Monoquat
Hindquarter muscle	0.12	100	-	-
Forequarter muscle	0.08	90	-	-
Subcutaneous fat	0.02	121	-	-
Peritoneal fat	0.03	49	-	6.5
Liver	0.56	48	3.2	3.4
Kidney	0.74	95	-	-

Sample	Radioactivity as paraquat ion equivalents mg/kg	% of radioactivity as		
		Paraquat	MP	Monoquat
Heart	0.16	118	-	-
Brain	0.13	106	-	-
Blood	0.06	82	-	-

NB: no reliable result could be obtained for lung, possibly due to vomiting at the time of slaughter and regurgitated diet containing radiolabelled paraquat entering the lungs.

In all tissues except liver and peritoneal fat, there appears to be no significant metabolism of paraquat. In the liver and peritoneal fat, approximately half of the radioactivity was attributable to paraquat with >5% identified as MP ion and approximately 5% as monoquat.

Laying hens. Three Warren 15-month old laying hens were dosed daily with 4.52 mg of [2,2′,6,6′-^{14}C]paraquat ion in gelatin capsules, equivalent to 30 ppm in the normal diet (Hendley *et al.*, 1976b) for ten days, and killed four hours after the final dose. Eggs and excreta were collected throughout the dosing period and samples of meat, fat, kidney and liver were taken after the hens were killed.

By the time the hens were killed 99% of the administered radioactivity had been excreted in the faeces; a minimum of 96.6% as unchanged paraquat.

The distribution of radioactivity in the hen tissues is shown in Table 9.

Table 9. Distribution of radioactivity in hens given [2,2′,6,6′-^{14}C]paraquat (Hendley *et al.*, 1976b).

Sample	Radioactivity as paraquat ion equivalents* mg/kg	% of radioactivity identified as	
		Paraquat	Monoquat
Breast muscle	0.008		
Leg muscle	0.040	98	
Kidney	0.113	86	4.1
Liver	0.072	80	3.6
Lung	0.029	86	
Heart	0.030	87	
Gizzard	0.079	98	
Subcutaneous fat	0.004		
Abdominal Fat	0.004	83**	

* Average of three birds, except for gizzard average of two birds.

** One bird.

In eggs the radioactivity in the albumen was never above 0.0014 mg/kg paraquat ion equivalents and in the yolks was <0.001 mg/kg paraquat ion equivalents on day 1, gradually increasing to 0.18 mg/kg (one bird) on day 8, the last day eggs were collected. All of the radioactivity in the yolks was identified as paraquat.

Proposed metabolic pathways in animals.

Studies demonstrated that administered paraquat is generally excreted, mostly in the faeces virtually unchanged and to a much lesser extent in urine. Excretion was particularly rapid in hens, with less than 0.05 mg/kg of paraquat found in the muscle, milk and eggs even at exaggerated dose rates. These findings indicate that only little paraquat was absorbed from the gastro-intestinal tract and no significant bioaccumulation of paraquat was expected to occur.

The metabolism of paraquat in these animals was very similar. No more than 50% of the absorbed paraquat was metabolized to monoquat and MP and to an even lesser extent to MINA.

Proposed metabolic pathways of paraquat in animals are shown in Figure 3.

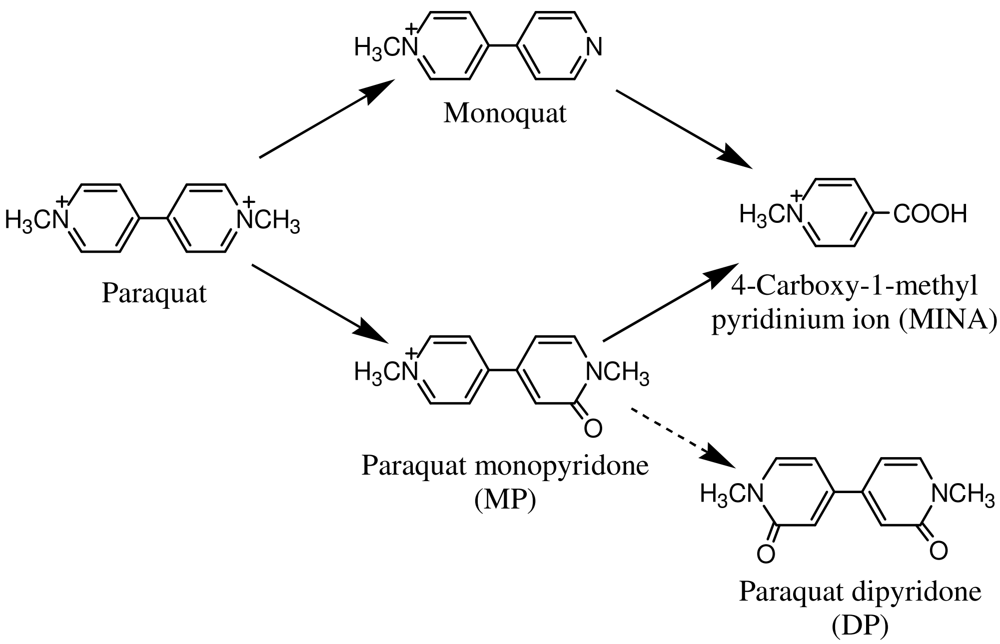


Figure 3. Proposed metabolic pathways of paraquat in animals.

Plant metabolism

The Meeting received information on the fate of paraquat after pre-emergence directed uses on lettuce and carrots and after desiccation uses on potatoes and soya beans.

Pre-emergence directed uses on lettuce and carrot. In pre-sowing, pre-planting, pre-emergence and post-emergence directed spray uses, paraquat is present in soil as residues to which crops are exposed but no direct contact of crops with paraquat will occur.

In a UK study by Grout (1994a) Lobjoits lettuce and Early Nantes carrots were sown in pots (two pots for each crop) containing sandy-loam soil and the pots sprayed evenly with [U-^{14}C-bipyridyl]paraquat immediately after sowing at rates equivalent to 14.3 kg ai/ha for lettuce and 14.7 kg ai/ha for carrots (about 13 times than the highest current single application rates). The pots were kept in a greenhouse and plants harvested 65 days (lettuce) and 96 days (carrots) after treatment. A control carrot sample was harvested 95 days after sowing.

The radioactivity in the lettuce leaves and carrots was very low (0.0034 and 0.0048 mg/kg paraquat ion equivalent). This result demonstrates that there is no significant translocation of residues of paraquat from treated soil to lettuce leaves or carrot roots.

Post-emergence uses on potato and soya beans. Paraquat can be used as a crop desiccant and harvest aid. In these uses, paraquat contacts crops directly.

In a greenhouse trial by Grout (1994b) in the UK potatoes and soya beans were grown in pots. To maximize residues the foliage was treated with [^{14}C]paraquat at rates equivalent to 8.7 or 8.8 kg ai/ha for potatoes, and 8.2 kg ai/ha soya plants. These rates were 14-15 times the highest current use for desiccation on potato plants and 16 times that on soya bean plants. Plants were harvested 4 days after treatment, except that a control soya plant which was harvested 3 days after the day of treatment. The plants were separated into foliage and tubers (potato) or pods, foliage and root (soya beans) with soil carefully removed. The potato tubers, soya beans and soya foliage were analysed for radioactivity and metabolites (TLC).

The total radioactive residue (TRR) in the potato tubers, soya beans and foliage was determined by combustion analysis. For characterization of radioactive residues, potato tubers, soya beans and soya foliage were extracted with a series of solvents (shown below) and the radioactivity of the obtained extracts was measured by liquid scintillation counting and of the remaining debris by combustion.

Potato tuber:	Acetonitrile → 2M HCl → 6M HCl (refluxing for 4 h)
Soya beans:	Hexane → Dichloromethane → Water (Extraction of the remaining debris: 2M HCl → 6M HCl (refluxing for 4 h))
Soya foliage:	Dichloromethane → 2M HCl → 6M HCl (refluxing for 4 h)

The TRR in the samples was calculated as a sum of the radioactivity in the extracts and in the debris. Extracts were analysed by TLC (solvent system I, acetonitrile:water:acetic acid, 5:4:1; and solvent system II, 2M HCl:iso-propanol, 19:1) and the results confirmed with reverse-phase HPLC (column, S5 ODS2, 25 cm x 4.6 mm i.d.; flow rate, 2.0 mgl/min; detection wavelength, 290 nm; mobile phase, water:methanol 3:1 plus 12.7 ml of orthophosphoric acid, 10.3 ml of diethylamine and 2.29 g of sodium octanesulphonate acid per l). The 2M HCl extract and of soya foliage sample was further analysed by HPLC with two different solvent systems (system III, water:methanol 19:1 plus 12.7 ml of orthophosphoric acid, 10.3 ml of diethylamine and 2.29 g of sodium octanesulphonate acid per l, followed by water:methanol 3:1 plus 12.7 ml of orthophosphoric acid, 10.3 ml of diethylamine and 2.29 g of sodium octanesulphonate acid per l; and sytem IV, deionized water followed by 7.4% trifluoroacetic acid in deionized water) for confirmation of the presence of monoquat and MINA.

The average TRRs expressed as paraquat ion equivalents in soya foliage and beans was 638 and 0.747 mg/kg and in potato tubers 0.082 mg/kg. In the potato tubers, soya beans and soya foliage, 90.2%, 88.9% and 93.8% of the TRR (sum of radioactivity in extracts and debris combined) of each sample respectively was identified as paraquat. The remainder consisted of 2 or 3 fractions, none of which exceeded 10% (Table 8). In soya foliage extracts, a small proportion of MINA (0.3% of the TRR of extracts and debris combined), a known phododegradation product of paraquat, and monoquat (0.3 % of the TRR of extracts and debris combined) were found.

Table 10. TRR in potato and soya beans (Grout, 1994b).

Sample	TRR as paraquat ion equivalents, mg/kg		
	Potato tuber	Soya beans	Soya foliage
Plant parts from treated plants (2)	0.089 0.075[1]	0.841[1] 0.652	506 769[1]
Plant parts from control plant (1)	<0.0012	<0.0034	<0.0035
Extracts + debris	0.088	0.793	844

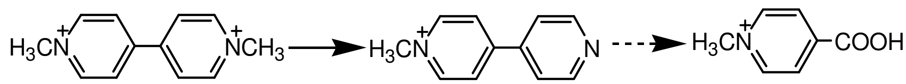
Sample	Fraction	% of TRR[2]	Residue as paraquat ion equivalent, mg/kg
Potato tuber	Identified as paraquat ion	90.2	0.079
	Aqueous fraction after reflux with 6M HCL	7.5	0.007
	Unextracted	1.0	<0.001
	TLC remainder[3]	2.4	0.002
	Loss on work-up	(-1.1)	(-0.001)
	Total	100.0	-
Soya beans	Identified as paraquat ion	88.9	0.705
	Hexane extract	0.4	0.003
	Unextracted	0.9	0.007
	TLC remainder[3]	4.4	0.035
	Loss on work-up	5.4	0.043
	Total	100.0	-
Soya foliage	Identified as paraquat ion	93.8	792
	Identified as MINA	0.3	2.5
	Identified as monoquat	0.3	2.5
	Unextracted	1.0	8.4
	TLC remainder[4]	5.1	43.1
	Loss on work-up	(-0.5)	(-4.2)
	Total	100.0	-

[1] Sample used for extraction and TLC analysis.
[2] Extracts and debris combined.
[3] Consists of background noise between regions of interest from TLC.
[4] Consists of background noise, an unknown from TLC analysis (Unknown 1, 1.2% of TRR) and some streaking between regions of interest from TLC, plus low levels of activity between regions of interest from HPLC.

Proposed metabolic pathway in plants

Pre-emergence and post-emergence directed use of paraquat does not cause crops to have direct contact with paraquat. Since paraquat is well adsorbed by soil, its uptake by the plant is insignificant even at exaggerated application rates. When paraquat was applied as a desiccant to potato and soya beans at a rate >10 times the highest recommended application rate, with a 4 day PHI, the predominant component in potato tubers, soya beans and soya foliage was paraquat. In soya foliage, monoquat and MINA were also found. Although MINA is a known photodegradation product and it was not found in soya beans or potato tuber, a possibility of biotransformation cannot be excluded because the TRR in them were too low for reliable identification. Since the fate of paraquat in soya foliage seems to involve photodegradation, its fate is considered to be common among plants.

The proposed metabolic pathways of paraquat in plants are shown in Figure 4.



Paraquat Monoquat 4-Carboxy-1-methyl pyridinium ion (MINA)

Figure 43. Proposed metabolic pathways of paraquat in plants.

Environmental fate in soil

The Meeting reviewed information on aerobic degradation and adsorption/desorption in soil as per the decision of the 2003 JMPR. Information on microbiological degradation of paraquat in soil was also reviewed in an attempt to estimate degradation pathways of paraquat in soil after its application.

When paraquat was applied to the slurries of four UK soils (10 g of loam, loamy sand, silty clay loam, and coarse sand in 200 ml of 0.01M calcium chloride in water) at two different rates that were regarded as above the adsorption capacity of the soil to give 0.01 mg/l in the equilibrium solution after a 16-hour equilibration on a reciprocal shaker, the calculated adsorption coefficients, Kd, ranged from 480 in the coarse sand to 50000 in the loam. With lower (normal) application rates Kd values were expected to be much higher but it was impossible to determine paraquat in the equilibrium solution (<0.0075 mg/l). No significant desorption was seen during the desorption step.

A field survey of 242 agricultural soils in Denmark, Germany, Greece, Italy, The Netherlands and the UK showed that paraquat is strongly adsorbed to all the soil types studied. The adsorption coefficients were calculated at rates much higher than normal application rates because the concentration in the equilibrium solution was below the limit of determination (0.01 mg/l) at normal application rates. The calculated Kd values ranged from 980 to 400000 and those adjusted for the organic carbon content in soil were 8400 – 40000000, although Kd is generally underestimated at higher application rates. Using the McCall scale (McCall *et al.,* 1980) for assessing mobility of chemicals in soil, paraquat was classified as "immobile" in all the soils studied and had no potential to be leached. The data showed that paraquat adsorption was predominantly related to clay content and the adsorption to clay was so strong that it masked any relationship between adsorption and soil organic matter content. Paraquat adsorption increased linearly as clay content increased with a high correlation coefficient of r^2=0.79 but paraquat adsorption showed no relationship to organic matter content. (Dyson *et al.,* 1994).

Aerobic degradation

[2,6-^{14}C]paraquat was applied to sandy loam soil in pots (3 cm h x 3.7 cm d) at a nominal rate of 1.05 kg/ha and incubated in darkness at 20 ± 2°C under aerobic conditions. At 0, 3, 7, 30, 61, 90 and 180 days after treatment, duplicate pots of soil was removed for extraction with methanol, followed by extraction with an aqueous solution of unlabelled paraquat and then with 6M HCL under reflux. The extracts were analysed by TLC and HPLC. Radioactivity recovered from soil extracts, extraction debris and volatile products were 92.5-107%. Less than 0.1% of the applied radioactivity was evolved as $^{14}CO_2$ over the 180 day incubation period. Paraquat accounted for >93% of the applied radiocarbon at the end of the incubation period and no degradation products were detected. This indicated a long half-life of paraquat in soil which could not be estimated. (Vickers *et al.*, 1989)

In the long-term field dissipation studies conducted on cropped plots located throughout the world, including Australia, Malaysia, The Netherlands, Thailand, the UK and the USA (Fryer *et al.*, 1975; Gowman *et al.*, 1980; Hance *et al.*, 1980; Wilkinson, 1980; Cole *et al.*, 1984; Hance *et al.*, 1984; Moore, 1989; Dyson & Chapman, 1995; Dyson *et al.*, 1995a; Dyson *et al.*, 1995b; Muller & Roy, 1997; Lane *et al.*, 2000; Lane & Ngim, 2000; Roberts *et al.*, 2002), no major effect of the location on the field dissipation rate was observed. Generally, paraquat residues declined to around 50% at the end of the studies, which was about 10 to 20 years. This implies that a DT_{50} is estimated to be in the rage of 10 to

20 years after applying single large treatments of paraquat to soil. However, a DT_{90} could not be estimated as time points after 90% degradation was not available.

Microbiological degradation in soil

Conventional laboratory studies could not provide useful information on the degradation route and rate of paraquat in soil because of its strong adsorption. Although paraquat is readily degraded by certain selected soil microorganisms when in a soil solution, its extremely strong adsorption to soil minerals and organic matter, accounting for its rapid biological deactivation, limits the rate at which degradation occurs. Alternative studies were therefore carried out to determine the route and rate of degradation of paraquat in soil.

The route of degradation has been elucidated from studies with paraquat in cultures of soil microorganisms, whilst the rate of degradation has been established from long-term field trials.

Baldwin found that the most effective organism for decomposing paraquat was a yeast, isolated from several soils and identified as *Lipomyces starkeyi*. This yeast can utilize paraquat as a sole source of nitrogen. When incubated with [1,1′-^{14}C]paraquat or [2,2′,3,3′-^{14}C]paraquat, it decomposed 95% of 20 mg/kg paraquat in the culture in 2 weeks and 82-84% of the radioactivity was released as CO_2 during 4 weeks at 24°C. No intermediate degradation products were detected in the culture medium (Baldwin *et al.*, 1966).

A large-scale incubation of *Lipomyces starkeyi* was carried out in 7 l of sucrose mineral salts medium with 100 mg/kg paraquat as the sole nitrogen source. After 4 weeks of incubation at 25 °C with continuous air agitation, the medium was acidified to pH 1 and heated to 100°C. The volume was then reduceds to 2 l and was extracted with ether. After two days crystals were formed in the ether extract, which were identified as oxalic acid after purification. When [1,1′-^{14}C]paraquat was added at the beginning of the incubation, oxalic acid formed after 12 days of incubation contained only 2% of the original radioactivity, but when [2,2′,3,3′-^{14}C]paraquat was added, the oxalic acid retained 25% of the original radioactivity. It was speculated that pyridine-ring carbons are liberated and then incorporated into the normal metabolic pathway. All the paraquat added to the medium was decomposed in 7 days and about 80% of the radioactivity was lost as $^{14}CO_2$ in 12 days (Baldwin, 1971).

[U-^{14}C-dipyridyl]paraquat was added at 10 or 100 mg/kg to incubation vessels containing either *Lipomyces starkeyi* cultures or cultures originating from two sandy loam soils taken from Frensham and Broadricks sites. This mixture was incubated at 20°C, in the absence of light and under aerobic conditions, for 20–36 days. Paraquat was extensively metabolized with the rapid production of $^{14}CO_2$. Typical mineralization to CO_2 was around 40, 50 and 55% for the *Lipomyces* culture, the Broadricks culture and the Frensham culture incubations respectively. TLC analysis of the incubation solutions showed almost identical radiolabelled metabolite profiles among the cultures. A major metabolite consisting >85% of the remaining radiochemical in the incubation solution, a minor metabolite (<5%) and a metabolite which was incorporated in the degrading microbial cultures (<10%) were characterized. The major metabolite was identified by HPLC, capillary electrophoresis and mass spectrometry as oxalic acid. No paraquat was identified in any of the incubation solutions where mineralization had taken place (Rickets, 1997).

An unidentified bacterium isolated from soil was incubated with [1,1′-14C]paraquat. The radioautography of the thin-layer chromatogram of the culture filtrate after 4 days incubation showed two new radioactive spots in addition to paraquat. These were tentatively identified as monoquat and MINA (Funderburk and Bozarth, 1967).

The degradation of MINA was studied by incubating the extract of Achromobacter D with 4-carboxy-1-methylpyridinium chloride which was labelled with ^{14}C at the *N*-methyl, carboxyl or pyridine ring (positions 2 & 3) moiety. The results showed that the extracts of Achromobacter D produced CO_2, methylamine, succinate and formate as metabolic end-products of MINA. The CO_2 was demonstrated to originate from the carboxyl group and methylamine from the *N*-methyl group by the experiments using carboxy-labelled paraquat and *N*-methyl labelled paraquat respectively. The carbon skeletons of formate and succinate were shown to arise from the C-2 and C-3-C-6 atoms of the pyridine ring respectively by the experiment using pyridine-labelled paraquat. The latter results indicated the cleavage of pyridine between C-2 and C-3 (Wright and Cain, 1972).

In order to determine the degradation rate of paraquat in soil, [U-^{14}C-dipyridyl]paraquat was incubated at 10 mg/kg with pure cultures of Lipomyces and mixed cultures derived from two soils (Frensham loamy sand and 18 Acres sandy clay loam). The aqueous soil extracts from these were used for both the mixed and pure cultures to represent typical chemical conditions in soil pore water with respect to the supply of minerals. In these culture systems, the degradation of paraquat was rapid, with DT_{50} values between 0.02 and 1.3 days following a lag phase of about 2 days. Degradation of the parent compound was also accompanied by rapid mineralization to CO_2, reaching a maximum of 71.6% 7 days after treatment. Several minor polar metabolites were found although not identified. These results confirmed that paraquat is biodegradable (Kuet *et al.*, 2001).

Photolysis on a soil surface

The photolysis of [2,2′,6,6′-^{14}C]paraquat was studied in the UK. Radiolabelled paraquat was added to the surface of a very sandy soil. Paraquat was exposed to natural sunlight for periods up to 85 weeks. Some samples were mixed at regular intervals while others were not mixed. Dark controls were stored at -12°C and analysed simultaneously with exposed samples. The proportion of radioactivity identified as paraquat declined throughout the 85 weeks in samples; and at the end of the study it represented less than 89.5% and 86.6% of the total radioactivity found in the unmixed soil and the mixed soil respectively. Paraquat accounted for 95.0% of the total activity in the dark control sample after 85 weeks. TLC analysis of the 6M HCl extracts of both mixed and unmixed soils showed monoquat ion and MP ion. After 85 weeks of experiment, monoquat ion and MP ion were 1.4% and 1.3% respectively of the total radioactivity in the unmixed soil; and 2.4% and 1.2% respectively in the mixed soil. A third, uncharacterized compound accounted for 1.8% (unmixed soil) or 2.4% (mixed soil) of the total radioactivity after 85 weeks. Photodegradation on the soil surface is not therefore considered to be a major environmental degradation process for paraquat and no reliable estimates of the half-life of paraquat could be made (Day and Hemingway, 1981).

Environmental fate in water/sediment systems

Hydrolysis

Paraquat was dissolved in sterilized aqueous buffer solutions at pH 5, 7 and 9 to make a final concentration of approximately 91 mg/l and kept at 25 or 40°C in the absence of light. After 30 days, no significant decrease in concentration of paraquat was observed, indicating that under these conditions, paraquat was stable to hydrolysis (Upton *et al.*, 1985).

Aqueous photolysis

Aqueous photolysis of paraquat was examined by maintaining ring-labelled paraquat in sterilized 0.01 M phosphate buffer solution (28 mg/l) at 25°C and exposing it to a Xenon lamp equivalent to Florida summer sunlight (latitude 25-35°N) for 36 days. Duplicate samples were removed at intervals, together with duplicate dark control samples and 0-time samples. All the samples were analysed by TLC and HPLC. After 36 days of irradiation, the irradiated solution showed that 94% to 95% of the recovered radioactivity was due to unchanged paraquat. No radioactive photodegradation products were detected in the solutions but 0.13% of the original radioactivity was recovered as $^{14}CO_2$. It was therefore concluded that paraquat is relatively stable to photolysis in solution at pH 7 (Parker and Leahey, 1988).

In other study designed to determine the possible route of degradation of paraquat, solutions of [^{14}C]methyl- and [^{14}C]pyridyl-labelled paraquat were exposed to unfiltered UV light from a medium-pressure mercury lamp. Degradation was rapid and no paraquat remained after a 3-day irradiation. Carbon dioxide, methylamine and MINA were identified; MINA was shown to be degraded to carbon dioxide and methylamine when it was further irradiated (Slade, 1965).

Degradation in water/sediment systems

Degradation was studied using [U-^{14}C-dipyridyl]paraquat and two different water/sediment systems collected in Virginia Water (sandy loam) and Old Basing (loam) in England (Long *et al.*, 1996). Both systems were set up in cylindrical polycarbonate vessels in the dark at 20±2°C. Following acclimatization of the test systems, [^{14}C]paraquat in deionized water was applied to the water surface of each vessel at a rate equivalent to 1.1 kg/ha uniformly distributed in a 30 cm depth of water. Each test system was continuously aerated from above the air-water interface by drawing CO_2-free, humidified air through the system. Duplicate incubation units were removed for analysis at intervals of 0, 0.25, 1, 2, 7, 14, 30, 54 and 100 days after test substance application. Sediment was separated from the aqueous phase and extracted by digesting it with sulfuric acid at 130-150°C.

Even immediately after treatment, paraquat was strongly adsorbed to the sediment in the both systems. The distribution of radioactivity expressed as a percentage of the applied radioactivity in the two systems after 100 days incubation iwas shown in Table 11.

Table 11. Distribution of radioactivity in sediment and water after treatment with [U-^{14}C]pyridine-labelled paraquat (Long *et al.*, 1996).

Fraction	% of the applied radioactivity*	
	Virginia Water	Old Basing
Aqueous phase	0.2	0.1
Sediment, extracted	92.9	94.9
Sediment, unextracted	4.5	4.2
Volatile products	<0.1	<0.1
Total recovery	97.5	99.2
Paraquat found in sediment extract and aqueous phase	92.1	94.3

* Average values of the duplicate units.

Most of the radioactivity recovered from the aqueous phase and sediment extract was attributed to paraquat. No degradation products were detected. DT_{50} or DT_{90} could not be estimated as no significant degradation of paraquat was observed during the experiment.

Proposed degradation pathways in soil and water

When paraquat is applied to soil, it is strongly adsorbed and only gradually degraded. Some microorganisms, such as *Lipomyces starkeyi*, isolated from soils can degrade free paraquat completely. Unfiltered UV light also degrades paraquat to CO_2 and methylamine through MINA. Degradation first involves demethylation or oxidation of one pyridine ring, which leads to bridge cleavage and then ring cleavage of the remaining ring. Cleavage of the second ring results in the formation of methylamine and CO_2 by both microbial and photolytic routes. Hydrolysis was not considered to be a significant degradation process for paraquat.

The proposed degradation pathways of paraquat in soil and water are presented in Figure 5.

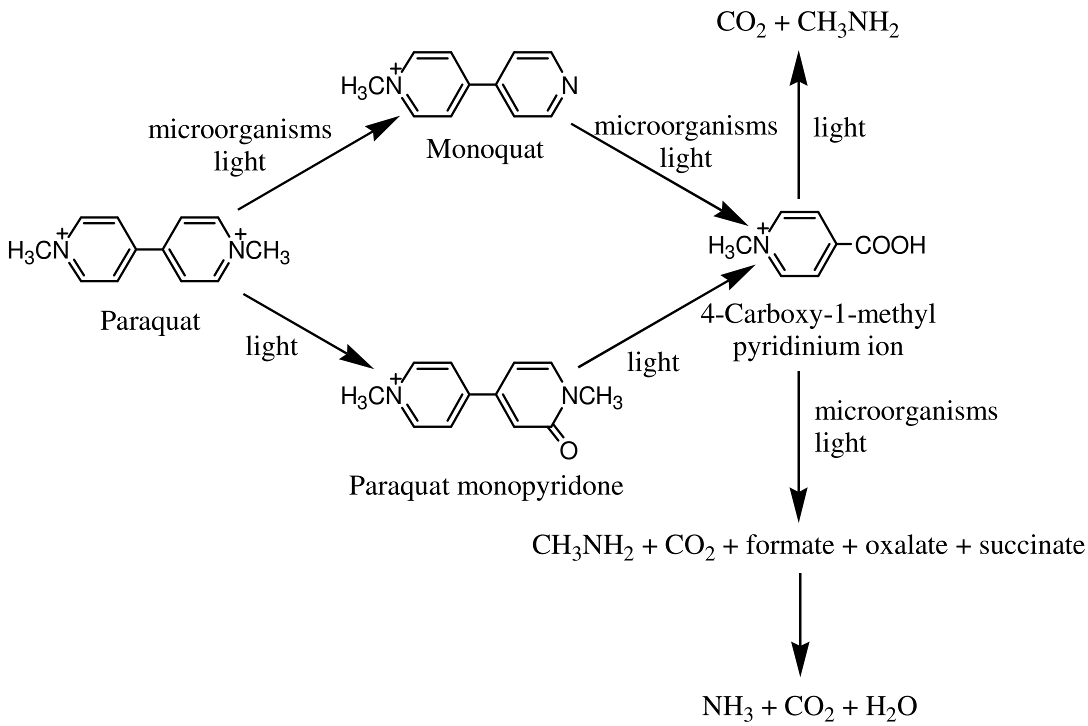


Figure 5. Proposed degradation pathways of paraquat by light and isolated microorganisms under laboratory conditions

Residues in succeeding crops

The Meeting received information on the uptake of paraquat by rotational crops.

A study was conducted in the UK to determine the nature and amount of paraquat residue uptake in rotational crops planted 0, 30, 120 and 360 days after soil treatment with paraquat (Vickers *et al.*, 1990). Seeds of wheat, lettuce and carrot were sown into individual pots containing a sandy loam soil 0, 30, 120 and 360 days after treating the soil in the pots with [2,2′,6,6′-^{14}C]paraquat at an application rate equivalent to 1.05 kg/ha. Seeds were also sown in control pots. At treatment, sowing and harvesting, cores of soil were taken to determine the magnitude and nature of the residues in the soil. The pots were maintained in a glasshouse until the plants grew to maturity. Immature wheat and mature plants were harvested and the total radioactive residues were determined.

Over the course of the study, the total radioactive residues in the soil represented an average of 99.2% of that applied on the basis of combustion and liquid scintillation counting. TLC analysis of soil extracts accounted for 72.7-99.3% of the total radioactive residues as [^{14}C]paraquat, whose identity was confirmed by HPLC, but no other radioactive compounds were detected in any soil samples.

The total radioactive residues determined in fractions of harvested crops are shown in Table 12. Since the radioactive residues in all fractions of the crops sown up to 120 days after treatment were less than 0.01 mg paraquat equivalents/kg, the crops sown 360 days after treatment were not analysed.

Table 12. Total radioactive residues in succeeding crops (Vickers *et al.*, 1990).

Planting interval, days	Total radioactive residues, mg/kg paraquat equivalents						
	Wheat				Lettuce	Carrot	
	Immature	Grain	Straw	Chaff		Tops	Root
0	<0.0006	<0.0023	0.0040	<0.0043	0.0003	0.0005	0.0009
30	<0.0003	<0.0023	0.009	<0.0044	0.0003	0.0010	0.0003
120	0.0003	<0.0018	0.0030	<0.0036	<0.0010	<0.0003	0.0005

Another study was conducted also in the UK to isolate and characterize any residues present above 0.01 mg/kg in root and leafy vegetables after application of paraquat as a pre-emergence soil treatment at an exaggerated rate (Grout, 1994a). Seeds of lettuce and carrot were sown in pots containing sandy loam soil, immediately after which the soil was treated with [^{14}C]paraquat radiolabelled uniformly in both the pyridine rings at exaggerated rates of 14.3 and 14.7 kg/ha respectively, which correspond to approximately 13 times the highest current application rate. These crops were grown to maturity: lettuce was harvested 65 days after treatment and carrots 96 days after treatment. Analysis of the lettuce leaves and carrot roots at harvest showed that radioactive residues were below 0.005 mg-paraquat equivalents/kg (0.0034 and 0.0048 mg/kg respectively). The result indicates that there is no significant uptake of paraquat into rotational crops, even when the soil is treated at exaggerated rates.

RESIDUE ANALYSIS

Analytical methods

The Meeting received information on analytical methods for paraquat in a variety of fruits, vegetables, cereals, oil seeds and animal tissues, milk and eggs.

Methods 1B, RAM 252/01 and RAM 252/02 involve extraction of paraquat by refluxing homogeinized or comminuted samples in 0.5M sulphuric acid, filtration and clean-up by cation-exchange chromatography, conversion of paraquat to its coloured free radical with sodium dithionite, and spectrophotometric measurement within 5 minutes of addition of dithionite. They differ in the washing solutions used in the cation-exchange chromatography and their flow rates, and the spectrophotometric measurements. In Method 1B, absorption of the free radical is measured against a solution prepared with saturated ammonium chloride and sodium dithionite. In Methods RAM 252/01 and RAM 252/02, absorption is measured in second derivative mode against a paraquat standard. Second derivative spectrometry consists of calculating the first, second, or higher order derivatives of a spectrum with respect to wavelength or frequency and plotting this derivative rather than the spectrum itself. Usually the derivative is obtained by the spectrophotometer or associated electronics and plotted as the spectrum is scanned. A scanning spectrophotometer in the second derivative mode gives an enhanced response and increase selectivity, allowing the quantification of paraquat.

Since paraquat has been registered for many years, many analytical methods have been used for measuring its residues in plant and animal samples. Because paraquat has proved to be very stable in plants and animals, all the submitted methods are for determining paraquat only. These methods involve acid extraction of paraquat (not liquid samples), filtration and clean-up by cation-exchange chromatography from which paraquat is eluted with saturated ammonium chloride. Five methods further involve conversion of paraquat to its coloured free radical form using 0.2% (w/v) sodium dithionite in 0.3 M NaOH and spectrophotometric measurement. Three other methods determine paraquat in the cleaned up sample solution by reverse phase ion pair HPLC with UV detection at 258 nm.

Analytical methods for determining paraquat in plant and animal commodities for which MRLs may be set are presented below. The limits of quantification, recoveries and some other details of each method are summarized in Tables 11, 12 and 13.

Samples of plant origin

Kennedy (1986) developed a spectrophotometric method (Method 1B) for the determination of paraquat in vegetables, fruits, cereals and sugar cane juice. A diced, chopped or crushed plant sample (50–250 g) was refluxed in 0.5M sulphuric acid solution (total volume 500 ml in a 2 l capacity vessel) for 5 hours (one hour for sugar cane juice). The filtered digest was percolated through a column of cation-exchange resin (Duolite C225 (SRC 14), 52-100 mesh, sodium form, in a 25 ml burette) which retains paraquat and some of the natural crop constituents. The column was washed at a flow rate of 3-4 ml/min successively with deionized water (25 ml) 2.5% ammonium chloride solution (100 ml) and deionized water (25 ml). Paraquat was eluted with saturated ammonium chloride solution at a flow rate of about 1 ml/min and the first 50 ml of eluate was collected. A flow rate above 1.0 ml/min would adversely affect the recovery of paraquat. 10 ml of the eluate was treated with 2 ml of 0.2% sodium dithionite in 0.3M NaOH, which reduces paraquat to a free radical. The reaction mixture was inverted and rolled once or twice. Within 5 minutes of addition of sodium dithionite, the absorption in the range 360-430 nm was measured with a spectrophotometer against a solution prepared with saturated ammonium chloride and sodium dithionite, and a calibration curve relating the peak height at 396 nm to the concentration of paraquat in mg/l was drawn. The limit of quantification ranged between 0.01 and 0.05 mg/kg depending on crops and weight. The mean recovery was reported to be 60-95% but the fortification level was not reported although it was stated that the added amount should be similar to the amounts expected in the treated samples. Grout validated the method by analysing soya beans from soya plant treated at 8.2 kg ai/ha and potato tubers from a potato plant treated at 8.7 kg ai/ha, previously analysed in the metabolism study (Grout, 1994b; Grout, 1996) by Method 1B. The results from the two separate extraction methods, one in the soya/potato metabolism study (see above) and the other by Method 1B, gave equivalent residue levels: 0.705 and 0.840 mg/kg for the soya beans, and 0.079 and 0.072 mg/kg for the potato tuber, respectively. These results verify the extraction efficiency of Method 1B for these samples.

Method RAM 252/01, a second derivative spectrophotometric method, for potatoes, peas, beans, rape seed oil and oil cake was described by Anderson (year not specified) and validated by Coombe (1994b) and by Reichert (1996). Samples were processed as in Method 1B until the spectrophotometric analysis, except that the cation-exchange column was washed successively by deionized water (25 ml), 2M HCl (100 ml), deionized water (25 ml), 2.5% ammonium chloride solution (100 ml) and then deionized water (25 ml) at a flow rate of 5-10 ml/min. Oil seeds must be pulverized before analysis. The concentrations of the radical are measured by second derivative spectrophotometry against paraquat standards in the range 380-430 nm. The limit of quantification ranged from 0.01 mg/kg and 0.5 mg/kg (rapeseed cake) and the mean recovery from 65 (rapeseed cake) to 87%. This method was also validated for potatoes, peas and beans by Reichert (1996); the mean recovery was 74-93%.

Method RAM 252/02 for vegetables, fruit, peas, beans, cereals, grass, oilseed or olive samples is the same as Method RAM 252/01 except that the flow rate of column washing is 3-5 ml/min. The limit of quantification ranged from 0.01 mg/kg to 0.5 mg/kg (oil seed cake), and the mean recovery from 67 to 87% (Anderson, 1995b).

In the currently used method, RAM 272/02, plant samples are processed in the same manner as Method RAM 252/02 until the eluate from the cation-exchange column is obtained. Ten ml of the eluate is cleaned up by passing through a preconditioned C18 SepPak solid phase extraction cartridge at a flow rate of approximately 1 ml/min allowing the first 5 ml to run to waste. A suitable volume of the second 5 ml is collected into an HPLC auto-sampler vial. Reverse phase ion pair HPLC is used for the determination of paraquat in the cleaned up sample solution. The HPLC conditions are as follows:

Column:	Hichrom Spherisorb S5P (phenyl)(250 mm x 4.6 mm i.d.)
Temperature:	40°C
Mobile phase:	Water:methanol (90:10) + 0.1% sodium-1-octanesulphonate + 1.0% diethylamine + 1.0% orthophosphoric acid
Flow rate:	1.5 ml/min
Injection volume:	100 to 200 µl depending on paraquat concentration in sample
Detection:	258 nm.

The paraquat concentration was calculated using single point calibration with a standard solution (0.1 µg/ml) or multiple point calibration with 0–1.0 µg/ml paraquat solutions. The limit of quantification ranged from 0.01 mg/kg to 0.05 mg/kg; and the mean recovery from 81 to 107% (Anderson, 1997). This method has been validated for crops by Anderson and Boseley in 1995 and by James in 1996, and again by Devine in 2001.

Anderson (1994a) developed Method RAM 254/01 for the determination of paraquat in liquid samples, such as milk and oil. An aliquot of oil (50 g) in a 500 ml bottle was mixed with deionized water (150 ml) and 3.5 g of cation-exchange resin conditioned by soaking it in saturated sodium chloride solution and thoroughly rinsing it with deionized water. Very viscous oil was warmed to 30°C. The bottle was rolled for 2 hours at 15-20 rpm. After carefully decanting as much oil as possible, the remaining resin was washed three times with 50 ml deionized water. Using deionized water, the resin was washed into a 25 ml burette. The column was washed at a flow rate of 3-5 ml/min with 2.5% ammonium chloride solution (200 ml) and then with deionized water (50 ml). Paraquat was eluted with saturated ammonium chloride solution at a flow rate of about 1 ml/min and the first 50 ml of eluate was collected. Paraquat was determined by second derivative spectrophotometry after converting it to the coloured free radical by mixing 10 ml of eluate with 2 ml of 0.2% (w/v) sodium dithionite in 0.3M NaOH and inverting and rolling the reaction mixture once or twice. Five minutes after adding the dithionite, the spectrum of the solution over the range of 360-430 nm was recorded using a scanning spectrophotometer in second derivative mode. As a confirmatory method, paraquat in water was analysed by reverse phase ion pair HPLC. The conditions of the HPLC were the same as those in Method RAM 272/02 except that the flow rate was 1.2 mlg/min. The limit of quantification was 0.05 mg/kg in oil in both spectrophotometric and HPLC methods. The mean recovery was 78% (n=6; RSD, 6%) at 0.05-0.50 mg/kg. An earlier method, Method 3B, determined paraquat with second derivative spectrometry only (Earl and Boseley, 1988).

Table 13. Limits of quantification of analytical methods for plant commodities.

Method & reference	Sample	LOQ, mg/kg
Method 1B Kennedy, 1986	Vegetables and fruits (250 g sample)	0.01
	Grain and seed (100 g)	0.02
	(50 g)	0.05
	Grass and straw (100 g)	0.02
	(25 g)	0.05
	Sugar cane juice (100 ml)	0.02
		0.01
Method RAM 252/01 Anderson (year not specified)	Fruits (250 g)	0.01
	Vegetables (250 g)	0.01
	Peas and beans (legumes) (100 g)	0.05
	Pulses (100 g)	0.05
	Potato (250 g)	0.01
	Cereals (100 g)	0.02
	Oil seed, cake (50 g)	0.5
	Oil seed, oil (50 g)	0.05
Method RAM 252/02 Anderson, 1995	Fruits (250 g)	0.01
	Vegetables (250 g)	0.01
	Peas and beans (legumes) (100 g)	0.05
	Pulses (100 g)	0.05
	Potato (250 g)	0.01
	Cereals (100 g)	0.02
	Oil seed, cake (50 g)	0.5
	Oil seed, oil (50 g)	0.05
	Oil seed, whole seed (25 g)	0.05
Method RAM 272/01 Anderson & Boseley, 1997	Potato (100g)	0.01
	Bean (50 g)	0.05
	Barley (50 g)	0.02
	Rapeseed	0.05

Table 14. Procedural recoveries of paraquat in various analytical methods (plant samples).

Method & reference	Matrix	Fortification mg/kg	Recovery, %		No.	RSD %
			Mean	Range		
Method 1B Kennedy, 1986	Vegetables and fruits 250 g	Not reported		70-85		
	Grain and seeds 50 g			60-75		
	100 g			60-75		
	Grass and straw 25 g			80-95		
	100 g			70-85		
	Sugar-cane juice 100 ml			80-95		
	100 ml			80-95		
Method 1B Summary of procedural recoveries from a 1990 study (reported by Anderson (year not specified))	Apple	0.01-1.0	94		20	4
	Potato	0.01-1.0	83		20	4
	Vine	0.01-1.0	76		20	10
	Strawberry	0.01-1.0	93		20	3
	Cabbage	0.01-1.0	74		20	10
Method RAM 252/01 Coombe, 1994b	Potato	0.01-0.50	87	81-92	6	4
	Pea	0.01-0.50	75	72-81	6	4
	Bean	0.05-0.50	79	74-83	10	3
	Rapeseed oil, extracted	0.05-0.50	78	74-87	6	6
	Rapeseed cake	0.10-10.0	65	63-77	6	2
Method RAM 252/01 Reichert, 1996	Potato	0.01-0.05	74	69-85	4	10
	Pea	0.05-0.10	99	94-105	4	5
	Bean	0.05-0.50	93	74-117	6	19
Method RAM 252/02 Anderson, 1995b	Potato	0.01-0.50	87	81-92	6	4
	Bean	0.05-0.50	79	74-83	10	3
	Pea	0.05-0.50	75	72-81	6	4
	Rapeseed, oil	0.05-0.50	78	74-87	6	6
	Rapeseed, cake	0.10-10.0	67	63-77	6	6
	Rapeseed, whole seed	0.05-2.0	80		10	9
	Sunflower seed, whole seed	0.05-2.0	84		10	8
Method RAM 252/02 Summary of procedural recoveries obtained since 1989 from GLP studies (reported by Anderson, 1995)	Apple	0.05-0.5	92		8	5
	Pear	0.05	92		4	1
	Cherry	0.05	97		4	1
	Peach	0.05	96		4	2
	Plum	0.05	92		2	1
	Grape	0.05-0.1	89		8	2
	Palm oil	0.05	80		6	3
	Olive oil	0.1	67		6	13
	Olive cake	0.05	77		5	14
	Potato	0.05-0.2	85		6	5
	Wheat grain	0.1	88		4	2

Method & reference	Matrix	Fortification mg/kg	Recovery, %		No.	RSD %
			Mean	Range		
	Wheat straw	0.1-0.2	78		3	6
	Rice grain	0.05-0.1	89		2	2
	Rice straw	0.05	87		2	3
	Maize cob	0.05-0.1	86		2	3
	Maize silage	0.05-0.1	80		2	0
	Cocoa bean	0.05-0.1	80		14	9
	Coffee bean	0.05-0.5	61		4	8
	Lucerne	5.0-30	99		6	4
Method RAM 272/02 Anderson & Boseley, 1995 Also reported by Anderson, 1997	Potato	0.01-0.05	87	78-94	10	7
	Barley	0.02-1.0	81	74-93	10	8
	Broad bean	0.05-0.50	95	82-93	10	10
	Rapeseed	0.05-2.0	107	88-126	10	11
Method RAM 272/02 Devine, 2001	Orange	0.01-0.10	99	90-109	10	9
	Tomato	0.01-0.10	94	82-105	10	8
	Rapeseed	0.05-0.50	71	64-78	10	9
	Wheat straw	0.05-0.50	90	77-98	10	8
Method RAM 272/02 James, 1996	Potato	0.01-0.2	92	70-102	8	15
	Rapeseed	0.05-1.0	93	87-98	10	3

Samples of animal origin

Earl and Boseley (1988) developed Method 4B, for determining paraquat in eggs and animal tissues. Tissue (25 g) is sliced, minced, and then homogenized with 50 ml of 10% trichloroacetic acid solution. Eggs should be thoroughly thawed and mixed before homogenization. After centrifugation, the solid is re-extracted with two further portions of 10% trichloroacetic acid solution. Supernatants from each centrifugation are combined. Fat in milk, skin with subcutaneous fat and fat samples should be removed by hexane extraction before cation-exchange. The combined supernatant is filtered to remove fine particles, then diluted with deionized water to 500 ml and percolated through a column of cation-exchange resin (particle size 0.15-0.30 mm, 52-100 mesh, sodium form; packed in a 25 ml burette) which retains paraquat and some of the natural tissue constituents. The column is washed at a flow rate of 3-4 ml/min successively with deionized water (25 ml), 2.5% ammonium chloride (100 ml) and deionized water (25 ml) to removed endogenous materials. Paraquat is eluted with saturated ammonium chloride solution at a flow rate of about 1 ml/min and the first 50 ml of eluate collected. A flow rate above 1.0 ml/min would adversely affect the recovery of paraquat. Paraquat is determined by reverse phase ion pair HPLC as in RAM 272/02.

The paraquat concentration was calculated using a linear calibration prepared with 0–1.0 µg/ml paraquat solutions. The limit of quantification was 0.005 mg/kg for egg and bovine and ovine tissue samples. The mean recovery ranged from 75 to 90% but fortification levels were not reported although it was stated that the added amount should be similar to the amounts expected in the treated samples.

Method RAM 254/01 (Anderson, 1994a) is also applicable to milk. An aliquot of milk (1000 ml) in a 2 l bottle is treated in the same manner as oil (see above). The limit of quantification was reported for water at 0.0001 mg/l but not for milk. No results of recovery test on milk were reported.

Methods for the determination of paraquat residues in the tissues of wildlife were developed and validated (Green, 1994). The method involves the measurement of the absorbance of a product formed using an ELISA kit. Paraquat was determined from a calibration curve. Positive detects were confirmed by HPLC with UV detection at 286 nm.

The current method, RAM 004/07, for determining paraquat in animal tissue samples and fluids, such as muscle, liver, kidney, fat, skin, milk and eggs, was developed and validated by Anderson (1994b, 1997). It is essentially similar to Method 4B. Anderson reported the limit of quantification to be 0.005 mg/kg for egg and chicken tissue samples. This method was also validated by Coombe (1994a) and Devine (2001b) (Table 15). The mean recoveries in these validation studies ranged from 77 to 105%.

Table 15. Procedural recoveries of paraquat in Method RAM 004/07 (animal samples).

Reference	Sample	Fortification mg/kg	Recovery, %		No.	RSD %
			Mean	Range		
Anderson, 1994b, 1997	Chicken muscle	0.005-0.50	89	77-96	12	7
	Chicken skin & subcutaneous fat	0.005-0.50	90	82-99	12	6
	Chicken liver	0.005-0.50	85	70-95	12	9
	Chicken fat	0.005-0.50	84	65-101	12	13
	Whole hen egg	0.005-0.50	86	72-101	12	12
	Hen egg yolk	0.005-0.50	81	60-96	12	13
	Hen egg white	0.005-0.50	92	84-96	12	4
Devine, 2001	Milk	0.005-0.05	105	101-110	10	2
	Kidney	0.005-0.05	77	71-86	10	7
Coombe, 1994a	Liver	0.01-0.05	95	89-99	4	5
	Fat	0.01-0.05	88	84-90	4	3
	Whole egg	0.01-0.05	94	86-103	4	8

The currently used methods, RAM 272/02 for plant samples and RAM 004/07 for animal samples, were found to be suitable for the quantification of paraquat in plant and animal commodities. These methods were fully validated and include confirmatory techniques. The earlier methods for the quantification of paraquat in plant and animal samples were also found to be suitable by validation, but mean recoveries were below 70% from rape seed cake, olive oil, and coffee beans.

Stability of pesticide residues in stored analytical samples

The Meeting received data on the stability of residues in ground samples of prunes, banana, cabbage, potato, carrot, tomato, maize (grain, forage, fodder and silage), wheat grain, coffee bean and birdsfoot trefoil (forage and hay) as well as meat, milk and eggs stored at a temperature below -15°C.

Plant samples

Stability was assessed using fortified samples in prunes, banana, cabbage, potato, carrot, tomato, maize (grain, fodder, forage and silage), wheat grain, and coffee bean, and incurred residues in birdsfoot trefoil forage and hay. Crop samples were frozen within 1-3 hours of harvest or purchase and kept frozen until grinding. Frozen or fresh samples were ground and the ground samples were stored in glass jars (sealed with plastic lined paper bag and screw cap), plastic lined paper bags or polyethylene containers in deep freeze conditions (<-15°C) corresponding to actual storage conditions for these crop samples for about 2 years, except that bananas and coffee beans were stored for about one year and cabbages and carrots up to 46 months. Paraquat was determined by second derivative spectrophotometric methods. Procedural recoveries were checked by analysing untreated samples fortified with known amounts of paraquat.

Table 16 shows the stability of paraquat residues in plant commodities stored over time at <-15°C. Residue data are not corrected for recovery. No decrease of residues of paraquat, whether fortified or incurred, was observed during the test periods, the longest being 46 months, except a slight decrease in birdsfoot trefoil forage which had been treated at a rate equivalent to 0.54 kg ai/ha and contained incurred residues at 57 mg/kg.

Table 16. Storage stability of paraquat[1] in fortified plant samples stored at <15°C.

Prune

Storage days	Paraquat after fortification & storage, mg/kg		Proc. recovery%	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg	Fortification, 0.20 mg/kg			
0	0.09	0.19	92	0.05	Roper, 1991c
28	0.08	0.17	77		
90	0.08	0.17	89		
181	0.08	0.17	89		
365	0.09	0.18	100		
561	0.08	0.17	97		
762	0.08	0.18	93		

Banana

Storage days	Paraquat after fortification & storage, mg/kg (average of triplicate samples)		Proc. recovery %	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg				
0	0.09		90	0.05	Coombe, 1995a
50	0.09		91		
97	0.09		93		
209	0.09		88		
363	0.09		93		

Cabbage

Storage days	Paraquat after fortification & storage, mg/kg (average of triplicate samples)		Proc. recovery %	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg				
0	0.12		109	0.05	Anderson, 1995a
32	0.11				
106	0.11				
168	0.11				
364	0.12				
538	0.11				
720	0.11				
1378	0.16				

Carrot

Storage days	Paraquat after fortification & storage, mg/kg (average of triplicate samples)		Proc. recovery %	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg				
0	0.10		104	0.05	Anderson, 1995a
31	0.10				
106	0.10				
168	0.10				
370	0.10				
535	0.10				
722	0.11				
1380	0.12				

Potato

Storage days	Paraquat after fortification & storage, mg/kg		Proc. recovery%	LOQ mg/kg	Reference
	Fortification, 0.05 mg/kg	Fortification, 0.10 mg/kg			
0	0.03	0.09	84	0.025	Roper, 1991b
29	0.04	0.09	88		
92	0.04	0.10	90		
182	0.04	0.10	92		
365	0.04	0.08	110		
585	0.04	0.09	89		
798	0.04	0.10	95		

Tomato

Storage days	Paraquat after fortification & storage, mg/kg		Proc. recovery%	LOQ mg/kg	Reference
	Fortification, 0.4 mg/kg	Fortification, 0.10 mg/kg			
0	0.04	0.08	66	0.025	Roper, 1991a
29	0.04	0.09	82		
92	0.04	0.09	92		
182	0.04	0.10	92		
365	0.05	0.10	80		

582	0.04	0.10	92		
763	0.05	0.10	95		
Maize Grain					
Storage days	Paraquat after fortification & storage, mg/kg		Proc. recovery %	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg	Fortification, 0.20 mg/kg			
0	0.09	0.17	68	0.05	Roper, 1991d
30	0.09	0.16	83		
92	0.09	0.17	93		
184	0.09	0.18	89		
366	0.09	0.17	87		
589	0.08	0.17	93		
806	0.09	0.17	83		
Maize Fodder					
Storage days	Paraquat after fortification & storage, mg/kg		Proc. recovery %	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg	Fortification, 0.20 mg/kg			
0	0.08	0.17	81	0.05	Roper, 1991e
30	0.09	0.17	83		
92	0.09	0.17	82		
184	0.08	0.17	82		
366	0.09	0.17	93		
580	0.08	0.16	77		
798	0.08	0.17	94		
Maize Forage					
Storage days	Paraquat after fortification & storage, mg/kg		Proc. recovery%	LOQ mg/kg	Reference
	Fortification, 0.05 mg/kg	Fortification, 0.10 mg/kg			
0	0.04	0.09	100	0.025	Roper, 1991g
30	0.04	0.09	96		
92	0.04	0.08	106		
184	0.04	0.09	91		
366	0.04	0.08	83		
581	0.04	0.08	90		
801	0.05	0.09	86		
Maize Silage					
Storage days	Paraquat after fortification & storage, mg/kg		Proc. recovery%	LOQ mg/kg	Reference
	Fortification, 0.05 mg/kg	Fortification, 0.10 mg/kg			
0	0.04	0.09	90	0.025	Roper, 1991f
30	0.04	0.08	86		
92	0.04	0.08	92		
184	0.04	0.09	91		
366	0.04	0.08	90		
590	0.04	0.08	93		
800	0.04	0.08	100		
Wheat grain					
Storage days	Paraquat after fortification & storage, mg/kg (average of triplicate samples)		Proc. recovery %	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg				
0	0.10		99	0.05	Anderson, 1995a
29	0.09				
102	0.10				
167	0.09				
360	0.10				
533	0.10				
730	0.11				
Coffee bean					
Storage days	Paraquat after fortification & storage, mg/kg (average of triplicate samples)		Proc. recovery %	LOQ mg/kg	Reference
	Fortification, 0.10 mg/kg				
0	0.09		99	0.05	Coombe, 1995a
50	0.09		91		
97	0.09		94		
215	0.09		90		
377	0.09		96		
Birdsfoot Trefoil Forage and Hay with Incurred Residue					

Storage weeks	Paraquat in treated crop sample after storage, mg/kg		Proc. recovery%	LOQ mg/kg	Reference
	Incurred, 57 mg/kg (Forage)	Incurred, 200 mg/kg (Hay)			
0	57	200	104	5	Roper, 1991h
12	55	178	89		
25	52	167	86		
57	48	207	91		
104	41	234	84		

[1] Residues in Birdsfoor Trefoil forageand hay were incurred

Animal samples

The storage stability of paraquat was examined in meat, milk, and eggs. Samples of chicken muscle after mincing, and eggs after thorough mixing were fortified with paraquat at 0.10 mg/kg and stored at <-18°C for up to 863 days (28 months). Milk was fortified at 0.1 mg/l and stored for 391 days. These conditions represent actual storage conditions of animal commodities subject to residue analysis. At predetermined intervals, triplicate samples were taken out for analysis. Hen muscle and egg samples were analysed by Method 4B and milk samples by a second derivative spectrophotometric method. The limit of quantification was 0.005 mg/kg.

Table 17 shows the results. Residue data are not corrected for recovery. No decrease of residues of paraquat was observed under storage for up to 28 months. These test matrices represent a diverse selection of animal tissues and demonstrate the stability of paraquat under various fortified animal sample storage conditions. However, the chicken egg and milk samples showed relatively low procedural recoveries.

Table 17. Storage stability of paraquat in animal samples fortified with paraquat and stored at <-18°C.

Storage Days	Chicken muscle fortified at 0.10 mg/kg		Chicken eggs fortified at 0.10 mg/kg		Milk fortified at 0.01 mg/l	
	Paraquat, mg/kg[1]	Proc. recovery, %	Paraquat, mg/kg[1]	Proc. recovery, %	Paraquat, mg/l[1]	Proc. recovery, %
0	0.08	83	0.08	75	0.010	80
31	0.10	83	0.07	75		
42					0.007	76
89					0.008	75
91			0.08	75		
92	0.08	83				
161	0.07	83				
178			0.07	75		
202					0.007	75
276	0.09	83				
391					0.007	73
405	0.09	83				
426			0.08	75		
560	0.09	83				
581			0.08	75		
843	0.08	83				
863			0.09	75		
-	Ref: Anderson *et al.*, 1991a		Ref: Anderson *et al.*, 1991b		Ref : Coombe, 1995b	

[1] Not adjusted for procedural recovery.

USE PATTERN

Paraquat, normally available as the dichloride or bis(methyl sulfate) salt, is registered in many countries to control weeds and permitted for use on a wide range of crops, including orchard and plantation uses, row crops and pasture, pre-plant, pre-emergence or post-emergence. The main uses of paraquat in food crops in many countries are as a non-selective herbicide. It is also registered for use as a pre-harvest desiccant (or harvest aid).

Registered uses of paraquat are very broad and are generally based on the range and size of the weeds to be controlled rather than the crop type or growth stage. As paraquat is a non-selective contact herbicide, use recommendations stress the need to shield any crops present at the time of spraying, in order to avoid phytotoxicity or crop damage. However, applications can be made to the base of bushes and trees without damage to the crop, as the bark and woody stems are resistant to paraquat.

The information available to the Meeting on uses on fruits, vegetables, cereals, tree nuts and oil seeds in Argentina, Australia, Brazil, India, Italy, Japan, Peru, the UK, the USA and Uruguay is summarized in Table 18XX. The weight of active ingredient is expressed on a paraquat cation basis. The formulation referred to in recommended uses is the soluble concentrate (SL).

Table 18. Registered uses of paraquat.

Crops	Country	Formulation Conc. g ai/l	Application				
			Use/Method	Max rate l/ha	Max rate kg ai/ha		
FRUITS							
Orchard fruits (incl. banana & vineyard)	Australia	250	Directed spray	3.2	0.8		-
Orchard fruits (incl. banana & vineyard)	Brazil	200	Directed spray	3.0	0.6	1	1
Orchard fruits (all)	Japan	36.2 (diquat, 37.5)	Directed spray	20	0.72	5	30
Orchard fruits (incl. vineyard)	Uruguay	200	Directed spray	3	0.6		-
Citrus Fruits							
Citrus fruits	Italy	200	Inter-row	5	1		
Citrus fruits	USA	360	Directed spray	3.2	1.14		-
Orange	Peru	200	Directed spray	3	0.6		2
Pome fruits							
Pome fruits	Italy	200	Inter-row	5	1		
Pome fruits	UK	120 (diquat, 80)	Directed spray	5.5	0.66	1	-
Pome fruits	USA	360	Directed spray	3.2	1.14		-
Stone fruits							
Peach	USA	360	Directed spray	3.2	1.14	3	14
Stone fruits	Italy	200	Inter-row	5	1		
Stone fruits	UK	120 (diquat, 80)	Directed spray	5.5	0.66	1	-
Stone fruits (excl. peach)	USA	360	Directed spray	3.2	1.14	3	28
Berries and other small fruits							
Cane fruits	UK	120 (diquat, 80)	Pre-plant	5.5	0.66	1	-
Cane fruits	USA	360	Postemergence directed spray	3.2	1.14		-
Grape	Italy	200	Inter-row	5	1		
Grape	Peru	200	Directed spray	3	0.6		2
Grape	USA	360	Directed spray	3.2	1.14		-

Crops	Country	Formulation Conc. g ai/l	Application				
			Use/Method	Max rate l/ha	Max rate kg ai/ha		
Strawberry	Japan	36.2 (diquat, 37.5)	Pre-plant	10	0.36	1	
Strawberry	UK	120 (diquat, 80)	Directed spray	5.5	0.66	1	-
Strawberry	USA	360	Postemergence directed spray	1.5	0.55	3	21
Other fruits							
Olive	Brazil	200	Directed spray	3.0	0.6	1	7
Olive	Italy	200	Inter-row, harvesting aid	5	1		40
Olive	USA	360	Directed spray	3.2	1.14	4	13
Banana	Peru	200	Directed spray	3	0.6		2
Banana	USA	360	Directed spray	3.2	1.14		-
Guava	USA	360	Directed spray	2.9	1.05		-
Kiwi	USA	360	Directed spray	3.2	1.14	3	14
Passion fruit	USA	360	Directed spray	2.9	1.05		-
VEGETABLES							
Vegetables (except potato, legumes & pulses)	Australia	250	Directed spray	2.4	0.6		-
Bulb vegetables							
Garlic	USA	360	Preplant/ pre-emergence	3.2	1.14	1	60†5
Onion	USA	360	Preplant/ pre-emergence	3.2	1.14	1	60†5
Onion, bulb	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Welsh onion	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Brassica vegetables							
Brassica vegetables	USA	360	Preplant pre-emergence	3.2	1.14		-
Broccoli	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Cabbage	Brazil	200	Pre-plant	3.0	0.6	1	1
Cabbage	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Cauliflower	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Chinese cabbage	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Fruiting vegetables							
Fruiting vegetables (excl. tomato and peppers)	USA	360	Preplant pre-emergence	3.2	1.14		-
Cucumber	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	14
Melon	Japan	36.2 (diquat, 37.5)	Pre-plant	10	0.36	1 (3)	
Pumpkin	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	14
Watermelon	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	1 (3)	-
Peppers	USA	360	Directed spray	1.5	0.55	3	-

Crops	Country	Formulation Conc. g ai/l	Application				
			Use/Method	Max rate l/ha	Max rate kg ai/ha		
Peppers, sweet	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	14
Tomato	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	14
Tomato	USA	360	Preplant pre-emergence	3.2	1.14		30
Tomato	USA	360	Directed spray	1.5	0.55	3	30
Tomato	Uruguay	200	Directed spray	3	0.6		
Leafy vegetables							
Collard	USA	360	Preplant pre-emergence	3.2	1.14		-
Lettuce	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Lettuce	USA	360	Preplant pre-emergence	3.2	1.14		-
Spinach	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	14
Legume vegetables and Pulses							
Beans	Brazil	200	Pre-plant	3.0	0.6	1	1
Beans (Lima, Snap)	USA	360	Preplant pre-emergence	3.2	1.14		-
Beans, dry	Argentina	200	Pre-harvest desiccant	2.0	0.4	1	-
Chickpea	Australia	250	Over-the-top spray	0.8	0.2		14
Faba bean	Australia	250	Over-the-top spray	0.8	0.2		14
Field bean	Australia	135 (diquat 115)	Pre-plant	2.4	0.32		
Field pea	Australia	250	Over-the-top spray	0.8	0.2		14
Legume and pulses	Uruguay	200	Desiccation	2	0.4	1	5
Lentil	Australia	250	Over-the-top spray	0.8	0.2		14
Lentil, dry	Argentina	200	Pre-harvest desiccant	2.0	0.4	1	-
Mung bean	Australia	135 (diquat 115)	Pre-plant	2.4	0.32		
Navy bean	Australia	135 (diquat 115)	Pre-plant	2.4	0.32		
Pea	USA	360	Preplant pre-emergence	3.2	1.14		-
Peas, dry	Argentina	200	Pre-harvest desiccant	2.0	0.4	1	-
Pigeon pea	Australia	135 (diquat 115)	Pre-plant	2.4	0.32		
Pulses (excluding soya bean)	USA	360	Harvest aid	1.5	0.55	2†3	7
Soya bean, dry	Argentina	200	Pre-harvest desiccant	2.0	0.4	1	-
Soya bean	Australia	135 (diquat, 115)	Pre-plant	3.2	0.43		
Soya bean	Brazil	200	Pre-plant	3.0	0.6	1	7
Soya bean	Brazil	200	Desiccation	2.5	0.5	1	7
Soya bean	USA	360	Preplant or pre-emergence.	3.2	1.14	†9	-
Soya bean	USA	360	Postemgence directed spray	0.39	0.14	2[†10]	-

Crops	Country	Formulation Conc. g ai/l	Application				
			Use/Method	Max rate l/ha	Max rate kg ai/ha		
Soya bean	USA	360	Harvest aid	0.78	0.28		15
Soya bean	Uruguay	200	Directed spray	3	0.6		-
Root and tuber vegetables							
Beet	Brazil	200	Pre-plant	3	0.6	1	7
Carrot	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Potato	Argentina	200	Pre-harvest desiccant	2.5	0.5	1	7
Potato	Australia	250	Over-the-top spray	1.6	0.4	1	-
Potato	Australia	135 (diquat, 115)	Over-the-top spray	3.2	0.43	1	-
Potato	Australia	250	Pre-harvest weed control	2.8	0.7	1	†1
Potato	Brazil	200	Pre-plant	3.0	0.6	1	7
Potato	Brazil	200	Desiccation	2.5	0.5	1	7
Potato	Japan	36.2 (diquat, 37.5)	Pre-germination	6	0.22	1	90
Potato	Peru	200	Harvest aid	3	0.6	1	7
Potato	UK	120 (diquat, 80)	Pre-emergence	5.5	0.66	1	-
Potato	Uruguay	200	Directed spray	3	0.6		-
Potato	Uruguay	200	Desiccation	2	0.4	1	5
Potato	USA	360	Preplant or pre-emergence broadcast	1.5	0.55		-
Potato (fresh market only)	USA	360	Broadcast (for pre-harvest vine killing and weed desiccation)	1.2	0.42	†6	3
Root and tuber vegetables (excl. potato)	USA	360	Preplant pre-emergence	3.2	1.14		-
Sugar beet	Uruguay	200	Directed spray	3	0.6		-
Sweet potato	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Stalk and stem vegetables							
Asparagus	Brazil	200	Pre-plant	3.0	0.6	1	1
Asparagus	Japan	36.2 (diquat, 37.5)	Pre-plant, inter-row	10	0.36	3	30
Asparagus	USA	360	Pre-plant or pre-emergence broadcast or banded over-row	3.2	1.14		-
Asparagus (≥ 2 y)	USA	360	Broadcast or Banded Over-Row	3.2	1.14		6
CEREALS							
Maize	Argentina	200	Pre-harvest desiccant	2.0	0.4	1	-
Maize	Australia	135 (diquat 115)	Pre-plant	2.4	0.32		
Maize	Brazil	200	Pre-plant	3.0	0.6	1	7
Maize	Brazil	200	Desiccation	2.5	0.5	1	7

Crops	Country	Formulation Conc. g ai/l	Application				
			Use/Method	Max rate l/ha	Max rate kg ai/ha		
Maize	USA	360	Preplant or Pre-emergence broadcast or banded over row	3.2	1.14		-
Maize	USA	360	Postemergence directed spray	1.5	0.55		-
Maize	Uruguay	200	Directed spray	3	0.6		-
Rice	Argentina	200	Pre-harvest desiccant	2.0	0.4	1	5
Rice	Australia	250	Pre-sowing	1.6	0.4		
Rice	Australia	135 (diquat, 115)	Pre-crop emergence	3.2	0.43		
Rice	Brazil	200	Pre-plant	3.0	0.6	1	7
Rice	Brazil	200	Desiccation	2.5	0.5	1	7
Rice	Japan	36.2 (diquat, 37.5)	Pre-plant	10	0.36	1	-
Rice	Peru	200	Directed spray	3	0.6		2
Rice	USA	360	Preplant or pre-emergence broadcast	3.2	1.14		-
Rice	Uruguay	200	Desiccation	1	0.2	1	7
Sorghum	Argentina	200	Pre-harvest desiccant	2.0	0.4	1	5
Sorghum	Australia	135 (diquat, 115)	Pre-plant	3.2	0.43		
Sorghum	Brazil	200	Pre-plant, inter-row	3.0	0.6	1	7
Sorghum	Brazil	200	Desiccation	2.5	0.5	1	7
Sorghum	USA	360	Preplant or pre-emergence broadcast	3.2	1.14		†7
Sorghum	USA	360	Postemergence directed spray	1.5	0.55	2†8	†7
Sorghum	Uruguay	200	Directed spray	3	0.6		-
Sorghum	Uruguay	200	Desiccation	1	0.2	1	7
TREE NUTS							
Hazelnut	Italy	200	Inter-row, harvesting aid	5	1		40
Pistachio	USA	360	Directed spray	3.2	1.14		7[†11]
Tree nuts (excl. pistachio)	USA	360	Directed spray	3.2	1.14		-
Walnut	Italy	200	Inter-row	5	1		
OILSEEDS							
Cotton	Argentina	200	Defoliant	1.0	0.2	1	-
Cotton	Australia	135 (diquat, 115)	Pre-harvest desiccant	1.6	0.22	1	7
Cotton	Brazil	200	Pre-plant, inter-row	3.0	0.6	1	7
Cotton	Brazil	200	Deciccation	2.5	0.5	1	7
Cotton	Uruguay	200	Directed spray	3	0.6		-
Cotton	USA	360	Preplant or Pre-emergence	3.2	1.14		-
Cotton	USA	360	Harvest aid	1.5	0.55	†2	3
Sunflower	Argentina	200	Pre-harvest desiccant	2.5	0.5	1	-
Sunflower	Australia	135 (diquat, 115)	Pre-plant	3.2	0.43		

Crops	Country	Formulation Conc. g ai/l	Application				
			Use/Method	Max rate l/ha	Max rate kg ai/ha		
Sunflower	Uruguay	200	Desiccation	1	0.2	1	7
Sunflower	USA	360	Preplant or pre-emergence broadcast or banded over row	3.2	1.14		-
Sunflower	USA	360	Desiccation	1.5	0.55		7
DRIED HERBS							
Hop	Australia	250	Directed spray	1.6	0.4		-
Hop	UK	120 (diquat, 80)	Directed spray for weed control and stripping	5.5	0.66	1	-
Hop	USA†4	360	Directed spray and/or suckering and stripping	1.5	0.55	3	14
TEA							
Tea	Brazil	200	Directed spray	3.0	0.6	1	7
Tea	India	200	pre-emergence or post-emergence directed between rows	4.25	0.75	1	-
Tea	Japan	36.2 (diquat, 37.5)	Inter-row	10	0.36	3	7
Tea	Peru	200	Directed spray	3	0.6		2

GAP of Japan: PHI applicable for inter-row application only; "1 (3)" indicates that the formulation containing diquat can be applied only once while paraquat can be applied up to three times.

†1, Applied 3 to 7 days before digging crop after all tops have died down.
†2, Repeat application if necessary. Do not exceed a total of 1.5 l/ha as a harvest aid.
†3, Not registered for use on dry beans in California. Not to make more than 2 applications or exceed a total of 1.5 l/ha.
†4, Indiana, Oregon and Washington states only.
†5, Preharvest interval for California only, 200 days
†6, Do not exceed 2.3 l/ha per season. Split applications must be applied a minimum of five days apart. Use only in the states of: Colorado, Delaware, Idaho, Illinois, Indiana, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, Nevada, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, South Dakota, Utah, Washington, Wisconsin and Wyoming.
†7, PHI: 48 days for grain and 20 days for forage.
†8, Do not exceed 2 postemergence-directed applications or exceed a total of 2.5 l per season.
†9, Do not exceed 1.9 l per season.
†10, If needed make a second and final application 7-14 days later.
†11, Do not exceed 2 applications after shells split.

Table 19. Summary of uses of paraquat in food crops.

Use	Crops	Rate, kg ai/ha	No	Pre-harvest/Pre-sowing interval (days)
Pre-planting or pre-sowing of crops	None present at time of treatment	0.3-0.8	1	4 hours-1 day
Post-sowing but pre-emergence	None present at time of treatment	0.3-1.1	1	1-3 days before emergence
Early post-emergence	Potatoes	0.4-1.1	1-2	Up to 10% emergence for early and seed potatoes, up to 40% emergence for main crop potatoes
Inter-row weeding	Soft fruits, berries, nuts, cane	0.4-1.1	1-2	Apply to soil at base of trees or

Use	Crops	Rate, kg ai/ha	No	Pre-harvest/Pre-sowing interval (days)
(post-emergence directed)	fruits; citrus, pome and stone fruits; grapes, maize; plantations			bushes or use directed or guarded sprays
Post harvest treatment of soil	Strawberries, asparagus, hops, grass for seed	0.4-0.8	1-2	N/A
Desiccation or Harvest aid	Maize, cotton, potato, legumes & pulses, soybean, sunflower, sorghum	0.2-0.6	1-2	3-15 days PHI

RESIDUES RESULTING FROM SUPERVISED TRIALS ON CROPS

Laboratory reports of trials included method validation with recovery experiments conducted at levels similar to those occurring in samples from the supervised trials. Dates of analyses or duration of sample storage were also provided. Most reports provided information on the lot size, weather, methods of application, weights and volumes, application dates, residue sample sizes and sampling dates. However, some very old trials were reported only in summary formats without sufficient details.

Residue data are recorded as mg paraquat cation/kg and not corrected for recovery. The formulation used in supervised trials was the soluble concentrate (SL). In most cases paraquat dichloride was used but in some cases the bis(methyl sulfate) was used.

Residue values from the trials conducted according to GAP were used for the estimation of maximum residue levels. These results are double-underlined. However, when all trials resulted in nil residues, results from trials according to GAP were not so marked.

Table number	**Crop**
20	Citrus fruits (lemon, lime and orange)
21	Pome fruits (apple and pear)
22	Stone fruits (cherry, peach and plum)
23	Berries and other small fruits (grape; blueberry; currant, black and red; gooseberry; raspberry; longanberry, strawberry)
24	Olive
25	Assorted tropical and sub-tropical fruits – inedible peel (banana, guava, kiwifruit and passion fruit)
26	Bulb vegetables (onion)
27	Brassica vegetables (broccoli, Brussels sprouts, cabbage, cauliflower and Chinese cabbage)
28	Fruiting vegetables, Other than cucurbits (peppers and tomato)
29	Fruiting vegetables, Cucurbits (cucumber, melon, summer squash)
30	Leafy vegetables (kale, lettuce and turnip tops)
31	Legume vegetables and pulses (beans, broad bean, chick peas, field beans, field peas, peas and soya beans)
32	Root and tuber vegetables (beet, carrot, parsnip, scorzonera, sugar beet, swede and turnips, potato)
33	Stalk and stem vegetables (artichoke, asparagus and celery)
34	Maize
35	Sorghum
36	Rice
37	Tree nuts (almond, hazelnut, macadamia nut and pecan)
38	Cotton seed
39	Sunflower seed
40	Hops
41	Tea

42	Soya forage and hay or fodder
43	Sugar beet tops
44	Maize forage and fodder
45	Sorghum forage (green) and straw and fodder, dry
46	Rice straw and fodder, dry
47	Almond hulls
48	Cotton fodder

<u>Citrus fruits</u>

Paraquat is used to control weeds around the base of citrus fruit trees.

Numerous supervised residue trials over several seasons and locations have been carried out on navel oranges in California, the USA, and on Valencia oranges, Hamlin oranges, limes, lemons and grapefruit in Florida, the USA. Paraquat was applied at rates of 1.12 to 2.8 kg ai/ha from one to 17 times (total applications in three years) and, in one series of trials, at an excessive rate (33.6 kg ai/ha), to control weeds by broadcast application under the fruit trees. Fruits were harvested, in some cases immature, from 0 to 177 days after the last application. In the case of the very high application rate, immature fruit were harvested 35 and 346 days and mature fruit 152 days after application.

Two residue trials in Italy and numerous trials in the USA have been conducted in which paraquat was applied as an inter-row treatment in orange orchards at a rate of 0.8 kg ai/ha.

Table 20. Paraquat residues in citrus fruits from supervised trials in Italy and the USA.

Country, year (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes and references	
ORANGE								
CA, USA, 1962 (Navel)	2.8	0.12		2	0B*	<0.01		Chevron 2001 T-326
					0	<0.01	Juice (procedural recovery, 45%)	Sprayed under tree up to drip line
					7	<0.01		
					15	<0.01		
					28	<0.01		
					0	<0.01	Pulp (procedural recovery, 67%)	
					7	<0.01		
					15	<0.01		
					28	<0.01		
CA, USA 1963-66 (Navel) Treatments 1963: 2 1964: 5 1965: 6					0B*	<0.01		T-630
1966	2.24	0.24	935	4 (17)	32	0.02, 0.01	Terminals	Terminals sprayed
					62	<0.01, <0.01	Immature fruit	
						0.01, 0.01	Terminals	
					92	<0.01, <0.01	Terminals	
					132	≤0.01, <0.01	Mature fruit	
1965	1.12	0.12	935	3 (10)	30	<0.01, <0.01	Immature fruit	Terminals sprayed
						<0.01, <0.01	Terminal	
				5 (12)	40	≤0.01, <0.01	Mature fruit	
						<0.01, <0.01	Terminals	
	2.24	0.24	935	3 (10)	30	<0.01, <0.01	Immature fruit	
						0.01, <0.01	Terminals	
				5 (12)	40	≤0.01, <0.01	Mature fruit	
						<0.01, <0.01	Terminals	
1964	1.12	0.12	935	2 (2)	46	≤0.01, <0.01	Fruit	Directed spray to the ground around the base of trees
						<0.01, <0.01	Terminals	
				5	13	≤0.01, <0.01	Fruit	
						<0.01, <0.01	Terminals	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
	2.24	0.24	935	2	46	<0.01, <0.01	Fruit	
				(4)		<0.01, <0.01	Terminals	
				5	13	<0.01, <0.01	Fruit	
				(7)		<0.01, <0.01	Terminals	
1963	2.24	0.17	935	2	38	<0.01	Fruit	
CA, USA					0B*	<0.01		T-648
1965	33.6	3.6		1	35	<0.01, <0.01	Immature fruit	Directed spray
(Navel)						<0.01, <0.01	Terminals	to ground
					152	<0.01, <0.01	Mature fruit	under trees and
						<0.01, <0.01	Terminals	rototiilled in
					346	<0.01, <0.01	Immature fruit	the top of soil
						<0.01, <0.01	Terminals	
CA, USA 1965 (Navel)	1.12	0.12	935	1	0B* 3	<0.01 0.08, 0.06	Spray hit lower branches and fruit; fruit dropped on sprayed weeds on day 0, 1, 2, and 3; composite samples taken on day 3	T-758
CA, USA					0B*	<0.01		T-936
1965	1.12	0.12	935	5	6	<0.01, <0.01	Fruit	
(Navel)				(10)				
	2.24	0.24	935	5	6	<0.01, <0.01	Fruit	
				(12)				
FL, USA 1964-66 Orange (Valencia) Treatments 1964: 4 1965: 4					0B*	<0.01		T-631 Broadcast spray around each tree on an area of 100 sq ft.
1966	2.24	0.054	2060	1	31	<0.01, <0.01	Mature fruit	
				(9)		<0.01, <0.01	Juice	
						<0.01, <0.01	Terminals	
					61	<0.01, <0.01	Terminals	
1965	1.12	0.054	2060	1	59	<0.01, <0.01	Immature fruit	
				(5)		0.03, 0.03	Terminals	
				4	177	<0.01, <0.01	Mature fruit	
							Juice	
	2.24	0.11	2060	1	59	<0.01, <0.01	Fruit	
				(5)			Terminals	
				4	63	<0.01, <0.01	Terminals	
				(8)				
				4	177	0.06, 0.03	Mature fruit	
						<0.01, <0.01	Juice	
						<0.01, <0.01		
						<0.01, <0.01		
1964	1.12	0.054	2060	1	58	<0.01, <0.01	Immature fruit	
						0.04, 0.03	Terminals	
	2.24	0.11	2060			<0.01, <0.01	Immature fruit	
						0.02, 0.02	Terminals	
FL, USA, 1965	2.44		2040	1	0B*	<0.01		T-903
(Hamlin)					3	0.01, <0.01	Mature fruit	
						<0.01, <0.01	Juice	
FL, USA 1972 (unknown)	1.12			1	0B* 14	<0.05 <0.05	Fruit	Ross *et al.* 1978 AGA No2561
Italy, 1993 (Biondo)	0.80	0.080	1000	1	0B* 7	<0.02 <0.02	Fruit	Dick *et al.* 1995b IT10-93-H348

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
(Navelina)	0.80	0.080	1000	1	0B* 7	<0.02 <u>≤0.02</u>	Fruit	IT10-93-H349
GRAPEFRUIT								
USA, 1970 Grapefruit (unknown)	1.12	-		1	0B* 3 35	<0.05 <u>≤0.05</u> <0.05	Fruit	Anon 1970 Summary only
LEMON								
USA, 1970 (unknown)	1.12			1	0B* 3	<0.05 <u>≤0.05</u>	Fruit	Anon 1970 Summary only
CA, USA 1972 (unknown)	1.12			1	0B* 49	<0.05 <u>≤0.05</u>	Fruit	Ross *et al.* 1978
LIME								
FL, USA 1966 (Tahiti)	1.12		1870	5	0B* 1	<0.01 <u>≤0.01</u>, <0.01	Fruit	Chevron 2001 T-1110

*B: control
Immature fruit 1-5 cm in diameter (size varies from trial to trial)
Numbers in parentheses are the cumulative application number since 1963 in T-630 and T- 936 (higher dose) or since 1964 in T-631 and T-936 (lower dose).

<u>Pome fruits</u>

Paraquat is used to control weeds around the base of pome fruit trees.

Trials were carried out in Canada, Germany and the UK using rates from 1.12 to 4.5 kg ai/ha and even a highly exaggerated rate of 12.3 kg ai/ha. In the last case, paraquat was applied directly to the bark of the tree to simulate worst-case conditions. In some cases, two applications were made, either in the same or subsequent years. Apples were harvested from 0 to 780 days, and pears 0-77 after the last application.

Table 21. Paraquat residues in pome fruits from supervised trials in Canada, Germany and the UK.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
APPLE								
Ontario, Canada, 1962 (Delicious)	2.24		935	1	0B* 14	<0.01 <0.01		Calderbank & Yuen 1963 Cambellville
(Spy)	1.68 1.12		935	1	0B* 14	<0.01 <0.01		Cambellville
(Delicious)	2.24		935	1	0B* 14	<0.01 <0.01		Inglewood
(Spy)	2.24		935	1	0B* 14	<0.01 <0.01		Inglewood
(McIntosh)	2.24 2.80		935	1 1	0B* 6 11	<0.01 <0.01 x 4 <0.01		Guelph
NS, Canada, 1962 (McIntosh)	2.24		374	1	0B* 12	<0.01 <0.01, <0.01		Kentville
BC, Canada, 1962 (Seedlings)	2.24		1871	1	0B* 13	<0.01 <0.01		Summerland

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Fernhurst, UK					0B*	<0.01	Sprayed to:	
1962	1.12		935	1	12	<0.01	Base of trees	
(Laxton Superb)	11.2			1	12	<0.01	Base of trees	
				1	12	<0.01	Bark of trees	
	12.32			1	12	<0.01	Bark of trees	
Ontario, Canada,	2.24		5610	1	0B*	<0.01		Kemptville
1961					16	<0.01		
(McIntosh)								
Ontario, Canada,					0B*	<0.01		Calderbank &
1963	2.24		935	1	85	<0.01, <0.01		McKenna 1964
(McIntosh)	4.48			1	85	<0.01, <0.01		Carlisle
	2.24			2	5	<0.01, <0.01		
	4.48			2	5	<0.01, <0.01		
(Winesap)	1.12		234	1	131	<0.01		Guelph
(McIntosh)					0B*	<0.01		Guelph
	1.12		234	1	131	<0.01		
(Delicious)					0B*	<0.01		
	2.24		935	1	5	<0.01		
	4.48					<0.01		
	2.24			1	27	<0.01		
	4.48					<0.01		
	2.24			2	27	<0.01		
	4.48					<0.01		
	2.24			1	122	<0.01		
	4.48					<0.01		
(McIntosh)					0B*	<0.01		Carlisle
	2.24		935	1	20	<0.01		
	4.48				20	<0.01		
	2.24			2	20	<0.01		
	4.48				20	<0.01		
Fernhurst, UK					0B*	<0.01		Second year
1963	0.56		702	2	780	<0.01		treatment
(Laxton Superb)								
Germany					0B*	<0.01		Earl &
1990	1.0		1000	1	0	<0.01	Fruit from tree	Anderson
(Golden					14	<0.01	Fruit from tree	1992a
delicious)						0.19	Fruit on ground	Rs9023B3
(Gloster)					0B*	<0.01		Rs9023B4
	1.0		1000	1	0	<0.01	Fruit from tree	
					14	<0.01	Fruit from tree	
						0.05	Fruit on ground	
(Idared)					0B*	<0.01		Rs9023E1
	1.0		1000	1	0	<0.01	Fruit from tree	
					14	<0.01	Fruit from tree	
						0.03	Fruit on ground	
(Cox orange)					0B*	<0.01		Rs9023G1
	1.0		1000	1	0	<0.01	Fruit from tree	
					14	<0.01	Fruit from tree	
						0.02	Fruit on ground	
PEAR								
Ontario, Canada,					0B*	<0.01		Calderbank &
1963	2.24		935	1	9	<0.01		McKenna 1964
(Clapp)	4.48					<0.01		Winona
	2.24			1	17	<0.01		
	4.48					<0.01		
	2.24			2	17	<0.01		
	4.48					<0.01		
	2.24			1	77	<0.01		
	4.48					<0.01		

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Germany 1990 (Williams Christ)	1.0		1000	1	0B* 0 14	<0.01 <0.01 <0.01 0.06	 Fruit from tree Fruit from tree Fruit on ground	Earl & Anderson 1992a Rs9023E2
(Vereindechant)	1.0		1000	1	0B* 0 14	<0.01 <0.01 <0.01 0.06	 Fruit from tree Fruit from tree Fruit on ground	Rs9023G2

*B: control

Stone fruits

Paraquat is used to control weeds around the base of stone fruit trees.

Residue trials have been carried out on peaches, cherries and plums in Canada, Germany, the UK and the USA. Application rates ranged from 1.0 to 4.5 kg ai/ha applied to the base of the fruit trees up to three times in a season and the fruit were harvested up to 103 days later.

In two special trials on plums in the UK, paraquat was applied directly to the suckers at rates from 0.22 to 1.34 kg ai/ha without leaving detectable residues in the fruits harvested 21 or 55 days later. In the trials in Germany, samples of fruit were placed onto the sprayed herbage on the ground and collected for analysis about one week later.

Table 22. Paraquat residues in stone fruits from supervised trials in Canada, Germany, the UK and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
PEACH								
Ontario, Canada, 1963 (Vedette)	 2.24 4.48 2.24 4.48 2.24 4.48		 935	 1 1 2 2 1 1	0B* 14 14 14 14 87 87	<0.01 <0.01 <0.01 <0.01 <0.01 <0.01 <0.01		Calderbank & McKenna 1964 Hamilton
(Veteran)	 1.12		 749	 2	0B* 44	<0.01 <0.01		
(Elberta)	 1.12		 749	 2	0B* 59	<0.01 <0.01		
Germany 1990 (Red Haven)	1.00		1000	 1	0B* 11	<0.01 <0.01 0.04	 Fruit from tree Fruit on ground	Earl & Anderson 1992a Rs9023E3
(Red Haven)	1.00		1000	 1	0B* 13	<0.01 <0.01 0.02	 Fruit from tree Fruit on ground	Rs9023E4
PLUM								
Canada, 1963 (Sapa & Dura)	 1.12		 234	 2	0B* 72	<0.01 <0.01		Calderbank & McKenna 1964 Guelph

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Fernhurst, UK 1963 (Coe's golden drop)					0B*	<0.01	All applied direct to suckers	Calderbank & McKenna 1964
	0.22		833	1	21	<0.01		
					55	<0.01		
	0.45				21	<0.01		
					55	<0.01		
	0.90				21	<0.01		
					55	<0.01		
	1.12				21	<0.01		
					55	<0.01		
	1.34				21	<0.01		
					55	<0.01		
NY, USA 1977 (unknown)	1.12			1	103	<0.05		Ross *et al.* 1978 AGA No5038
MI, USA, 1977 (unknown)	1.12			1	94	<0.05		AGA No5018
CA, USA, 1987 (French)					0B*	<0.01	Fresh plum	Roper 1989a 45CA-87-523
						<0.05	Dried prune	
	4.48	1.93		3	28	<0.01	Fresh plum	
						<0.05	Dried prune	
(French)					0B*	<0.01	Fresh plums	45CA-87-599
						<0.05	Dried Prunes	
	4.48	1.93		3	28	<0.01	Fresh plum	
						<0.05	Dried prune	
Germany, 1990 (unknown)					0B*	<0.01		Earl & Anderson 1992a Rs9023B2
	1.00		1000	1	14	<0.01	Fruit from tree	
						<0.01	Fruit on ground	
APRICOT								
BC, Canada, 1964 (unknown)					0B*	<0.01		McKenna 1966
	2.24		935	1	58	<0.01		
CHERRY								
Canada, 1963 (Montmorency)					0B*	<0.01		Calderbank & McKenna 1964
	2.24		935	1	9	<0.01		
	4.48					<0.01		
	2.24			2	9	<0.01		
	4.48					<0.01		
	2.24			1	42	<0.01		
	4.48					<0.01		
Germany 1990 (Bocca)					0B*	<0.01		Earl & Anderson 1992a Rs9023B1
	1.0		1000	1	14	<0.01	Fruit from tree	
						0.07	Fruit on ground	
(Hedelfinger)					0B*	<0.01		RS9023G4
	1.0		1000	1	12	<0.01	Fruit from tree	
						0.07	Fruit on ground	
WA, USA, 1977 Sour cherry (unknown)	1.12			1	63	<0.05		Ross *et al.* 1978 AGA No4745
MI, USA, 1977 Sour cherry (unknown)	1.12			1	25	<0.05		AGA No4685

*B: control

Berries and other small fruits

Paraquat is used to control grass and broad-leaved weeds round grape vines where the chemical is applied between the rows of established vines, usually once or twice during the growing season.

Residue trials have been conducted on grapes in Canada, Japan, Switzerland and the USA at rates between 0.3 and 4.5 kg ai/ha applied once or twice in a season. Grapes were harvested at maturity, from 0 to 196 days after the last application.

In six trials in Germany paraquat was applied between the rows of established vines at a rate of 1.0 kg ai/ha. Grapes were sampled between 10 and 14 days after application. In these trials, bunches of grapes were also placed on the sprayed herbage a few days after application and collected for analysis about 7 days later.

Paraquat is recommended for use on strawberries either as a guarded spray for inter-row weeding or as a post-harvest treatment for the control of suckers. The maximum use rate is 1.1 kg ai/ha applied up to twice in a season. Paraquat was applied to strawberry plants in France, Germany, Ireland and the UK at rates of 0.84 to 1.32 kg ai/ha applied once or twice.

Paraquat is recommended as an inter-row directed spray for cane and bush fruits. Residue trials were conducted in Canada on red and black currants, raspberries, loganberries, blueberries and gooseberries and fruits were harvested 10 to 226 days after application at rates from 0.56 to 2.2 kg ai/ha.

Table 23. Paraquat residues in berries and other small fruits from supervised trials in Canada, France, Germany, Ireland, Japan, Switzerland, the UK and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
GRAPE								
Canada, 1961 (Siebel 6339)	1.1		1300	2	67	≤0.02	Post-emergence inter-row application Treated with bis(methyl sulfate) salt	Edwards 1974
(Siebel 13053)	1.1		1300	2	67	≤0.02		
(Siebel 9249)	1.1		1300	2	67	≤0.02		
(Siebel 10878)	2.2		560	1	84 119	≤0.01 <0.01		
Canada, 1962 (Siebel 6339)	1.1 2.2		270	1	101 102	≤0.01 ≤0.01	Post-emergence inter-row application	Edwards 1974
(Siebel 29186)	1.1		270	1	101	≤0.01		
(President)	2.2		NA	1	80	≤0.01		
Canada, 1963 (Siebel 29186)	0.7 1.9		1500	1 1	122	≤0.01 ≤0.01	Post-emergence directed	Edwards 1974
(Siebel 6339)	1.0 1.9		1500	1 1	122	≤0.01 ≤0.01		
(Concord)	2.2		1130	1	6	≤0.01		
					19	<0.01		
					122	<0.01		
				2	19	≤0.01		
	4.4			1	6	≤0.01		
					19	<0.01		
					122	<0.01		
				2	19	≤0.01		
Switzerland, 1971 (unknown)	0.3		1000	1	85	<0.01		Edwards 1974
					133	<0.01		
	0.4				196	<0.01		
Japan, 1973 (Golden Queen)	0.72		NA	5	7	≤0.01, <0.01		Edwards 1974
(Muscat Bailey A)	0.72		NA	5	1	≤0.01, <0.01		

Country, year (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes and references	
Germany, 1990 (Riesling)	 1.0		 1000	1	0B* 0 10	<0.01 <0.01 <0.01 0.13	 From vine From vine From ground	Earl & Anderson 1992b Rs9022E1
(Scheurebe)	 1.0		 1060	1	0B* 0 14	<0.01 <0.01 <0.01 0.09	 From vine From vine From ground	Rs9022E2
(Portogieser)	 1.0		 1000	1	0B* 0 14	<0.01 <0.01 <0.01 0.10	 From vine From vine From ground	Rs9022E3
(Weissbur gunder)	 1.0		 1000	1	0B* 0 14	<0.01 <0.01 <0.01 0.17	 From vine From vine From ground	Rs9022E4
(Bacchus)	 1.0		 1000	1	0B* 0 14	<0.01 <0.01 <0.01 0.04	 From vine From vine From ground	Rs9022E5
(Morio Muskat)	 1.0		 1000	1	0B* 0 14	<0.01 <0.01 0.07	 From vine From ground	Rs9022E6
NY, USA, 1977 (unknown)	1.12			1	0B* 135 149	<0.05 <0.05 <0.05		Ross *et al.* 1978 AGA No4953 AGA No5039
CA, USA, 1997 (Thompson Seedless)	5.6		279	1	0B* 0 0 21	<0.01 <0.05 <0.01 <0.01 <0.05	Fresh grape, juice Dried grape Fresh grape Juice Dried grape	Spillner *et al.* 1998 Broadcast 02-CA-97-601
CANE FRUITS								
Ontario, Canada, 1963 Blackcurrant (Saunders Topsy)	2.24		749-935	1	0B* 35	<0.01 <0.01	Post-emergence directed	Calderbank & McKenna 1964
Redcurrant (Cherry Perfection)	2.24		749-935	1	0B* 35	<0.01 <0.01		
Ontario, Canada, 1964 Blackcurrant (Unknown)	2.24		935	1	0B* 42 71	<0.01 <0.01 <0.01	Post-emergence directed	McKenna 1966 Guelph
Ontario, Canada, 1964 Redcurrants (Cherry reflection)	2.24		935	1	0B* 71	<0.01 <0.01	Post-emergence directed	McKenna 1966 Guelph
BC, Canada, 1963 Blueberries (Dixie)	 0.84 1.40		 899 899	1	0B* 80	<0.01 <0.01 <0.01	Post-emergence directed	Calderbank & McKenna 1964
BC, Canada, 1963 Blueberries (Dixie)	0.84 1.40		899 899	1	85	<0.01 <0.01		
BC, Canada, 1964 Blueberries (Dixie)	 0.56 1.12 1.68 2.24		 748	1	0B* 65	<0.01 <0.01 <0.01 <0.01 <0.01	Post-emergence directed	McKenna 1966 Pitt Meadows

Country, year (variety)	Application kg ai/ha	Application kg ai/hl	Application water, l/ha	Application no.	PHI days	Paraquat mg/kg	Notes and references	
BC, Canada, 1964 Blueberries (Dixie)	 0.56 1.12 1.68 2.24		 748	 1	0B* 65	<0.01 <0.01 <0.01 <0.01 <0.01	Post-emergence directed	McKenna 1966 Saanich
BC, Canada, 1963 Loganberries (unknown)	 0.56 1.12 2.24		 438 438 438	 1 1 1	0B* 111 111 111	<0.01 <0.01 <0.01 <0.01, <0.01	Post-emergence directed	Calderbank & McKenna 1964
BC, Canada, 1964 Loganberries (thornless)	 2.24		 374	 1	0B* 10 20 31	<0.01 <0.01, <0.01, <0.01 <0.01, <0.01, <0.01 <0.01, <0.01, <0.01	Post-emergence directed	McKenna 1966 Port Coquitlam
Ontario, Canada 1964 Gooseberries (Captivator)	 2.24		 935	 1	0B* 72	<0.01 <0.01	Post-emergence directed	McKenna 1966 Guelph
Ontario, Canada, 1963 Raspberry (Viking)	 2.24		 749	 1	0B* 83	<0.01 <0.01	Post-emergence directed	Calderbank & McKenna 1964
BC, Canada, 1963 Raspberry (Puyallup)	1.14 2.24		935	1	90 90	<0.01 <0.01, <0.01, <0.01, <0.01		
Ontario, Canada, 1963 Raspberries (Latham)	 1.12		 234	 1	0B* 128	<0.01 <0.01		
BC, Canada, 1964 Raspberries (Viking)	 2.24		 935	 1	0B* 34	<0.01 <0.01, <0.01	Post-emergence directed	McKenna 1966 Abbotsford
(Comet)	 2.24		 935	 1	0B* 71	<0.01 <0.01 For control, Latham variety was analysed		
(Puyallup)	 2.24		 842	 1	0B* 39 95	<0.01 <0.01, <0.01, <0.01 <0.01		
STRAWBERRY								
Ireland, 1963 (Cambridge Vigour)	 0.42 0.84		 562 562	 2 2	0B* 210 210	<0.01 <0.01, <0.01 <0.01, <0.01	Post-emergence directed	Calderbank & McKenna 1964
Germany 2001 (Hummi silva)	 1.0		 400	 1	0B* 224	<0.01 <0.01	In plastic greenhouse For runner control	Devine & Balluff 2002e G01W058R
(Darselec)	 1.0		 400	 1	0B* 226	<0.01 <0.01		G01W059R
France, 2001 (Hummi grande)	 1.0		 400	 1	0B* 217	<0.01 <0.01		F01W039R
UK, 2000 (Elsanta)	 1.32 1.265 1.142		 240 230 208	 1 1 1	0B* 50 48 47	<0.05 <0.05 <0.01 <0.01		Nagra & Kingdom 2001 TN-00-003 TN-00-004 TN-00-005

*B: control

Olives. Paraquat is used for the control of weeds in olive groves, where it is applied around the base of the trees. Residue trials have been carried out in Greece, Italy, Spain and the USA (California).

In six trials in Spain in 1991/92, olives were harvested from the ground 0, 1 and 7 days after application. In other trials in Spain, mature olives were sprayed directly on the ground with paraquat at rates from 0.36 to 1.3 kg ai/ha. The fruit were collected after 3-17 days. In one trial in Greece, mature olives were directly sprayed with paraquat at a rate of 1.0 kg ai/ha to simulate possible direct spraying of fruit fallen through collection nets during weed control.

In trials in Italy, paraquat was applied at rates up to 1.8 kg ai/ha to the base of trees. Olives were harvested from the ground 7 to 21 days after application. In the trial in California, the USA, paraquat was applied four times at an exaggerated rate (5.6 kg ai/ha; 22.4 kg/ha total) and the fruit were harvested from the trees for processing into oil and cake.

Table 24. Paraquat residues in olives from supervised trials in Spain, Greece, Italy and the USA.

Country, year Olives (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Spain 1991/1992							Fruit taken from ground	Anderson & Earl 1993
(Cornicabra)					0B*	0.17	Whole fruit	ES10-91H008
						<0.02	Oil	
						0.24	Cake	
	0.60		N/A	1	0	5.2	Whole fruit	
					1	10		
					7	6.9		
					0	0.03	Oil	
					1	0.04		
					7	0.04		
					0	7.8	Cake	
					1	15		
					7	10		
(Cornicabra)					0B*	0.08	Whole fruit	ES10-91H108
						<0.02	Oil	
						0.12	Cake	
	0.60		N/A	1	0	6.4	Whole fruit	
					1	6.0		
					7	4.6		
					0	0.06	Oil	
					1	0.04		
					7	0.03		
					0	9.8	Cake	
					1	9.1		
					7	7.1		
(Hojiblanco)					0B*	<0.02	Whole fruit	ES10-91H208
						<0.02	Oil	
						<0.02	Cake	
	0.60		N/A	1	0	0.64	Whole fruit	
					1	1.5		
					7	2.0		
					0	<0.02	Oil	
					1	<0.02		
					7	<0.02		
					0	0.86	Cake	
					1	2.1		
					7	2.8		

Country, year Olives (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	Reference
(Hojiblanco)					0B*	<0.02	Whole fruit	ES10-91H308
						<0.02	Oil	
						<0.02	Cake	
	0.60		N/A	1	0	1.6	Whole fruit	
					1	3.6		
					7	1.6		
					0	<0.02	Oil	
					1	<0.02		
					7	<0.02		
					0	2.1	Cake	
					1	4.9		
					7	2.1		
(Manazel)					0B*	0.03	Whole fruit	ES10-91H408
						<0.02	Oil	
						0.04	Cake	
	0.60		N/A	1	0	6.8	Whole Fruit	
					1	7.6		
					7	4.9		
					0	0.06	Oil	
					1	0.03		
					7	<0.02		
					0	9.3	Cake	
					1	10		
					7	6.8		
(Manazel)					0B*	0.05	Whole fruit	ES10-91H508
						<0.02	Oil	
						0.07	Cake	
	0.60	-	N/A	1	0	9.1	Whole fruit	
					1	8.7		
					7	5.8		
					0	0.03	Oil	
					1	0.02		
					7	<0.02		
					0	13	Cake	
					1	12		
					7	8.1		
Greece 1985 (Tsounati)					B*	<0.005	Olives picked & then directly sprayed Oil	Kennedy 1985 INT H 11.85
	1.0		500	1	5	<0.005		
Italy, 1986 (Coratina)					0B*	<0.05	Fruit picked up from ground	Gatti 1987 60/86/1
	0.54		1000	1	7	<0.05		
					14	<0.05		
					21	<0.05		
	0.89		1000	1	7	<0.05		
					14	<0.05		
					21	<u><0.05</u>		
	1.79		1000	1	7	<0.05		
					14	<0.05		
					21	<0.05		
Italy, 1993 (Frantioio)							Fruit picked from tree	Dick *et al.* 1995a
							Fruit	
	1.56		N/A	1	0B*	<0.10	Oil	IT10-93-H338
						<0.05	Fruit	
					7	<u><0.10</u>	Oil	
						<0.05		
Italy, 1993 (Coratina)							Fruit picked from tree	IT10-93-H339
							Fruit	
	1.56		N/A	1	0B*	<0.10	Oil	
						<0.05	Fruit	
					7	<u><0.10</u>	Oil	
						<0.05		

Country, year Olives (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	Reference
CA, USA, 1988							Fruit picked from tree	Roper 1989i
(Manzanilla)							Fruit, Oil, Cake	73CA88-526
	5.6		N/A	4	0B*	<0.05	Fruit	
					13	<0.05	Oil	
						<0.05	Cake	
						<0.05		
Spain, 1987					0B*	<0.05	Analysed fruit were	Kennedy
(Picual)	0.36		500	1	6	0.11	sprayed and picked up	1987
					17	0.08	from ground	VG-H.1
	0.60		500		6	0.20		
					17	0.23		
	0.60		500		6	0.57		
					17	0.50		
	1.00		500		6	0.86		
					17	0.63		
Spain, 1986					0B*	<0.02	Sampled from ground	Massey 1987d
(Picual)	0.36		600	1	7	0.40		VG-H.2
					14	0.42		
	0.60		600		7	0.73		
					14	0.74		
	0.60		600		7	2.2		
					14	2.1		
	1.00		600		7	3.9		
					14	4.4		
Spain, 1999					0B*	<0.05		Jones 2000a
(Hojiblanco)							44-58% of analysed olives were on ground at treatment	ES50-99-S03 3
	1.23		336	1	7	2.1	Fruit , unwashed	
						<0.05	Oil, from unwashed	
						0.77	Fruit, washed	
						<0.05	Oil, from washed	
	1.35		368	1	3	3.4	Fruit , unwashed	
						<0.05	Oil, from unwashed	
						1.3	Fruit, washed	
						<0.05	Oil, from washed	
Spain, 1999					0B*	<0.05		ES50-99-S13
(Arbequina)							17-32% of analysed olives were on ground at treatment	3
	1.08		293	1	3	0.66	Fruit , unwashed	
						<0.05	Oil, from unwashed	
						0.66	Fruit, washed	
						<0.05	Oil, from washed	
	1.18		321	1	7	0.24	Fruit , unwashed	
						<0.05	Oil, from unwashed	
						0.47	Fruit, washed	
						<0.05	Oil, from washed	
Spain 2001 (Hojiblanca)					0B*	<0.05	14-37% of analysed olives were on ground at treatment	Devine *et al.* 2003 ES051-01-S0 13
	1.09		347	1	3	0.45	Whole fruit	
						0.19	Unwashed fruit	
						0.12	Washed fruit	
						<0.05	Virgin oil	
						<0.05	Refined oil	
					7	0.29	Whole fruit	

Country, year Olives (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
(Arbequina)					0B*	<0.05	Ca 10% of analysed olives were on ground at treatment	ES060-01-S1 13
	1.10		200	1	3	0.10	Whole fruit	
						0.06	Unwashed fruit	
						<0.05	Washed fruit	
						<0.05	Virgin oil	
						<0.05	Refined oil	
	1.05		192		7	0.08	Whole fruit	
(Hojiblanca)					0B*	<0.05	20-30% of analysed olives were on ground at treatment	ES050-01-S2 13
	1.05		383	1	3	0.88	Whole fruit	
	1.32		360		7	1.45		
Spain 2002 (Picual)					0B*	<0.05	58-83% of analysed olives were on ground at treatment	ES052-01-S3 13
	1.09		298	1	3	1.67	Whole fruit	
	1.15		314		7	1.66		

*B: control

Assorted tropical fruits – inedible peel

Paraquat is recommended for use on fruit trees as a directed spray to the soil around the trees.

Residue trials have been carried out on passion fruit in Hawaii, USA, using a single application at 1.12 to 4.48 kg ai/ha. Fruit were harvested from 1 to 28 days after application.

Residue trials have been carried out on kiwifruit in California, USA, using a single application at 0.56 to 2.24 kg ai/ha. Fruit were harvested from 7 to 14 days after the third application.

Residue trials have been carried out on guava in Hawaii, USA, using a single application of paraquat at 1.12 to 4.48 kg ai/ha. Fruit were harvested from 1 to 28 days after application.

Residue trials have been carried out on banana in Honduras, using three applications of paraquat at 1.4 kg ai/ha, or a single application at double this rate. Fruit were harvested from 0 to 90 days after the last application.

Table 25. Paraquat residues in assorted tropical fruits with inedible peel from supervised trials in Honduras and the USA.

Country, year crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
HI, USA, 1970 Passion Fruit (Yellow Lilikoi)					0B*	<0.01		Chevron 1972b WC-98& WC-127 (2 trials)
	1.12	0.911	123	1	1	<0.01, 0.13	Whole fruit	
						0.01, 0.01	Edible pulp	
						<0.01, 0.21	Peel	
					4	<0.01, 0.06	Whole fruit	
						0.01, 0.01	Edible pulp	
						<0.01, 0.07	Peel	
					7	0.01, 0.02	Whole fruit	
						<0.01, 0.01	Edible pulp	
						0.02, 0.03	Peel	
					14	<0.01, 0.01	Whole fruit	
						<0.01, 0.01	Edible pulp	
						<0.01, 0.01	Peel	
					28	<0.01, 0.01	Whole fruit	

Country, year crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
						<0.01, 0.02	Edible pulp	
						<0.01, 0.01	Peel	
	2.24	1.82	123	1	1	0.02, 0.08	Whole fruit	
						0.01, 0.02	Edible pulp	
						0.02, 0.11	Peel	
					4	<0.01, 0.10	Whole fruit	
						0.01, 0.06	Edible pulp	
						<0.01, 0.13	Peel	
					7	0.02, 0.02	Whole fruit	
						0.01, 0.02	Edible pulp	
						0.02, 0.03	Peel	
					14	0.01, 0.03	Whole fruit	
						<0.01, 0.02	Edible pulp	
						0.01, 0.03	Peel	
					28	<0.01, 0.02	Whole fruit	
						0.01, 0.04	Edible pulp	
						<0.01, 0.01	Peel	
	4.48	3.64	123	1	1	0.01, 0.19	Whole fruit	
						0.01, 0.01	Edible pulp	
						0.02, 0.29	Peel	
					4	<0.01, 0.02	Whole fruit	
						<0.01, 0.01	Edible pulp	
						<0.01, 0.05	Peel	
					7	0.01, 0.06	Whole fruit	
						0.01, 0.06	Edible pulp	
						0.01, 0.07	Peel	
					14	<0.01, 0.02	Whole fruit	
						<0.01, 0.01	Edible pulp	
						<0.01, 0.03	Peel	
					28	<0.01, 0.02	Whole fruit	
						<0.01, 0.01	Edible pulp	
						<0.01, 0.03	Peel	
CA, USA, 1976 Kiwifruit (Hayward)					0B*	<0.01		IRP-4 1981
	0.56		468	3	7	<0.01		
					14	<0.01		
	1.12				7	<0.01		
					14	<0.01		
	2.24				7	<0.01		
					14	<0.01		
HI, USA, 1970 Guava (Clonal selections)					0B*	<0.01		Chevron 1972a Malama-Ki Farm
	1.12		748	4	1	<0.01	Edible pulp	
						<0.01	Peel	
					4	<0.01	Edible pulp	
						<0.01	Peel	
					7	<0.01	Edible pulp	
						<0.01	Peel	
					14	<0.01	Edible pulp	
						<0.01	Peel	
					28	<0.01	Edible pulp	
						<0.01	Peel	
	2.24		748	4	1	<0.01	Edible pulp	
						<0.01	Peel	
					4	<0.01	Edible pulp	
						<0.01	Peel	
					7	<0.01	Edible pulp	
						<0.01	Peel	
					14	<0.01	Edible pulp	
						<0.01	Peel	
					28	<0.01	Edible pulp	
						<0.01	Peel	
	4.48		748	1	1	<0.01	Edible pulp	
						<0.01	Peel	
					4	<0.01	Edible pulp	

Country, year crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	Reference
						<0.01	Peel	
					7	<0.01	Edible pulp	
						<0.01	Peel	
					14	<0.01	Edible pulp	
						<0.01	Peel	
					28	<0.01	Edible pulp	
						<0.01	Peel	
HI, USA, 1970 Guava (Beaumont)					0B*	<0.01		Waimanalo Farm
	1.12		748	4	1	<0.01	Edible pulp	
						<0.01	Peel	
					4	<0.01	Edible pulp	
						<0.01	Peel	
					7	<0.01	Edible pulp	
						<0.01	Peel	
					14	<0.01	Edible pulp	
						<0.01	Peel	
					28	<0.01	Edible pulp	
						<0.01	Peel	
				2	6	<0.01	Frozen canned juice	
				(8)		<0.01	Discarded skin & seed	
						<0.01	Discarded stone cells	
	2.24		748	5	1	<0.01	Edible pulp	
						<0.01	Peel	
					4	<0.01	Edible pulp	
						<0.01	Peel	
					7	<0.01	Edible pulp	
						<0.01	Peel	
					14	<0.01	Edible pulp	
						<0.01	Peel	
					28	<0.01	Edible pulp	
						<0.01	Peel	
	4.48		748	1	1	<0.01	Edible pulp	
						<0.01	Peel	
					4	<0.01	Edible pulp	
						<0.01	Peel	
					7	<0.01	Edible pulp	
						<0.01	Peel	
					14	<0.01	Edible pulp	
						<0.01	Peel	
					28	<0.01	Edible pulp	
						<0.01	Peel	
				2	6	<0.01	Frozen canned juice	
				(8)		<0.01	Discarded skin & seed	
						<0.01	Discarded stone cells	
Honduras, 1964 Bananas (Valery)					0B*	<0.01		McKenna 1966
	1.40		584	3	0	<0.01 x4	Fruit flesh	
						0.01, <0.01 x3	Peel	
					3	<0.01 x4	Fruit flesh	
						<0.01 x4	Peel	
					7	<0.01	Fruit flesh	
						<0.01	Peel	
						≤0.01 x3	Whole fruit	
					14	<0.01 x4	Whole fruit	
					21	<0.01 x4	Whole fruit	
					45	<0.01 x4	Whole fruit	
					90	<0.01 x4	Whole fruit	
	2.80			1	0	0.66	Peel	
						<0.01	Fruit flesh	
						0.12, 0.01, <0.01 x2	Whole fruit	
					3	<0.01 x4	Whole fruit	
					7	<0.01 x4	Whole fruit	

Country, year crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
					14 23 44 90	<0.01 x4 <0.01 x4 <0.01 x4 <0.01 x4	Whole fruit Whole fruit Whole fruit Whole fruit	

*B: control
Number in ( ): application number from previous year.

Bulb vegetables

Residue trials have been conducted on onions in Canada, Germany and the UK.

In trials in Canada, paraquat was sprayed at a rate of 1.12 kg ai/ha for pre-emergence, or 2.2 kg ai/ha for inter-row application.

Supervised residue trials were carried out on onions in Germany using paraquat for inter-row weed control. In 1983 paraquat was applied twice or four times at rates of 1.0 to 2.1 kg ai/ha and the onions harvested from 0 to 21 days after the last application. In 1984 onions were harvested 0 to 21 days after one or three applications of 1.0 to 1.3 kg ai/ha. In a German trial in 1965 paraquat was applied at 1.79 kg ai/ha as a harvest aid.

Table 26. Paraquat residues in onions from supervised trials in Canada, Germany and the UK.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Manitoba, Canada, 1962 (Autumn Spice) (Brigham Yellow Globe)	 1.12 1.12		 187 187	 1 1	0B* 143 143	<0.01 <0.01 <0.01		Calderbank & Yuen 1963
Canada, 1964 (Unknown)	2.20		1120	1	0B* 36	<0.01 <0.01		Edwards 1974 Ref No. 4148
Germany, 1965	1.79		303	1	0B* 20	<0.01 0.30 0.14	Harvest aid Peeled Unpeeled	McKenna 1966
UK, 1964 Spring (Unknown)	 1.68 1.68 2.24		 N/A N/A N/A	 1 1+ 3	0B* 126 21	<0.01 0.02 <0.01	 Pre-sowing Pre-sowing & inter-row	McKenna 1966
Germany, 1983 (Weibe Königin)	1.0		1000	2	0B* 0 5 9 14 21	<0.01 <0.01 0.02 0.01 0.02 <0.01	Post-emergence directed application	Swaine 1983a RS8378 B4
(Stuttgarter Riesen)	 2.1 1.6		 2100 1600	 1+ 1	0B* 0 3 8 12 16	<0.05 0.02 <0.01 <0.01 <0.01 <0.01		RS8378 E2

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
(Jumbo)					0B*	<0.02		RS8378 E3
	1.56		1560	1+				
	0.9		900	1+				
	1.25		1250	1+				
	1.05		1050	1	0	0.01		
					4	<0.01		
					8	0.01		
					12	<0.01		
					16	<0.01		
					21	<0.01		
Germany, 1984					B*	<0.01	Post-emergence	Massey 1987a
(Stuttgarter	1.3		1300	1	0	0.01	directed application	RS8423E3
Riesen)					3	<0.01		
					8	<0.01		
					14	<0.01		
					21	<0.01		
	0.9		3000	1	0	<0.01		RS8427E2
					3	<0.01		
					8	<0.01		
					14	<0.01		
					21	<0.01		
(Jumbo)					B*	<0.01		RS8423B3
	1.0		1000	3	0	<0.01		
					4	<0.01		
					9	<0.01		
					14	<0.01		
					21	<0.01		
	0.75		2500	3	0	<0.01		RS8427B4
					4	<0.01		
					9	<0.01		
					14	<0.01		
					21	<0.01		
						<0.01		

*B: control

Brassica vegetables

Paraquat is recommended for use in the cultivation of Brassica vegetables either during seed bed preparation as a pre-plant or pre-emergence treatment, or applied as a post-emergence directed or guarded spray for inter-row weed control.

Residue trials have been carried out on a number of Brassica crops, including cabbage in Canada, Japan, Spain and the USA; broccoli in Canada; Brussels sprouts in The Netherlands; and cauliflower in Canada. In trials in Canada, Spain and the USA, paraquat was applied once or twice at 0.56 to 2.24 kg ai/ha for inter-row weed control and the crop harvested 5 to 52 days after the last application.

In trials on cabbage in Japan, paraquat was applied three times at 0.96 kg ai/ha or once at a highly exaggerated rate (19.2 kg ai/ha). The crop was harvested 5 days after the last of the three applications or 52 days after the high rate application.

The trials on Brussels sprouts in The Netherlands involved a harvest aid application directly to the sprouts.

Table 27. Paraquat residues in Brassica vegetables from supervised trials in Canada, Japan, Netherlands, Spain and the USA.

Country, year Brassica (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Ontario, Canada, 1964 Broccoli (Unknown)	2.2			1	0B* 36	<0.01 <0.01		McKenna 1966
Japan, 1973 Cabbage (Taibyo Ace)	 0.96 19.2			 3 1	0B* 5 52	<0.03 <0.03, <0.03 <0.03, <0.03		Edwards 1974
Japan, 1973 Cabbage (Wase Syuho)	 0.96 19.2			 3 1	0B* 5 52	<0.03 <0.03, <0.03 <0.03, <0.03		
Spain, 1998 Cabbage (Savoy Prince)	1.0		197	1	0B* 15	<0.05 <0.05	Post-emergence directed	Coombe & Gallardo 1999 ES10-98-SH015
Spain, 1998 Cabbage (Savoy King)	1.0		290	1	0B* 16	<0.05 <0.05		ES10-98-SH115
Ontario, Canada, 1964 Cabbage (Copenhagen bald)	2.2			1	0B* 51	<0.01 0.06		McKenna 1966
FL, USA, 1989 Chinese cabbage (Joi choy)	 1.05 pre 0.56 1.05 pre 0.56		280	 1+ 3 1+ 3	0B* 21 21	<0.05 <0.05, <0.05, <0.05, <0.05 <0.05, <0.05, 0.06, 0.07	1 pre & 3 post-emergence directed applications	Choban 1991
Ontario, Canada, 1964 Cauliflower (unknown)	2.2			1	0B* 45	<0.01 <0.01		McKenna 1966
Netherlands, 1965 Brussel spout (Unknown)	1.2			1	0B* 31 31	<0.01 1.6 7.3	Harvest aid Peeled spouts Unpeeled sprouts	McKenna 1966

*B: control

Fruiting vegetables

Paraquat is recommended for use in the cultivation of fruiting vegetables, either during seed bed preparation as a pre-plant or pre-emergence treatment, or applied as a post-emergence directed or guarded spray for inter-row weed control.

Numerous residue trials have been carried out on cucumbers, melons and summer squash in the USA, on tomatoes in Canada and the USA, and on peppers in Canada and the USA.

In residue trials on cucumbers, melons and squash in California, USA, paraquat was applied at 1.12 kg ai/ha pre-emergence followed by three inter-row applications at 0.56 kg ai/ha.

The trials in Canada on tomatoes were for pre-emergence (or pre-planting) weed control in which paraquat was used at a low rate (0.11 kg ai/ha) in combination with residual herbicides. The trials on tomatoes in the USA were generally with post-emergence directed application at 0.56 to 2.24 kg/ha, but also involved an exaggerated single high rate (11.2 kg ai/ha) pre-emergence or applications of 1.12

kg ai/ha followed by three inter-row directed applications at 2.8 kg ai/ha (the last for a processing study).

The trials on peppers were for inter-row weed control using paraquat at 0.56 to 2.24 kg ai/ha.

Table 28. Paraquat residues in fruiting vegetables, other than cucurbits, from supervised trials in Canada and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
TOMATO								
USA					0B*	<0.01	Post-emergence directed application	Chevron 1975c T-2866
FL, 1974								
(Walter)	0.56		412	1	0	<0.01, 0.02		
					7	0.01, 0.02		
					14	<0.01, 0.02		
					21	0.03, 0.04		
TX, 1974 (Homestead 24)	0.56		514	3	0	<0.01, <0.01		T-2867
					7	<0.01, 0.02		
					14	<0.01, 0.02		
					21	<0.01, <0.01		
	1.12		514	3	0	<0.01, <0.01		
					7	<0.01, <0.01		
					14	<0.01, <0.01		
					21			
FL, 1975 (Walter)	0.56		359	1	0	<0.01		T-2872
					7	<0.01		
					14	<0.01		
					21	<0.01		
	1.12		359	1	0	<0.01		
					7	<0.01		
					14	0.01		
					21	<0.01		
FL, 1975 (Walter)	0.56		421	1	0	<0.01, <0.01		T-2875
					7	<0.01, <0.01		
					14	<0.01, <0.01		
					21	<0.01, <0.01		
	1.12		421	1	0	<0.01, <0.01		
					7	<0.01, <0.01		
					14	<0.01, <0.01		
					21	<0.01, <0.01		
LA, 1975 (Creole)	0.56		187	5	0	0.02, 0.02		T-2877
					7	0.01, 0.02		
					14	<0.01, 0.01		
					21	<0.01, <0.01		
	1.12		187	5	0	<0.01, 0.02		
					7	<0.01, 0.01		
					14	<0.01, <0.01		
					21	<0.01, <0.01		
Fl, 1974 (Walter)	0.56		421	1	0	<0.01, <0.01		T-3148
					7	<0.01, <0.01		
					12	<0.01, <0.01		
					21	<0.01, <0.01		
	1.12		421	1	0	<0.01, <0.01		
					7	<0.01, <0.01		
					12	<0.01, <0.01		
					21	<0.01, <0.01		
MD, 1975 (Campbell 28)	1.12 pre		374	1+				T-3333
	1.12		299	4	7	0.02		
					14	0.01		
					21	0.02		
	1.12 pre		374	1+				
	2.24		299	4	7	0.02		
					14	0.02		
					21	0.07		

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, USA, 1988							1 pre+3	Roper 1989q
(Jack Pot)							post-emergence	18CA88-789
							directed applications	
					B*	<0.005	Unwashed tomato	
						<0.005	Juice	
						<0.025	Catsup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	
	1.12pre			1+				
	2.8			3	30	<0.005	Unwashed tomato	
						<0.005	Juice	
						<0.025	Ketchup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	
(Jack Pot)					B*	<0.005	Unwashed tomato	18CA88-790
						<0.005	Juice	
						<0.025	Catsup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	
	1.12pre			1+				
	2.8			3	30	<0.005	Unwashed tomato	
						<0.005	Juice	
						<0.025	Catsup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	
Ontario, Canada,					0B*	<0.01	Post-emergence	Calderbank
1963	0.11		1348	1	69	<0.01	directed application	McKenna
(Heinz 1350)	0.22		1122		69	<0.01		1964
(Heinz 1350)	0.11		1122	1	0B*	<0.01		
					71	<0.01, <0.01, <0.01		
FL, USA	11.2			1	0B*	<0.01	Pre-emergence	Roper 1989h
1987					76	<0.01	application	75FL-87-517
(Unknown)								E
CA, USA	11.2			1	0B*	<0.01		45CA-87-518
1987					87	<0.01		
(Unknown)								
PEPPERS								
USA					0B*	<0.01	Post-emergence	Chevron
FL, 1975							directed application	1975c
Sweet pepper								T-2868
(Early Cal	0.56		421	1	0	<0.01, <0.01		
Wonder)					7	<0.01, <0.01		
					12	<0.01, <0.01		
					21	<0.01, <0.01		
	1.12		421	1	0	<0.01, <0.01		
					7	<0.01, <0.01		
					12	<0.01, <0.01		
					21	<0.01, <0.01		
TX, 1974	0.56		514	3	0	<0.01, <0.01		T-2869
Sweet pepper					7	<0.01, <0.01		
(Yolo Wonder 34)					12	<0.01, <0.01		
					21	0.01, 0.01		
	1.12		514	3	0	0.01, 0.03		
					7	<0.01, <0.01		
					12	<0.01, <0.01		
					21	<0.01, 0.02		

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
FL, 1974	0.56		421	1	0	<0.01, <0.01		T-2873
Sweet pepper					7	<0.01, <0.01		
(Early Cal					12	<0.01, <0.01		
Wonder)					21	<0.01, <0.01		
	1.12		421	1	0	<0.01, <0.01		
					7	<0.01, <0.01		
					12	<0.01, <0.01		
					21	<0.01, <0.01		
LA, 1975	0.56		187	4	0	<0.01, <0.01		T-3152
Sweet pepper					7	<0.01, <0.01		
(Keystone Giant					14	<0.01, <0.01		
Resistant)					21	<0.01, <0.01		
	1.12		187	4	0	<0.01, <0.01		
					7	<0.01, <0.01		
					14	<0.01, <0.01		
					21	<0.01, <0.01		
MD, 1975	1.12pre		374	1+				T-3332
Sweet pepper	1.12		299	4	7	<0.01		
(Yolo Wonder)					12	<0.01		
					21	0.03		
	1.12pre		374	1+				
	2.24		299	4	7	<0.01		
					12	0.03		
					21	<0.01		
Canada, 1964 Pepper (California Wonder)	2.2		1120	1	0B*	<0.01	Post-emergence directed application	Edwards 1974 Ref No 3778
					27	<0.01		

*B: control

Table 29. Paraquat residues in fruiting vegetables, cucurbits, from supervised trials in the USA.

Country, year Cucurbits (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CUCUMBER								
CA, USA, 1988 (Unknown)					0B*	<0.025	1 pre + 3 post directed application	Roper 1989e 19CA-88-428
	1.12 pre			1+				
	0.56			3	31	<0.025		
CA, USA, 1988 (Unknown)					0B*	<0.025		19CA-88-429
	1.12 pre			1+				
	0.56			3	23	<0.025		
CA, USA, 1988 (Unknown)					0B*	<0.025		18CA-88-430
	1.12 pre			1+				
	0.56			3	8	<0.025		
CA, USA, 1988 (Unknown)					0B*	<0.025		18CA-88-431
	1.12 pre			1+				
	0.56			3	8	<0.025		
MELON								
CA, USA, 1988 Melons (Unknown)					0B*	<0.025	1 pre + 3 post directed application	Roper 1989e 19CA-88-432
	1.12 pre			1+				
	0.56			3	52	<0.025		
CA, USA, 1988 Melons (Unknown)					0B*	<0.025		19CA-88-433
	1.12 pre			1+				
	0.56			3	52	<0.025		
CA, USA, 1988 Melons (Unknown)					0B*	<0.025		17CA-88-434
	1.12 pre			1+				
	0.56			3	62	<0.025		
CA, USA, 1988 Melons (Unknown)					0B*	<0.025		17CA-88-435
	1.12 pre			1+				
	0.56			3	62	<0.025		
SUMMER SQUASH								

Country, year Cucurbits (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, USA, 1988					0B*	<0.025	1 pre + 3 post directed application	Roper 1989e
Summer Squash	1.12 pre			1+				18CA-88-436
(Unknown)	0.56			3	8	≤0.025		
CA, USA, 1988					0B*	<0.025		18CA-88-437
Summer Squash	1.12 pre			1+				
(Unknown)	0.56			3	8	≤0.025		
CA, USA, 1988					0B*	<0.025		18CA-88-438
Summer Squash	1.12 pre			1+				
(Unknown)	0.56			3	8	≤0.025		
CA, USA, 1988					0B*	<0.025		17CA-88-439
Summer Squash	1.12 pre			1+				
(Unknown)	0.56			3	33	≤0.025		

*B: control

Leafy vegetables

Paraquat is recommended for use in the cultivation of leafy vegetables either during seed bed preparation as a pre-plant or pre-emergence treatment, or applied as a post-emergence directed or guarded spray for inter-row weed control.

Residue trials on lettuce have been carried out in Canada, Germany, Spain, the UK and the USA at rates of 0.42 to 2.24 kg/ha, and lettuce was sampled 0 to 147 days after application. In most of these trials, the whole lettuce head was analysed without removal of the outer wrapper leaves.

Residue trials on kale have been carried out in France, Italy and the UK at rates of 1.0 to 2.24 kg/ha, and kale was sampled 0 to 147 days after application. In trials in France and Italy, the residue levels of paraquat immediately after spray drying (0 days) represent a worst-case situation.

Six trials on turnip greens were carried out in the USA at a rate of 1.12 kg/ha pre-emergence and tops were sampled 55 to 128 days after application.

Table 30. Paraquat residues in leafy vegetables from supervised trials in Canada, France, Germany, Italy, Spain, the UK and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
LETTUCE								
Ontario, Canada,					0B*	<0.01		McKenna
1964	2.24		935	1	36	<0.01		1966
(Mixed)	2.24		935	1	55	0.08		Pre-emergenc
	1.12		935	1	55	0.05		e
	2.24		935	1	55	0.05		
	1.12		935	1	55	0.04		
	0.49		468	1	71	0.01		
	0.97		468	1	71	0.01		
UK, 1965					0B*	<0.01	Head, unwashed	
(Unknown)						<0.01	Head, washed	
	0.841		N/A	1	39	0.01	Head, unwashed	
						<0.01	Head, washed	
	0.841		N/A	1	58	0.02	Head, unwashed	
						<0.01	Head, washed	
	0.841		N/A	1	72	≤0.01	Head, unwashed	
						<0.01	Head, washed	
UK, 1964					0B*	<0.01		
(Unknown)	1.68 pre		N/A	1+				
	2.24		N/A	2	46	0.02, 0.03	Head	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
FL, USA, 1978 Crisphead (Minetto)	0.42 0.84		449 449	1 1	41 41	<0.01 <0.01	Mature head, trimmed Mature head, trimmed	Florida Dep. of Agri. 1978 Post-emergence directed T-4574
FL, USA, 1978 Crisphead (Minetto)	0.42 0.84		449 449	1 1	56 56	<0.01 <0.01	Head, trimmed Head, trimmed	T-4575
FL, USA, 1978 Butter lettuce (Green Boston)	0.56		655	1	24	0.02	Head, trimmed	T-4576
FL, USA, 1978 Romaine lettuce (Volmaine)	0.56		655	1	18	<0.01	Head, trimmed	T-4577
FL, USA, 1978 Leaf lettuce (Florida Deep Heart)	0.56		468	1	69	<0.01	Bunch, trimmed	T-4578
FL, USA, 1978 Romaine lettuce (Paris Island Los)	0.56		561	1	32	<0.01	Heads, trimmed	T-4580
FL, USA, 1978 Crisphead (Great Lakes)	0.56		561	1	49	<0.01	Heads, trimmed	T-4581
Germany, 1983 (Unknown)	 1.00 0	 0.100	 1000	 2	0B* 0 4 9 14 21	<0.01 0.39 0.40 0.01 0.02 <0.01		Swaine 1983c Rs8378B1
Germany, 1983 (Unknown)	1.00	0.100	1000	2	0 4 9 14 21	0.35 0.21 0.04 0.04 <0.01		Rs8378B2
Germany, 1983 (Unknown)	1.80 pre 1.60		1800 1600	1+ 1	0 3 6 9 14	0.06 0.09 0.22 0.13 0.06		Rs8378B3
Germany, 1983 (Capitan)	 0.75 0.75		 1250 2500	 1+ 1	B* 0 4 9 14 21	0.02 0.48 0.05 0.02 0.02 <0.02	 Head	Kennedy 1984b RS8372B1
(Meridian)	 0.75 0.75		 1250 2500	 1+ 1	B* 0 4 9 14 21	0.02 0.10 0.05 <0.02 <0.02 <0.02	 Head	RS8372B2
Endive (Solera)	 0.69 0.84		 2300 1400	 1+ 1	B* 0 3 7 10	0.02 <0.02 <0.02 0.02 0.02	 Head	RS8372E1

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Germany, 1984					0B*	0.01	Post-emergence directed	Massey 1987c RS8423E1
(Eichblatt)	1.30		1300	1	0	1.4	Heads	
					3	0.25		
					7	0.16		
					12	0.10		
					16	0.03		
Endive	1.25		1250	1	0	0.56	Heads	RS8423E2
					4	0.33		
					7	0.26		
					14	0.39		
					21	0.20		
(Capitan)					B*	0.01	Heads	RS8423B1
	1.00		1000	2	0	0.01		
					4	0.01		
					10	<0.01		
					14	<0.01		
					21	<0.01		
(Eichblatt)					B*	<0.01	Heads	RS8427E1
	0.96		1600	1	0	1.3		
					3	0.44		
					7	0.16		
					12	0.06		
					16	0.04		
(Capitan)					B*	0.01	Heads	RS8427B1
	0.75		1000	2	0	<0.01		
					4	0.01		
					10	<0.01		
					14	<0.01		
					21	<0.01		
(Astra)					B*	0.01	Heads	RS8427B3
	0.75		2500	2	0	0.01		
					4	0.01		
					9	0.01		
					14	<0.01		
					21	0.01		
NY, USA, 1986 (Montello)					0B*	<0.02	Post-emergence directed	Massey 1987e 34NY86-014 R
	1.12		N/A	1	31	<0.02, <0.02, <0.02		
			N/A	1	31	<0.02, <0.02, <0.02		
(Green Lake)					0B*	<0.02		34NY86-015 R
	0.56		N/A	1	31	<0.02, <0.02, <0.02		
Spain, 1999 (Verna)	0.60	0.200	300	1	0	0.01		Jones 2000d AF/4716/ZE/1 Andalucia
(Odra)	0.60	0.200	300	1	0	<0.01		AF/4716/ZE/2 Andalucia
KALE								
UK, 1964					0B*	<0.01		McKenna 1966
Kale	1.68 pre			1+				
(Unknown)	2.24			1	113	0.04		
	2.24			1	72	0.03		
	1.12 pre		31	1	147	0.02		
	2.24 pre		31	1	147	0.02		
France, 1998 (Winterbor)					0B*	<0.05	Post-emergence directed; sampled after spray dried	Jones & Cowley 1999 AF/4148/CE/1
	0.97		291	1	0	0.07		

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Italy, 1998 (Cavolonero di Firenze)	1.02		307	1	0 0	0.16		AF/4148/CE/2
TURNIP GREENS								
USA, 1988 AL (7-top)	 1.12			 1	0B* 128	<0.025 <0.025	Pre-emergence	Roper 1989p 44AL-88-410
GA (Purple top)	1.12			1	97	<0.025		45GA-88-411
CA (Purple top)	1.12			1	55	0.03		18CA-88-413
FL (Purple top)	1.12			1	70	0.05		42FL-88-414
TN (Purple top)	1.12			1	66	0.04		43TN-88-415
TX (Purple top)	1.12			1	62	<0.025		12TX-88-416

*B: control

Legume vegetables and pulses

Paraquat is recommended as a pre-emergence or post-emergence directed inter-row treatment for legume vegetables and pulses, and for use as a harvest aid desiccant for soya beans.

Residue trials have been carried out on beans (except soya beans) in Canada, Germany, Spain, Italy, and The Netherlands using paraquat for pre-emergence weed control at single applications of 0.56 or 2.24 kg ai/ha or post-emergence directed inter-row weeding at rates from 0.28 to 1.12 kg ai/ha.

Residue trials have been carried out on peas in Canada and the UK using paraquat for pre-emergence weed control as single applications or post-emergence directed inter-row weeding at rates from 0.14 to 1.68 kg ai/ha, with harvest 55 to 152 days after application.

Paraquat was applied at 0.20 or 1.12 kg ai/ha to peas as a harvest aid desiccant in Australian and US trials with samples taken 1 to 38 days after application.

Several trials on soya beans were conducted in Brazil from 1981 to 1983 with a harvest aid desiccation application of paraquat at 0.25 to 0.80 kg/ha with sampling 2 to 21 days after application.

US trials involved a pre-emergence application with or without a post-emergence directed application from 0.14 to 1.4 kg/ha, or 5 applications of paraquat (3.3 kg/ha total) followed by a harvest aid desiccation at 0.7 kg/ha with sampling of seeds 1 to 17 days after the last application, or a harvest aid desiccation of 0.28 or 0.56 kg/ha with sampling after 6 to 36 days.

Table 30. Paraquat residues in legume vegetables and pulses from supervised trials in Australia, Brazil, Canada, Germany, Italy, Netherlands, Spain, the UK and the USA.

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
PHASEOLUS								
Italy, 1999 Beans with pods (Masai)	0.66		300	1	0B* 0	<0.01 0.04 0.01	Post-emergence directed Plants without pods Pods	Jones 2000b AF/4714/ZE/1
Spain, 2001 Dried field beans (Pinet)	1.0		300	1	0B* 0	<0.05 <0.05 7.6	Post-emergence directed Dried field bean Straw	Devine & Balluff 2002d S01W033R

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.			Notes	References
Germany, 2001	1.0		400	1	0B*	<0.05	Post-emergence directed	Devine &
Dried field beans							Dried field bean	Balluff 2002c
(Optimus)					0	<0.05	Straw	G01W056R
						2.6		
Germany, 2001	1.0		400	1	0B*	<0.05	Post-emergence directed	Devine &
Beans with pods							Beans with pods	Balluff 2002b
(Maja)					0	<0.05	Straw	G01W054R
						1.4	Beans with pods	
					3	0.10	Straw	
						0.34	Beans with pods	
					7	<0.05	Straw	
						0.91		
Spain, 2001	1.0		400	1	0B*	<0.05	Post-emergence directed	Devine &
Beans with pods							Beans with pods	Balluff 2002a
(Cleo)					0	0.09	Straw	S01W031R
						0.41	Beans with pods	
					3	<0.05	Straw	
						0.09	Beans with pods	
					7	<0.05	Straw	
						0.15		
The Netherlands 2002	1.0		300	1	0B*	<0.05	Post-emergence directed	Devine &
							Beans with pods	Poppezijn 2003
Beans with pods					7	<0.05	Straw	CEMS-1839/01
(Valance)						0.08		
Spain, 2002	1.0		200	1	0B*	<0.05	Post-emergence directed	Devine &
Beans with pods							Beans with pods	Orellana 2003a
(Moncayo)					7	<0.05	Straw	AF/6396/SY/1
						0.21		
Ontario, Canada, 1963					0B*	<0.01	Pre-emergence	Calderbank &
								McKenna 1964
Beans	0.56		281	1	122	<0.01	Seed	
(Small white)						<0.01	Pod	
						<0.01	Stalk	
(Small white)	0.56		281	1	123	<0.01	Seed	
						<0.01	Pod	
						<0.01	Stalk	
(Michelite)	1.12		225	1	105	<0.01	Seed	
						<0.01	Pod	
						<0.01	Stalk	

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Ontario, Canada, 1963					0B*	<0.01	Post-emergence directed	Calderbank &
Beans							Seed	McKenna 1964
(Small white)	0.28		281	1	107	<0.01	Pods	Edwards 1974
						<0.01	Stalk	
						<0.01	Seed	
					119	<0.01	Pods	
						<0.01	Stalk	
						<0.01	Seed	
	0.56		281	1	55	<0.01	Seed	
					68	<0.01	Seed	
	1.12		281	1	72	<0.01	Stalk	
						<0.01	Seed	
	0.56		561	1	71	<0.01	Pods	
						<0.01	Stalk	
						<0.01	Seed	
	0.56		NA	1	68	<0.01	Pods	
						<0.01	Stalk	
					86	<0.01	Seed	
	1.12		NA	1	68	<0.01	Pods	
						<0.01	Stalk	
					86	<0.01	Seed	
	0.28		281	1	101	<0.01	Podd	
						<0.01	Stalk	
						<0.01	Seed	
					118	<0.01	Pods	
						<0.01	Stalk	
						<0.01		
Ontario, Canada, 1964 Beans (Small white)					0B*	<0.01	Pre-emergence	McKenna 1966
	1.12		468	1	60	≤0.01	Seed	
VICIA								
UK, 1964 Broad beans (unknown)					0B*	<0.01	Pre+post-emergence	McKenna 1966
	1.68pre		N/A	1+				
	2.24		N/A	1	71	<0.01	Seed	
						<0.01	Pod	
					85	<0.01	Seed	
						0.01	Pod	
Spain, 2000 Broad beans (Reina Mora)	0.69		314	1	0B*	<0.01	Post-emergence directed	Jones 2000c
							Seed	AF/4715/ZE/1
					0	<0.01	Pod	
						<0.01		
Spain, 2002 Fresh broad bean (Muchamiel)	1.0		200	1	0B*	<0.05	Post-emergence directed	Devine &
							Fresh broad bean	Orellana 2003b
					0	<0.05	Straw with empty pods	AF/6397/SY/1
						1.5		
PEAS								
Ontario, Canada, 1963 (Lincoln)	0.56		38	1	0B*	<0.01	Pre-emergence	Calderbank &
					123	<0.01	Vines	McKenna 1964

Country, year Crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes and references	
Ontario, Canada, 1963					0B*	<0.05	Post-emergence directed Seed	Calderbank & McKenna 1964
(Lincoln)	1.12		281	1	72	<0.01	Seed	
	0.56		281	1	68	<0.01	Seed	
	0.56		281	1	55	<0.01	Seed	
(Dark green	0.28		270	1	70	<0.01	Seed	
perfection)	0.14		270	1	70	<0.01	Seed	
(Lincoln)	0.56		561	1	71	<0.01	Pods	
					71	<0.01	Stalk	
					71	<0.01	Seed	
(unknown)	0.56		N/A	1	68	<0.01	Stalk	
					68	<0.01	Seed	
	0.56		N/A	1	68	<0.01	Stalk	
					68	<0.01	Vines	
(Lincoln)	0.28		281	1	119	<0.01		
UK, 1964 Peas (Unknown)	1.68		N/A	1	0B*	<0.01	Pre-emergence	McKenna 1966
					152	<0.01 <0.01	Seed	
						<0.01 <0.01	Pod	
Australia, 1992 Field peas					0B*	<0.05	Post-emergence harvest aid	Markus 1993a AU10-93-H206
(Alma)	0.20		70	1	15	0.09	Seed	
						12	Whole plant	
					25	0.31	Seed	
						12	Whole plant	
	0.40		70	1	15	0.10	Seed	
						21	Whole plant	
					25	0.50	Seed	
						15	Whole plant	
Australia, 1993 Field peas					0B*	<0.05	Post-emergence harvest aid	Brown 1994b AU10-93-E204
(Dunn)	0.20		70	1	1	0.11	Seed	
						9.1	Straw	
					7	0.36	Seed	
						12	Straw	
					14	0.39	Seed	
						9.6	Straw	
					21	0.41	Seed	
						6.4	Straw	
	0.40		70	1	14	0.54	Seed	
						18	Straw	
					21	0.51	Seed	
						16	Straw	
ID, USA 1993					0B*	<0.05	Post-emergence harvest aid	Lurvey 1997 93-ID04
Dry Pea (Columbian)	0.56		240	1	7	0.16, 0.18, 0.20, 0.25		
	1.12		240	1	7	0.10, 0.11, 0.14, 0.17		
WA, USA 1993					0B*	<0.05	Post-emergence harvest aid	93-WA32
Dry Pea (D.S. perfection)	0.56		193	1	7	<0.05, 0.10, 0.13, 0.15		
	1.12		193	1	7	0.09, 0.12, 0.12, 0.16,		
CHICK PEA								
Australia, 1992 Chick Peas	0.20		70	1	0B*	<0.05	Post-emergence harvest aid	Markus 1993b MAP-GRA-92
(Amethyst)					38	0.23	Grain	
						1.0	Straw	
	0.40		70		38	0.44	Grain	
						4.0	Straw	

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Australia, 1993 Chick Peas (Desi)	0.20		70	1	0B*	<0.05	Post-emergence harvest aid	Brown 1994a AU10-94-H105
					16	0.05	Seed	
						1.4	Straw	
					22	<0.05	Seed	
						2.0	Straw	
	0.40		70	1	16	0.21	Seed	
						4.1	Straw	
					22	0.19	Seed	
						3.1	Straw	
SOYA BEANS								
Brazil, 1981 (UFV1)					0B*	<0.05	Harvest aid	Hayward & Robbins 1981a
	0.40		300	1	8	≤0.05	Beans	
					9	<0.05		
					10	<0.05		
					12	<0.05		
(Davis)	0.40			1	4	≤0.05	Beans	
(unknown)	0.80			1	4	<0.05	Beans	
(IAC4)	0.40			1	5	0.16	Beans	
(Parana)	0.40			1	10	0.08	Beans	
(Boussler)	0.40			1	8	0.28	Beans	
(Davis)	0.40			1	5	0.11	Beans	
Brazil, 1982 (Various)					0B*	<0.05	Harvest aid	Kennedy & Robbins 1982
	0.40		100	1	4	0.34	Beans	
			100		6	0.09		
			178		7	0.10		
			170		8	0.11		
			170		7	0.07		
			170		9	0.13		
Brazil, 1983 (Various)					0B*	<0.02	Harvest aid	Kennedy *et al.* 1983
	0.30		250	1	3	0.08	Beans	
			30	1	11	0.02		
	0.32		80	1	2	<0.02		
			200	1	5	<0.02		
			80	1	8	0.05		
	0.40		125	1	3	0.16		
			125	1	3	0.18		
			250	1	3	0.43		
			55	1	4	0.21		
			125	1	5	0.16		
			250	1	5	0.28		
			250	1	5	0.28		
			125	1	6	0.08		
			350	1	6	0.03		
			250	1	9	0.03		
			340	1	9	≤0.02		
			25	1	11	0.02		
			250	1	11	0.02		
			250	1	15	0.14		
			350	1	16	0.06		
			300	1	17	0.07		
			350	1	18	0.03		
			330	1	20	<0.02		
			330	1	21	<0.02		

Country, year Crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes and references	
Brazil, 1986 (Various)					0B*	<0.05	Harvest aid (+diquat) Beans	Earl & Muir 1988
	0.25		300	1	7	<0.05		88JH402
					7	<0.05		
					7	<0.05		
					7	<0.05		
					7	<0.05		
					8	<0.05		
					9	<0.05		
					9	<0.05		
					11	<0.05		
					13	<0.05		
MS, USA, 1992 (Asgrow 5979)					0B*	<0.05	Post-emergence harvest aid	Roper 1993l
	1.4		187	1	13	<0.05	Beans	
						<0.05	Unscreened beans	
						0.52	Dust, <2540 µm	
USA, 1987					OB*	<0.025	Pre-emergence, post-emergence directed	Roper 1989m
NE (Asgrow 3127)	1.1 pre 0.14 post			1+ 2				92NB-87-560
					52	<0.025	Forage	
					63	<0.025	Hay or fodder	
					88	<0.025	Seed	
IL (William 82)	1.1 pre 0.14 post			1+ 2				US04-87-561
					59	<0.025	Forage	
					59	<0.025	Hay or fodder	
					90	<0.025	Seed	
IA (Pioneer 9271)	1.1 pre 0.14 post			1+ 2				A1IA-87-562
					37	<0.025	Forage	
					84	0.2	Hay or fodder	
					84	0.03	Seed	
LA (Yield King 613)	1.1 pre 0.14 post			1+ 2				36LA-87-563
					19	0.05	Forage	
					48	0.1	Hay or fodder	
					63	<0.025	Seed	
MS (Centennial)	1.1 pre 0.14 post			1+ 2				US05-87-564
					65	<0.025	Forage	
					79	0.05	Hay or fodder	
					79	<0.025	Seed	
MO (Asgrow 3544)	1.1 pre 0.14 post			1+ 2				48MO-87-565
					53	<0.025	Forage	
					102	<0.025	Hay or fodder	
					102	<0.025	Seed	
AR (DPL 504)	1.1 pre 0.14 post			1+ 2				06AR-87-566
					74	<0.025	Forage	
					41	<0.025	Hay or fodder	
					109	<0.025	Seed	
AL (Braxton)	1.1 pre 0.14 post			1+ 2				62AL-87-567
					70	<0.025	Forage	
					138	<0.025	Hay or fodder	
					138	<0.025	Seed	
GA (Kirby)	1.1 pre 0.14 post			1+ 2				83GA-87-568
					34	<0.025	Forage	
					79	0.04	Hay or fodder	
					79	<0.025	Seed	
De (Pioneer 9441)	1.1 pre 0.14 post			1+ 2				44DE-87-569
					3	1.8	Forage	
					30	0.3	Hay or fodder	
					30	<0.025	Seed	

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
USA, 1997					0B*	<0.05	Pre-emergence; two post-emergence directed; one spot; one desiccation application	Spillner *et al.* 1999
	1.40 pre			1+				
	0.56 post			2+				
	0.05 spot			1+				
NC(Hyperformer	0.70 des			1	3	0.06	Seed	01-NC-97-610
574)					7	<0.05		50-TN-97-611
TN(Hutachson)					3	<0.05		49-AR-97-612
AR(AG5901)					3	0.09		69-LA-97-613
LA(Delta Pine					3	<0.05		63-IA-97-615
DP3478)					3	0.11		63-IA-97-616
IA(Pella)					3	0.05		63-IA-97-617
IA(D260)					1	0.07		04-IL-97-618
IA(L2233)					2	0.07		
IL(Asgrow A3237)					6	<0.05		
					11	0.07		
					15	0.05		
					3	0.06		60-IL-97-619
					3	<0.05		60-IL-97-620
IL(Asgrow 4401)					3	<0.05		67-IN-97-621
IL(Asgrow 2704					3	0.07		67-IN-97-622
STS)					3	<0.05		37-KS-97-623
IN(Pioneer 9342)					3	0.06		36-MN-97-624
IN(Alder 373)					3	<0.05		37-MO-97-625
KS(Ciba 373)					3	0.06		68-NE-97-626
MN(ICI D162)					3	<0.05		89-OH-97-627
MO(Ciba 3362)					3	<0.05		34-SD-97-628
NE(Pioneer 9281)					3	<0.05		79-WI-97-629
OH(Asgrow 3701)					1	0.25		05-MS-97-631
SD(Garst D210)					3	0.69		
WI(Asgrow					7	0.20		
XP19505)					11	0.16		
MS(Asgrow 5979)					17	0.16		
USA (unknown)					0B*	<0.01	Harvest aid desiccation	Chevron 1985
IA, 1975	0.28		327	1	15	<0.01, 0.03	Bean	T-3402A
LA, 1977	0.56		47	1	10	0.18, 0.23	Bean	T-3996
LA, 1977	0.28		47	1	10	0.11, 0.05 0.12, 0.23	Bean Hull	T-4145
GA, 1977	0.28		37	1	14	0.08 0.67	Bean Hull	T-4147
IA, 1977	0.28		28	1	19	0.04, 0.03 0.07, 0.08	Bean Hull	T-4191
IA, 1977	0.28		28	1	27	<0.01, <0.01 <0.01, <0.01	Bean Hull	T-4192
IL, 1977	0.28		28	1	22	0.03, 0.01 0.12, 0.08	Bean Hull	T-4193
IL, 1877	0.28		28	1	16	0.02, 0.02 0.05, 0.05	Bean Hull	T-4194
NE, 1978	0.28		47	1	14	0.05, 0.06	Bean	T-4716
IA, 1978	0.28		28	1	17	0.02, 0.01	Bean	T-4717
IL, 1978	0.28		47	1	7	0.02, 0.03	Bean	T-4729
IL, 1978	0.28		28	1	15	0.01, 0.02	Bean	T-4730
FL, 1978	0.28		28	1	11	<0.01, <0.01	Bean	T-4767
DE, 1978	0.28		47	1	8	0.15, 0.09	Bean	T-4811
DE, 1978	0.28		47	1	11	0.10, 0.10	Bean	T-4812

Country, year Crop (variety)	Application kg ai/ha	 kg ai/hl	 water, l/ha	 no.	PHI days	Paraquat mg/kg	Notes and references	
DE, 1978	0.28		47	1	36	0.12, 0.12	Bean	T-4813
GA, 1978	0.28		47	1	10	<0.01	Bean	T-4818
DE, 1978	0.56		280	1	19	<0.01, 0.03	Bean	T-4858
VA, 1979	0.28		47	1	16	0.07, 0.03	Bean Hull	T-4859
VA, 1979	0.28		47	1	17	0.03, 0.05 0.25, 0.28	Bean Hull	T-4860
OH, 1979	0.28		47	1	6	0.09, 0.07 0.36	Bean Hull	T-4861
OH, 1979	0.28		47	1	7	0.07, 0.08 0.34	Bean Hull	T-4862
IA, 1979	0.28		47	1	10	0.08, 0.07 0.43, 0.31	Bean Hull	T-4949
NE, 1979	0.28		47	1	8	0.07, 0.09 0.50, 0.34	Bean Hull	T-4950
GA, 1979	0.28		47	1	12	<0.01, <0.01	Bean	T-5001
SC, 1979	0.28		47	1	17	<0.01, 0.02	Bean	T-5002
SC, 1979	0.28		47	1	31	<0.01, <0.01	Bean Hull	T-5003
TX, 1979	0.28		47	1	6	0.05, 0.03	Bean	T-5007
IN, 1979	0.28		47	1	6	0.06, 0.08 0.36	Bean Hull	T-5011
IN, 1979	0.28		47	1	7	0.03, 0.05	Bean	T-5012
IN, 1979	0.28		47	1	8	0.04, 0.03	Bean	T-5013
TN, 1979	0.28		252	1	12 19	0.04, 0.04 0.08, 0.07	Bean	T-5014
MS, 1979	0.28		47	1	15	0.04, 0.04	Bean	T-5015
MS, 1979	0.28		47	1	6	0.01, 0.02	Bean	T-5016
FL, 1979	0.28		280	1	13 15	0.02, 0.03 0.03, 0.02	Bean	T-5017
VA, 1979	0.28		47	1	11	0.09, 0.13 0.47, 0.63	Bean Hull	T-5022
VA, 1979	0.28		47	1	28	0.05, 0.07 0.53, 0.56	Bean Hull	T-5023
IL, 1980	0.28		187	1	6 12 14	0.03, 0.02 0.04, 0.06 0.09, 0.08	Bean	T-5218
USA, 1988					B*		Harvest aid	Roper 1989n
						<0.05	Forage	
						<2	Hay	
						<0.05	Seed	
IL (Fayette)	2.24		38	1	0	20	Hay	22IL-88-458
					5	26	Forage	Ground
					10	24	Forage	application
					15	22	Forage	
					21	0.1	Seed	
IA (Pioneer 9271)	2.24		38	1	0	24	Forage	36IA-88-459
						45	Hay	Ground
					5	8	Forage	application
					10	9	Forage	
					15	9	Forage	
						0.05	Seed	
					B*	<25 <15 <0.05	Forage Hay Seed	

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
IN (Dekalb CX324)	2.24		38	1	0	78	Forage	23IN-88-460
					5	49	Forage	Ground
						70	Hay	application
					10	58	Forage	
					15	45	Forage	
						<0.05	Seed	
MS (DPL 506)	2.24		38	1	0	70	Forage	48MS-88-461
						124	Hay	Ground
					5	49	Forage	application
					10	88	Forage	
					15	73	Forage	
						0.05	Seed	
MO (Williams)	2.24		38	1	0	49	Forage	40MO-88-462
						29	Hay	Ground
					5	51	Forage	application
					11	54	Forage	
					15	43	Forage	
					20	0.1	Seed	
MN (Evans)	2.24		38	1	0	30	Forage	33MN-88-463
						16	Hay	Ground
					5	40	Forage	application
					10	29	Forage	
					15	24	Forage	
						0.1	Seed	
OH (unknown)	2.24		38	1	0	135	Forage	27OH-88-464
						140	Hay	Ground
					5	221	Forage	application
					10	125	Forage	
					15	161	Forage	
					36	2	Seed	
					B*	<0.05	Forage	
						<2	Hay	
						<0.05	Seed	
IL (Pioneer 9271)	2.24		38	1	0	20	Hay	22IL-88-536
					5	26	Forage	Aerial
					10	24	Forage	application
					15	22	Forage	
					21	0.1	Seed	
IA (Sieben SS-235)	2.24		38	1	0	0.12	Forage	36IA-88-537
						80	Hay	Aerial
					5	10	Forage	application
					10	15	Forage	
					15	9	Forage	
						0.2	Seed	
IN (Century)	2.24		38	1	0	29	Forage	24IN-88-538
					5	26	Forage	Aerial
						23	Hay	application
					10	25	Forage	
					15	13	Forage	
					25	<0.05	Seed	
MS (DPL 506)	2.24		38	1	1	38	Forage	48MS-88-539
						31	Hay	Aerial
					5	27	Forage	application
					10	47	Forage	
					15	33	Forage	
					15	0.2	Seed	
MO (Williams 82)	2.24		38	1	0	19	Forage	37MO-88-540
						38	Hay	Aerial
					5	10	Forage	application
					10	10	Forage	
					15	<5	Forage	
					19	0.1	Seed	

Country, year Crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes and references	
MN (BSR 101)	2.24		38	1	0	59	Forage	30MN-88-541 Aerial application
						2	Hay	
					5	23	Forage	
					10	23	Forage	
					15	22	Forage	
					22	0.08	Seed	
					B*	<1	Forage	
						<2	Hay	
						<0.05	Seed	
OH (Asgrow 3427)	2.24		38	1	0	15	Forage	27OH-88-542 Aerial application
						6	Hay	
					5	19	Forage	
					10	8	Forage	
					15	1	Forage	
						0.08	Seed	

B*=control

<u>Root and tuber vegetables</u>

Residue trials were carried out on <u>beetroot</u> in Canada and the UK using paraquat pre-sowing or pre-emergence at 1.12 or 1.7 kg ai/ha, followed (in the UK) with two applications directed inter-row at 2.2 kg ai/ha after crop emergence. Beetroots were harvested 84 to 112 days after the last application.

Similar trials were conducted on <u>sugar beet</u> in the UK with pre-sowing followed by inter-row weed control at rates up to 2.2 kg ai/ha. Beets were harvested 94 to 125 days after the last application. In seven trials in four different States of the USA, a single pre-emergence application was given to sugar beet at 1.12 kg ai/ha and, in one case, at 5.6 kg ai/ha. The crop was harvested 136 to 178 days after application.

Residue trials on <u>carrots</u>, using paraquat for pre-emergence or inter-row weed control, have been carried out in Canada, Germany, the UK and Japan. In one Japanese trial, a highly exaggerated rate of 19.2 kg ai/ha was used. In Germany in 1983 two applications were made to carrots for inter-row weed control at rates from 0.85 to 1.35 kg ai/ha with sampling of roots from 0 to 21 days after the second application, and in further trials in the same year paraquat was applied twice at 0.75 kg ai/ha, or at 0.71 and 0.98 kg ai/ha with roots harvested at intervals up to 22 days after the last application. In trials in Germany in 1984 paraquat was applied from one to three times with harvest after 0-22 days. In trials in Canada and the UK paraquat was applied 1-3 times for inter-row weed control at rates of 0.28 to 2.24 kg ai/ha.

Other residue trials were carried out on parsnips (UK), swedes (UK) and turnips (UK and Canada) using paraquat for pre-emergence weed control (Canada) or pre-emergence followed by inter-row weed control (UK). Rates of application were 0.56 to 2.24 kg ai/ha. In one trial in France on black salsify paraquat was applied as an inter-row treatment at 0.5 and 0.8 kg ai/ha. Salsify roots were harvested 8 and 30 days after treatment.

On potatoes paraquat is recommended for pre-emergence and early post-emergence directed for early and seed potatoes up to 10% emergence; directed for potatoes up to 40% emergence; or for harvest aid desiccation.

In a series of trials in Germany during 1990 paraquat was applied to six different varieties of potatoes, at BBA growth stage 11, for control of grasses and broadleaved weeds, at a rate of 0.40 kg ai/ha. Samples of potato tubers were harvested 59 to 131 days after application.

In trials in the UK in 1963 and 1965 paraquat was applied to potatoes as a post-emergence harvest aid at a rate of 0.56 to 6.72 kg ai/ha and sampled 14 to 41 days post application.

In several residue trials in Canada during 1963 and 1964 paraquat was applied for weed control by pre-emergence, post-crop emergence, or as a harvest aid at 0.20 to 1.12 kg ai/ha. Tubers were harvested 68 to 119 days after application.

In several residue trials in the USA during 1963, 1966, and 1988 paraquat was applied for weed control by pre-emergence, post-emergence directed, and/or harvest aid desiccation at 1.12 to 2.8 kg ai/ha. Tubers were harvested 45 to 83 days after application.

Table 32. Paraquat residues in root and tuber vegetables from supervised trials in Canada, France, Germany, Japan, the UK and the USA.

Country, year crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
BEET & SUGAR BEET								
Ontario, Canada,				1	0B*	<0.01	pre-emergence	Calderbank &
1963	0.56		539		86	<0.01	Root	McKenna 1964
Beetroot	1.12		539		82	<0.01		
(Detroit dark red)					86	<0.01		
UK, 1964	1.68 pre		N/A	1+	112	<0.01	Root	McKenna 1966
Beetroot	2.24			2		0.01	Tops	
(unknown)	direct							
UK, 1964	1.68 pre		N/A	2+	72	0.01	Root	McKenna 1966
Sugar beet	2.24			1		0.08	Tops	
(Klein)	direct							
	1.68 pre		N/A	2+	84	<0.01	Root	
	2.24			1		0.06	Tops	
	direct							
UK, 1967					0B*	<0.01	Pre-emergence	Edwards 1974
Sugar beet	0.26		340	1+				
(Klein E)	0.50		340	2	96	<0.01, <0.01, <0.01		Ref No 3635, 3636, 3637
	1.10		340	2	94	0.02, 0.02, <0.01, 0.03		Ref No 3411, 3412, 3418, 3419
	1.10		340	2	125	0.02, 0.03, 0.02, <0.01		Ref No 3653, 3654, 3655, 3656
ID, USA, 1988	5.6		N/A	1	0B*	<0.05, <0.025		Roper 1989c
Sugar Beet					137	<0.05	Unwashed Root	16ID88-599
(HH-32(Holly))						<0.05	Unwashed Root**	
						<0.05	Washed Root**	
						<0.025	Wet pulp	
						<0.05	Dry pulp	
						<0.05	Molasses	
						<0.025	Sugar	
USA, 1988	1.12		N/A	1	0B*	<0.025	Pre-emergence	Roper 1989c
Sugar Beet					136	≤0.05	Root	33MN88-405
(unknown)						<0.025	Top	
					138	≤0.05	Root	33ND88-406
						<0.025	Top	
					151	≤0.05	Root	17CA88-403
						<0.025	Top	
					152	≤0.05	Root	34ND88-407
						<0.025	Top	
					160	≤0.05	Root	16ID88-404
						<0.025	Top	
					178	≤0.05	Root	73CA88-402
						<0.025	Top	

Country, year crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CARROT								
NB, Canada, 1963					0B*	<0.01	pre-emergence	Calderbank &
(Gold Pak)	0.28		674	1	104	<0.01	Root	McKenna 1964
						<0.01	Tops	
	0.56		674		104	<0.01	Root	
						<0.01	Tops	
UK, 1963					0B	<0.01	Harvest aid	Calderbank &
(unknown)	0.56		1210	1	26	0.03	Root	McKenna 1964
	0.84		1210	1	26	0.08		
Ontario, Canada,					0B*	<0.01	Root	McKenna 1966
1964	2.24		935	1	36	<0.01		
(Long Hyperator)								
UK, 1964					0B*	<0.01	Pre-sowing	McKenna 1966
(unknown)	1.68			1	144	0.02	Root	
						0.14	Tops	
							Pre-emergence &	
	1.68 pre			1+			inter-row	
	2.24			2	63	0.02	Root	
	direct					0.22	Tops	
Japan, 1973					0B*	<0.03		Edwards 1974
(Karuda Gosun)	0.96		N/A	2	113	<0.03		
				3	5	<0.03		
				3	5	<0.03		
	19.2		N/A	1	11	<0.03		
					140	<0.03		
Germany, 1983	1.00		1000	2	0B*	<0.01	Post-emergence	Swaine 1983b
					4	<0.01	Root	RS8378B2
(Caramba)					9	<0.01		
					14	<0.01		
					22	<0.01		
(Elfie)	0.85		850	1+				RS8378E4
	0.95		950	1	0	0.14	Root	
					4	<0.01		
					9	<0.01		
					14	<0.01		
					21	<0.01		
(Karotan)	1.35		1350	1+				RS8378E5
	1.10		1000	1	0	0.02	Root	
					3	0.02		
					7	<0.01		
					11	<0.01		
					15	0.01		
Germany, 1983					0B*	<0.02		Kennedy 1984b
	0.98		3250	1+	0	<0.02		RS8372E4
(Nantaise)	0.71		2350	1	4	<0.02		
					9	0.02		
					14	<0.02		
					21	<0.02		
(Caramba)	0.75		2500	1+	0	<0.02		RS8372B3
	0.75		1250	1	4	<0.02		
					9	<0.02		
					14	<0.02		
					22	<0.02		
(Caramba)	0.75		2500	1+	0	<0.02		RS8372B4
	0.75		1250	1	4	<0.02		
					9	<0.02		
					14	<0.02		
					22	<0.02		

Country, year crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
Germany, 1984								
(Lange Rote)	0.75		2500	3	0	<0.01		RS8427B5
					4	<0.01		
					9	<0.01		
					14	<0.01		
(Tip-top)	0.75		1200	1	0	<0.01		RS8427E4
					4	0.01		
					8	<0.01		
					13	<0.01		
					19	0.01		
Germany, 1984	1.00		1000	1	0	0.01		Massey 1987b
					4	0.02		RS8423E5
(Tip-top)					8	0.01		
					13	0.03		
					19	0.01		
(Minota)				2	4	<0.01		RS8423B2
					10	<0.01		
					14	<0.01		
					22	<0.01		
(Nantaise)				3	0	0.01		RS8423B4
					4	0.01		
					9	<0.01		
					14	<0.01		
					21	<0.01		
POTATO								
Germany, 1990 (Hansa)	0.40		400	1	0B*	<0.01	Post-emergence directed	Earl & Anderson 1991
					71	<0.01	Tuber	Rs9024B1
					93	<0.01		
Germany, 1990 (Cilena)	0.40		400	1	0B*	<0.01	Post-emergence directed	Earl & Anderson 1991
					76	<0.01	Tuber	Rs9024B2
					100	<0.01		
Germany, 1990 (Hela)	0.40		400	1	0B*	<0.01	Post-emergence directed	Earl & Anderson 1991
					59	<0.01	Tuber	Rs9024B3
					77	<0.01		
Germany, 1990 (Rebecca)	0.40		400	1	0B*	<0.01	Post-emergence directed	Earl & Anderson 1991
					71	<0.01	Tuber	Rs9024G1
					131	<0.01		
Germany, 1990 (Agria)	0.40		400	1	0B*	<0.01	Post-emergence directed	Earl & Anderson 1991
					73	<0.01	Tuber	Rs9024G2
					115	<0.01		
Germany, 1990 (Nicola)	0.40		400	1	0B*	<0.01	Post-emergence directed	Earl & Anderson 1991
					74	<0.01	Tuber	Rs9024G3
Ontario, Canada,					0B*	<0.01	Pre-emergence	Calderbank &
1963	0.56		281	1	122	<u><0.01</u>	Tuber	McKenna 1964
(Sebago)	0.56		281	1	123	<u><0.01</u>		
	1.12		281	1	100	<0.01		
	1.12		281	1	101	<0.01		
	1.12		281	1	108	<0.01		

Country, year crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
Ontario, Canada, 1963					0B*	<0.01	Early post-emergence	Calderbank & McKenna 1964
(Sebago)	0.28		281	1	101	<0.01	directed	
					118	<0.01	Tuber	
	0.28		281	1	107	<0.01		
					119	<0.01		
(unknown)	0.56		281	1	68	0.02		
(Sebago)	0.56		281	1	79	<0.01		
					98	<0.01		
	0.56		281	1	92	<0.01		
					104	<0.01		
(unknown)	1.12		281	1	86	<0.01		
(Majestic)	1.12		281	1	90	<0.01, <0.01		
Canada, 1963 (Netted Gem)					0B*	<0.01	Harvest aid	Calderbank & McKenna 1964
NB	0.20		674	1	28	<0.01	Tuber	
BC	0.28		1123	1	20	<0.01		
NB	0.40		674	1	28	<0.01		
BC	0.56		1123	1	20	<0.01		
PEI (Green	0.28		1348	1	28	<0.01		
Mountain)	0.56		1348	1	28	0.07		
	0.84		1348	1	28	0.06		
Ontario	0.28		1123	1	16	0.02, 0.04		
(Katahdin)	0.56		1123	1	16	0.04, 0.04		
	0.84		1123	1	16	0.03, 0.04		
BC (Kennebec)	0.28		1123	1	20	0.02		
	0.56		1123	1	20	0.02		
UK, 1963					0B*	<0.01	Harvest aid	Calderbank & McKenna 1964
(King Edward)	1.12		1123	1	14	0.06, 0.07, 0.09, 0.09, 0.10, 0.10, 0.10, 0.13, 0.14, 0.20		
(Majestic)	0.56		225	1	27	0.02, 0.05		
					34	0.04, 0.04		
					41	0.03, 0.03, 0.03, 0.04		
	1.12		225	1	27	0.03, 0.04		
					34	0.02, 0.06		
					41	0.03, 0.04, 0.05, 0.05		
(Cobbler)	0.56		449	1	23	0.02, 0.04, 0.07		
	0.84		449	1	23	0.03, 0.07		
(Warba)	0.56		449	1	23	0.04, 0.04		
	0.84		449	1	23	0.04, 0.05, 0.05, 0.06		
(King Edward)	0.56		225	1	40	0.06, 0.06		
	1.12		225	1	40	0.06, 0.06, 0.08		

Country, year crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
Ontario, Canada, 1964					0B*	<0.01	Early post-emergence directed	McKenna 1966
(Kennebec)	0.56		234	1	110	≤0.01		
	1.12		234	1	108	<0.01		
(Norland)	0.28		75.8	1	84	<0.01		
	0.56		75.8	1	84	≤0.01		
	0.56		75.8	1	98	≤0.01		
(Sebago)	0.56		234	1	117	≤0.01		
	1.12		234	1	106	<0.01		
Ontario, Canada, 1964							Harvest aid	McKenna 1966
(Netted Gem)	2.24			1	30	0.03		
	4.48			1	30	0.04		
	0.42			1	30	0.05		
(Norland)	0.42		468	1	22	<0.01		
(Katahdin)	0.42		468	1	14	0.02		
(Kennebec)	0.42		468	1	14	0.02		
(Sebago)	0.42		468	1	12	0.11		
UK, 1965 (Maris Peer)					0B*	<0.01	Harvest aid	McKenna 1966
	0.84		562	1	31	0.04, 0.06, 0.04, 0.08, 0.04, 0.06		
	1.68		562	1	31	0.05, 0.04, 0.07, 0.04, 0.08, 0.14, 0.04, 0.07		
	3.36		562	1	31	0.07, 0.07, 0.07, 0.09, 0.04, 0.06		
	6.73		562	1	31	0.09, 0.06, 0.10, 0.09, 0.08, 0.05, 0.10, 0.08		
USA, 1963					0B*	<0.01	Pre-emergence	Chevron 1967
NJ (Green Mountain)	1.12		468	1	45	<0.01	Tuber	T-387
					95	<0.01		
FL (unknown)	1.12		468	1	52	<0.01		T-388
					72	<0.01		
USA, 1966					0B*	<0.01	Early post-emergence	
NJ (Katahdin)	1.12		321	1	83	<0.01	Tuber	T-1193
NJ (Katahdin)	1.12		277	1	82	<0.01		T-1194
NJ (Katahdin)							Post-emergence	Chevron 1967
	1.12		321-331	2	56	0.01	Tuber	T-1195
	1.12		277-331	2	62	0.01		T-1196
							Post-emergence; then harvest aid	
NJ (Katahdin)	1.12		321-556	2+ 1	3	0.01	Tuber	T-1197
	1.12		277-556	2+ 1	3	0.02		T-1198
CA (CA long white)	1.12		468	2+ 1	3	0.04		T-1174
ID, USA, 1988 (Russet Burbank)							Harvest aid	Roper 1989b 16ID88-400
					0B*	<0.05	Unwashed tuber	
						<0.025	Washed tuber	
	2.8			1	7	<0.05	Unwashed tuber from field	
						<0.05	Unwashed tuber from processor	
						0.05	Washed tuber from processor	

Country, year crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
ME, USA, 1988							Harvest aid	Roper 1989b
(Superior)					0B*	<0.05	Unwashed tuber	56ME88-401
						<0.05	Washed tuber	
	2.8		N/A	1	7	0.11	Unwashed tuber from field	
						0.22	Unwashed tuber from processor	
						0.10	Washed tuber from processor	
OTHER ROOT AND TUBER VEGETABLES								
Ontario, Canada,					0B*	<0.01	pre-emergence	Calderbank &
1963	0.56		281	1	122	<0.01	Root	McKenna 1964
Turnip	1.12		281	1	101	≤0.01		(Winona)
(Laurentian)								
	1.12		281	1	108	≤0.01		(Arthur)
Ontario, Canada,					0B*	<0.01	post-emergence	Calderbank &
1963	0.56		281	1	80	<0.01	Root	McKenna 1964
Turnip					97	<0.01		(Winona)
(Laurentian)								
	0.56		281		92	<0.01		(Arthur)
					104	<0.01		
UK, 1964	1.68 pre		N/A	1+	64	<0.01	Roots	McKenna 1966
Turnips	2.24			1		0.02	Tops	
(unknown)	direct							
	1.68 pre		N/A	1+	49	<0.01	Roots	
	2.24			2		0.03	Tops	
	direct							
UK, 1964							Pre-sowing+	McKenna 1966
Parsnips							inter-row	
(unknown)	1.68 pre		N/A	1+	116	<0.01	Root	
	2.24			1		0.18	Tops	
	direct							
UK, 1964	1.68 pre		N/A	2+	54	0.01	Root	McKenna 1966
Swedes	2.24			2		0.10	Tops	
(Wilhelmsburger)	direct							
	1.68 pre		N/A	2+	72	0.01	Root	
	2.24			1		0.04	Tops	
	direct							
France, 1988					0B*	<0.02		Benet 1989
Scorzonere/								FR 10/88H
BlackSalsify	0.50		300	1	8	<0.02	Root	
(Benstar)					30	<0.02		
	0.80		300	1	8	<0.02		
					30	<0.02		

*B: control
** from processor

Stalk and stem vegetables

Paraquat is recommended as a pre-emergence or post-emergence directed inter-row treatment for stem vegetables.

Residue trials have been carried out on asparagus, celery, and globe artichokes in Canada and the USA using paraquat for post-emergence directed inter-row weeding with single applications of 1.12 to 3.25 kg ai/ha to asparagus and celery, and three applications of 1.12 or 1.34 kg/ha to artichokes.

Table 33. Paraquat residues in stalk and stem vegetables from supervised trials in Canada and the USA.

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Ontario, Canada, 1963 Asparagus (Waltham)	1.12		281	1	0B*	<0.05	Pre-emergence directed	Calderbank & McKenna 1964
					103	≤0.05	Stalk	
						<0.05	Fern	
Ontario, Canada, 1964 Asparagus (Waltham)	1.12		234	1	0B*	<0.02	Pre-emergence	Chevron 1970 T-1403
					70	≤0.02		
USA, 1969 Asparagus					0B*	<0.02	Pre-emergence	Chevron 1970 T-1839
MI (California 711)	1.12		337	1	25	≤0.02, <0.02		T-1838
CA (U-72)	2.24		1870	1	8	<0.02, 0.02		T-1837
CA (U-72)	3.25		1870	1	8	<0.03, <0.03		
Ontario, Canada, 1964 Celery (Mixed)	2.24		935	1	0B*	<0.05	Post-emergence	McKenna 1966
					36	<0.05	Stalk	
CA, USA					0B*	<0.05	Post-emergence directed	Lurvey 1996
1992 Globe Artichoke (unknown)	1.12		187	3	1	<0.05		92:CA:126
	1.35		627	3	1	<0.05		92:CA:125

*B: control

Cereals

Maize. Paraquat is recommended for use in the cultivation of maize during pre-plant or pre-emergence treatment, post-emergence directed or guarded spray for inter-row weed control, or as a harvest aid desiccation.

Two residue trials were conducted on maize in Italy in 1993 in which paraquat was applied at a rate of 0.92 kg ai/ha to the seed bed one day before sowing. Maize silage and cobs were sampled 104 and 136 days after treatment respectively.

Residue trials were carried out in Canada in 1963 on pre-emergence weed control using a rate of 1.12 kg ai/ha, with harvest after 101 to 107 days, and post-emergence at 0.28-1.12 kg ai/ha (harvest 68-122 days). In the following year, similar trials on post-emergence weed control were at 0.56 to 2.2 kg ai/ha. Cobs were harvested 25 to 63 days after application.

A trial was carried out in the UK in 1964 with two pre-sowing applications of 1.7 kg ai/ha followed by a similar directed application of 2.2 kg ai/ha after crop emergence. Maize grain was harvested 84 days after the last application.

Several trials were conducted over several years in several locations in the USA. In 1987 paraquat was applied as a pre-emergence spray at 1.12 kg/ha followed by two post-emergence directed spays at 0.31 kg/ha and sampled after 28 to 95 days. In 1998 one or two post-emergence sprays were used at 0.56 kg ai/ha. In 1972-74 paraquat was applied as a harvest aid desiccation at rates of 0.56 to 1.12 kg/ha and sampled 3 to 27 days after application. Residue levels of paraquat in fodder, cob, grain, oil, and other processed fractions were measured.

Table 34. Paraquat residues in maize from supervised trials in Canada, Italy, South Africa, the UK and the USA.

Country, year (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
Italy, 1993					0B*	<0.05	Pre-emergence	Anderson & Lant 1994
(Pioneer 3471)	0.92		521	1	104	<0.05	Silage	IT10-93-H385
					136	<0.05	Cob	
(Pioneer 3471)	0.92		483	1	104	<0.05	Silage	IT10-93-H386
					136	<0.05	Cob	
Canada, 1963					0B*	<0.01	Pre-emergence	Calderbank & McKenna 1964
Ontario (Golden glow)	1.02		281	1	101	≤0.01	Seed	
						<0.01	Straw	
Ontario (Gloden glow)	1.12		281	1	107	≤0.01	Seed	
						<0.01	Straw	
Ontario (Golden glow)							Post-emergence	
	0.56		561	1	71	≤0.01	Seed	
	0.56		281	1	96	≤0.01	Seed	
						<0.01	Straw	
Ontario (Golden glow)	0.56		281	1	97	≤0.01	Seed	
						<0.01	Straw	
	0.56		281	1	92	≤0.01	Seed	
						<0.01	Straw	
Manitoba (unknown)	0.56		-	1	68	≤0.01	Seed	
	1.12				86	<0.01	Seed	
Ontario (Warwick 605)	0.28		562	1	122	<0.01	Seed	
	0.70		562	1	122	≤0.01	Seed	
	1.12		562	1	122	<0.01	Seed	
France (INRA260)							Harvest aid	
	0.30		39	1	15	0.18	Grain	
	0.49		39	1	15	0.23	Grain	
Canada, 1964					0B*	<0.01	Post-emergence directed	McKenna 1966
(unknown)	1.12		468	1	60	<0.01	Cob	
						0.01, 0.02	Stalk	
	0.56		477	1	49	0.02	Cob	
	1.12		477	1	49	0.13	Cob	
Ontario (unknown)	1.4		935	1	25	<0.02	Cob	
						1.0	Stalk	
	1.4		1870	1	25	<0.01	Cob	
	1.4		935	1	25	0.23	Stalk	
	2.2		935	1	63	<0.01	Cob	
						<0.01	Stalk	
South Africa, 1965 (unknown)	0.28		93.5	1	60	0.04	Seed	
	0.56		93.5	1	60	0.08	Seed	
UK, 1964					0B*	<0.01	Pre-emergence followed by post-emergence directed	McKenna 1966
(Sweet corn)	1.68 pre			2+				
	2.24 post			1	84	<0.01	Seed	
						<0.01	Sheaths & stalks	
(Forage corn)	1.68 pre			1+				
	2.24 post			1	84	<0.01	Cob	
						0.07 (wet)	Sheath & stalks	
						0.21 (dry)		

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
USA, 1987					0B*	<0.025	Pre-emergence followed by 2 post-emergence directed sprays	Roper, 1989f A1IA-87-538
IA (Pioneer 3295)	1.12pre			1+				
	0.31post			2	43	<0.025	Forage	
						<0.025	Silage	
					79	<0.025	Kernels	
						<0.025	Fodder	
MI (Jacques)	1.12pre			1+				71MI-87-539
	0.31post			2	36	0.09	Forage	
						0.04	Silage	
					83	<0.025	Kernels	
						0.06	Fodder	
MD (Dekalb 524)	1.12pre			1+				64SD-87-540
	0.31post			2	39	<0.025	Forage	
					41	<0.025	Silage	
					95	<0.025	Kernels	
					95	<0.025	Fodder	
NB (NK9540)	1.12pre			1+				92NB-87-541
	0.31post			2	33	<0.025	Forage	
					47	<0.025	Silage	
					93	<0.025	Kernels	
						<0.025	Fodder	
WI (High Lysine 32)	1.12pre			1+				A1WI-87-543
	0.31post			2	51	<0.025	Forage	
						<0.025	Silage	
					86	<0.025	Kernels	
						<0.025	Fodder	
IL (Pioneer 3540)	1.12pre			1+				US04-87-544
	0.31post			2	28	<0.025	Forage	
					49	<0.025	Silage	
					80	<0.025	Kernels	
					80	<0.025	Fodder	
GA (Pioneer 3165)	1.12pre			1				83GA-87-557
	0.31pos			2	30	<0.025	Forage	
					41	<0.025	Silage	
					70	<0.025	Kernels	
					70	<0.025	Fodder	
NC (Pioneer 3369A)	1.12pre			1				61NC-87-558
	0.31pos			2	35	<0.025	Forage	
					35	<0.025	Silage	
					71	<0.025	Kernels	
					71	<0.025	Fodder	
TX (Pioneer 3380)	1.12pre			1				72TX-87-559
	0.31pos			2	63	<0.025	Forage	
					63	<0.025	Silage	
					93	<0.025	Kernels	
					93	<0.025	Fodder	
USA, 1988					B*	<0.025	Post-emergence directed	Roper 1989g
IA (Garst 8383)	0.56			1	0	2	Forage	35IA-88-440
					7	2		
					14	0.5		
					21	0.6		
					22	0.3	Silage	
	0.56			2	48	<0.025	Kernels	
						1	Fodder	

Country, year (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
IL (Agrigold A6445)	0.56			2	0	2		21IL-88-441
					7	3	Forage	
					14	2		
					21	3		
						1	Silage	
					56	≤0.025	Kernels	
						1	Fodder	
NE (NC+511)	0.56			2	0	0.6	Forage	41NB-88-442
					26	0.3		
					29	0.2	Silage	
					35	≤0.025	Kernels	
						0.2	Fodder	
OH (unknown)	0.56			2	0	1	Forage	25OH-88-443
					7	3		
					14	0.1		
					21	0.08		
					34	0.07	Silage	
					76	≤0.025	Kernels	
					76	0.03	Fodder	
SC (Pioneer 3165)	0.56			2	14	≤0.025	Kernels	46SC-88-444
						6	Fodder	
NC (Pioneer 3165)	0.56			2	0	0.3	Forage	47NC-88-445
					6	2		
					14	0.1		
					21	0.1		
					6	0.05	Silage	
					47	≤0.025	Kernels	
					47	0.05	Fodder	
SC (Pioneer 3165)	0.56			2	14	≤0.025	Kernels	46SC-88-446
					14	2	Fodder	
US, 1972					0B*	<0.01	Harvest aid	Chevron 1975b
GA (Coker 71)	0.56		47	1	7	0.03	Grain	T-2228
						3.2	Fodder	(pre-emergence x1)
	1.12		47	1	3	0.05	Grain	
					7	0.04	Grain	
						5.6	Fodder	
MS (Funks G-4761)	0.56		150	1	7	0.04	Grain	T-2229
	1.12		150	1	3	0.03	Grain	
					7	0.05	Grain	
IA (Pioneer 3369A)	0.56		187	1	7	0.03	Grain	T-2230
	1.12		187	1	3	0.05	Grain	
					7	0.07	Grain	
IL (Dekalb XL-66)	0.56		93	1	8	0.04	Grain	T-2231
						2.5	Fodder	
	1.12		93	1	3	0.05	Grain	
					8	0.03	Grain	
						4.4	Fodder	
USA, 1973					0B*	<0.01	Harvest aid	
IL (unknown)	0.56		23	1	7	<0.01	Grain	T-2789
						7.4	Fodder	
MS (Funks G-4761)	0.56		187	1	7	<0.01	Grain	T-2790
						7.8	Fodder	
						<0.01	Cobs (w/o kernel)	
GA (Coker 67)	0.56		47	1	7	0.01	Grain	T-2791
						1.1	Fodder	
IL (Funks G-4646)	0.56		28	1	7	0.01	Grain	T-2792
					8	6.8	Fodder	
					7	<0.01	Refined oil	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
MN (Funks 4433)	0.56		47	1	8	0.04	Grain	T-3106
						<0.01	Solvent extracted oil	
							Corn gluten feed	
						0.11	Grain	
	1.12		47	1	8	0.07	Solvent extracted oil	
						<0.01	Corn gluten feed	
						0.19		
IA (Pioneer 3366)	0.56		47	1	27	0.06	Grain	T-3108
						<0.01	Solvent extracted oil	
							Germ cake after	
						0.02	extraction	
							Bran	
						0.06		

*B: control

Sorghum. Paraquat is recommended for use in the cultivation of sorghum as a pre-plant or pre-emergence treatment, as a post-emergence directed or guarded spray for inter-row weed control, or as a harvest aid desiccation.

Several residue trials were carried out in the USA over several years and locations in which paraquat was applied for weed control, either pre-emergence or post- directed, or as a harvest aid at rates of 0.21 to 7.8 kg ai/ha. In the pre-emergence or the post-emergence directed trials, sorghum was sampled 20 to 131 days post application. For harvest aid desiccation, paraquat was applied at rates of 0.21 to 2.8 kg/ha, with sampling 7 to 49 days after application. Residue levels of paraquat in fodder, silage, forage hay, hulls, and other processed fractions were measured.

Table 35. Paraquat residues in sorghum from supervised trials in the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	No.				
USA, 1967					0B*	<0.01	Post-emergence directed	Kalens *et al.* 1971
MS (BR-62)	0.56		280	1	48	<0.01	Forage	T-1286
					105	<0.01	Grain	
						<0.01	Fodder	
OK (RS 612)	0.56		280	1	35	0.01	Forage	T-1287
					105	<0.01	Grain	
						<0.01	Fodder	
TX (RS 671)	0.56		374	1	75	<0.01	Forage	T-1288
					106	<0.01	Grain	
						<0.01	Fodder	
MS (unknown)	0.56		280	1	49	<0.01	Forage	T-1289
					106	<0.01	Grain	
						<0.01	Fodder	
USA, 1971					0B*	<0.01	Pre-emergence followed by post-emergence directed	Kalens *et al.* 1971
MS (Funks BR 79)	0.28 pre		234	1+	36	<0.01	Forage	T-2155
	0.28 post			1	86	<0.01	Grain	
						<0.01	Fodder	
	0.56 pre		234	1+	36	<0.01	Forage	
	0.56 post			1	86	<0.01	Grain	
						0.01	Fodder	
TX (RS 671)	0.28 pre		206	1+	63	<0.01	Forage	T-2156
	0.28 post			1	131	<0.01	Grain	
						<0.01	Fodder	
	0.56 pre		206	1+	63	<0.01	Forage	
	0.56 post			1	131	0.01, 0.01	Grain	
						0.02, 0.02	Fodder	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	No.				
TX (DeKalb E 56)	0.56 pre 0.28 post		206	1+ 1	40 131	<0.01 <0.01 <0.01	Forage Grain Fodder	T-2157
TX (NK 222)	0.56 pre 0.56 post		206	1+ 1	40 67	<0.01 <0.01 <0.01	Forage Grain Fodder	T-2159
USA, 1969					0B*	<0.01	Harvest aid	Anon 1975a
CA (Lindsay 744)	0.21 0.43		206 206	1 1	7 21 7 21	0.04 0.04 0.11 0.06	Grain	T-1863
CA (Lindsay 744)	0.21 0.43		206 206	1 1	7 21 7 21	0.03 0.02 0.11 0.03	Grain	T-1864
TX (DeKalb C42)	0.21 0.43		9 9	1 1	7 21 7 21	0.22 0.04 0.67 0.57	Grain	T-1865 (air)
TX (DeKalb C42)	0.21 0.43		9 9	1 1	7 21 7 21	0.17 0.12 0.58 0.31	Grain	T-1866 (air)
NE (unknown)	0.21 0.43		47 47	1 1	7 21 7 21	0.08 0.07 0.36 0.13	Grain	T-1867 (air)
NE (unknown)	0.21 0.43		47 47	1 1	7 21 7 21	0.14 0.09 0.41 0.09	Grain	T-1868 (air)
USA, 1970					0B*	<0.008	Harvest aid	Anon 1975a
TX (DeKalb F65A)	0.21		47	1	7 24	0.47 0.06 2.5 0.94 0.27 0.05 1.0 0.43	Grain Flour Bran Shorts Grain Flour Bran Shorts	T-2004 (air)
CA (unknown)	0.21		47	1	7 21	0.71 0.31 0.39 0.25	Grain Flour Grain Flour	T-2005 (air)
USA, 1973					0B*	<0.01	Harvest aid	Anon 1975a
IA (unknown)	0.43		28	1	7	2.0 10	Grain Fodder & Forage	T-2778 (air)
NE (Pioneer 878)	0.43		28	1	8	2.5 0.10 6.0 8.4 0.86 5.6	Grain Flour Bran Shorts Germ Fodder	T-2779 (air)
IL (unknown)	0.43		131	1	7	28	Fodder	T-2780

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	No.				
NE (various)	1.12		234	1	24	0.16, 0.28, 0.22, 0.19, 0.26, 0.15	Grain	T-2977
						0.85, 0.49, 1.3, 0.69, 0.52, 0.91	Fodder	
	1.12		234	1	40	0.05	Grain (broadcast)	
						0.22	Fodder (broadcast)	
						0.06	Grain (direct)	
						0.18	Fodder (direct)	
					49	0.07	Grain (broadcast)	
						0.30	Fodder (broadcast)	
						0.07	Grain (direct)	
						0.26	Fodder (direct)	
USA, 1974					0B*	<0.01	Harvest aid	Anon 1975a
KA (Pioneer)	0.43pre		28	1+	7	1.3	Grain	T-3129
	0.43			1		3.7	Fodder	(air)
KA (Pioneer)	0.56 pre		28	1+	7	2.1	Grain	T-3130
	0.43			1		5.0	Fodder	(air)
NE (Prairie Valley 500)	0.43		28	1	7	2.0	Grain	T-3131
						4.8	Fodder	(air)
USA, 1987					0B*	<0.025	Pre-emergence and then post-emergence directed	Roper 1989k
TX (Pioneer 8493)	1.12 pre			1+				
	0.56 post			2	52	<0.025	Forage	72TX-87-570
						0.025	Silage	
						<0.025	Hay	
					86	<0.025	Fodder	
						≤0.025	Grain	
NE (DeKalb DK41V)	1.12 pre			1+				92NB-87-571
	0.56 post			2	48	<0.025	Forage	
						0.025	Silage	
					62	0.06	Hay	
					73	0.03	Fodder	
						≤0.025	Grain	
KS (Paymaster 1022)	1.12 pre			1+				48KS-87-572
	0.56 post			2	20	0.025	Forage	
						0.04	Silage	
					25	<0.025	Hay	
					72	0.06	Fodder	
						≤0.025	Grain	
SD (Sokota 910GS)	1.12 pre			1+				64SD-87-573
	0.56 post			2	22	0.025	Forage	
						0.025	Silage	
						<0.025	Hay	
					67	0.03	Fodder	
						≤0.025	Grain	
	7.85 pre			1+				64SD-87-573
	3.92 post			2	67	<0.025	Grain	E
NE (NC+172)	1.12 pre			1+				92NB-87-574
	0.56 post			2	29	0.06	Forage	
						0.04	Silage	
					41	0.09	Hay	
					65	<0.025	Fodder	
						≤0.025	Grain	
	7.85 pre			1+				92NB-87-574
	3.92 post			2	65	<0.025	Grain	E
MO (Stauffer 530)	1.12 pre			1+				06MO-87-575
	0.56 post			2	44	0.04	Forage	
						0.2	Hay	
					56	<0.025	Fodder	
						≤0.025	Grain	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	No.				
AZ (Funks	1.12 pre			1+				38AX-87-576
G522DR Hybrid)	0.56 post			2	35	<0.025	Forage	
						<0.025	Silage	
						0.04	Hay	
					61	<0.025	Fodder	
						<0.025	Grain	
AL (Funks	1.12 pre			1+				62AL-87-578
GB125)	0.56 post			2	23	<0.025	Forage	
						<0.025	Hay	
					70	<0.025	Fodder	
						<0.025	Grain	
AR (Stauffer 530)	1.12 pre			1+				06AR-87-579
	0.56 post			2	35	<0.025	Forage	
						<0.025	Hay	
					59	<0.025	Fodder	
						<0.025	Grain	
NC (Northrup	1.12 pre			1+				US01-87-580
King 2660)	0.56 post			2	36	0.025	Forage	
						0.025	Silage	
						0.04	Hay	
					61	0.05	Fodder	
						<0.025	Grain	
IL (Pioneer 6790)	1.12 pre			1+				US04-87-581
	0.56 post			2	32	<0.025	Forage	
						<0.025	Hay	
					39	<0.025	Silage	
					71	<0.025	Fodder	
						<0.025	Grain	
AZ (Dekalb	1.12 pre			1+				
DK42V)	0.56 post			2	28	0.2	Forage	
						0.34	Silage	
						0.2	Hay	
					48	0.1	Fodder	
						<0.025	Grain	
USA, 1988					0B*	<0.5; <1; <10	Harvest aid	Roper 1989j
TX (Golden Acres	2.8			1	3	12.5	Whole grain from field	11TX88-793
FE Y75)							Whole grain from	
						10.4	processor	
							Dry milled bran	
						69.7	Coarse grits	
						3.3	Flour	
						3.6	Wet milled bran	
						44.8	Starch	
						1.4		
NE (NK2230)	2.8			1	7	26.4	Whole grain from field	41NB88-794
							Whole grain from	
						9.2	processor	
							Hulled grain	
						1.8	Dry milled bran	
						51.6	Coarse grits	
						2.2	Flour	
						2.5	Wet milled bran	
						23.8	Starch	
						0.7		
USA, 2000					0B*	<0.02 grain	Pre-emergence	Carringer &
						<0.5 stover	followed by a harvest	Yuen 2001
							aid desiccation	
NC (DK36)	1.12pre		184	1+	3	14	Grain	PARA-00-MR
	1.12post		184	1		18	Stover	-01-343

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	No.				
MS (Terral TV1050)	1.12pre 1.12post		226 237	1+ 1	3	304 13 2.5, 2.9, 3.2 2.6, 2.6, 2.5 81, 106, 107	Grain Stover Grain, dirty Grain, cleaned Aspirated grain fraction	PARA-00-MR -01-344
IL (Northrup King KS585)	1.12pre 1.12post		193 195	1+ 1	3	4.5 18	Grain Stover	PARA-00-MR -01-345
NE (NK 1486)	1.12pre 1.12post		93 91	1+ 1	3	4.6 23	Grain Stover	PARA-00-MR -01-346
NE (NK 1486)	1.12pre 1.12post		321 313	1+ 1	1 3 7 14	8.4 24 6.7 19 6.0 15 4.1 9.9	Grain Stover Grain Stover Grain Stover Grain Stover	PARA-00-MR -01-347
KS (NC+6B70)	1.12pre 1.12post		280 280	1+ 1	3	1.9 16	Grain Stover	PARA-00-MR -01-348
OK (Mycogen 730B)	1.12		243	1	3	5.6 40	Grain Stover	PARA-00-MR -01-349
TX (Sprint)	1.12pre 1.12post		237 236	1+ 1	3	4.9 39	Grain Stover	PARA-00-MR -01-350
NE (NK 1486)	1.12pre 1.12post		235 235	1+ 1	3	12 14	Grain Stover	PARA-00-MR -01-351
OK (TR432)	1.12pre 1.12post		279 279	1+ 1	3	5.2 33	Grain Stover	PARA-00-MR -01-352
TX (Cherokee)	1.12pre 1.12post		96 98	1+ 1	3	4.1 44	Grain Stover	PARA-00-MR -01-353
TX (9300)	1.12pre 1.12post		187 189	1+ 1	3	2.8 43	Grain Stover	PARA-00-MR -01-354

*B: control

Rice. Paraquat is recommended for use in the cultivation of rice as either a pre-plant or pre-emergence treatment to the seed beds for weed control.

In two residue trials in Italy in 1993 paraquat was applied at a rate of 0.92 kg ai/ha to the seed bed five days before sowing rice. Grain and straw samples were taken at harvest.

Two residue trials were conducted in Guatemala in 1983 where paraquat was applied as pre-emergence at rates of 0.60 and 1.0 kg ai/ha. Grain and straw samples were taken at harvest.

In residue trials in the USA in 1978 and 1982 paraquat was applied pre-emergence at rates of 0.56 and 1.12 kg ai/ha.

Table 36. Paraquat residues in rice from supervised trials in Guatemala, Italy and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Guatemala 1983 (Blue Belle)	 0.60 1.00 0.30		 400 400 400	 1 1 1	0B* 108 108 108	<0.05 <0.05 <0.05 <0.05	Pre-emergence Dehusked seed	Kennedy 1984a
Italy, 1993 (Loto) (Koral)	 0.92 0.92		 400 400	 1 1	0B* 119 151	<0.05 <u><0.05</u> <0.05 <u><0.05</u> <0.05	5 days Pre planting grain straw grain straw	Anderson *et al* 1995 IT10-93-H370 IT10-93-H371

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, USA, 1978					0B*	<0.01 grain <0.02 straw	Pre-emergence	Anon 1985
(Calrose)	0.56		187	1	217	<0.01 <0.06	Grain Straw	M209-4642
(Calrose)	0.56		187	1	230	<0.01 <0.05	Grain Straw	M209-4641
CA, USA, 1982					0B*	<0.01 grain <0.02, <0.03 straw	Pre-emergence	Anon 1985
(M-9)	0.56		93.5	1	163	<0.01 <0.03	Grain Straw	M209-5650
(M-301)	0.56		93.5	1	166	<0.01 <0.02	Grain Straw	M209-5651
	1.12		187	1	166	<0.01 <0.02	Grain Straw	
(M-101)	0.56		93.5	1	167	<0.01 0.04	Grain Straw	M209-5649
	1.12		187	1	167	<0.01 <0.03	Grain Straw	
(Labelle)	1.12		187	1	106	<0.01 <0.02	Grain Straw	M209-5583

*B: control

Tree nuts

Paraquat is registered to control weeds around the base of nut trees.

Supervised residue trials were carried out over a number of years in Italy on hazelnuts, and in the USA on almonds (California), macadamia nuts (Hawaii), pecans (Alabama and Texas), pistachio (California) and walnuts (California).

In trials in Italy hazelnuts were harvested from the ground between 1 and 10 days after treatment around the base of the trees at rates between 0.4 and 1.8 kg ai/ha.

In the USA, paraquat was applied at rates between 0.56 and 9.0 kg ai/ha from one to ten times, to control weeds under mature nut trees. In some cases applications were made over two years. Nuts were harvested, in some cases immature, from 1 to 171 days after the last application. In a worst-case situation, almonds were knocked off the tree and harvested from the ground only one day after the last application.

Table 37. Paraquat residues in tree nuts from supervised trials in Italy and the USA.

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Italy, 1986 Hazelnuts (Gentile Romana)					0B*	<0.05	Shelled nut analysed (picked from ground)	Gatti 1987
	0.54		1000	1	1 3 7 10	<0.05 <0.05 <0.05 <0.05		
	0.89		1000	1	1 3 7 10	<0.05 <0.05 <0.05 <0.05		
	1.8		1000	1	1 3 7 10	<0.05 <0.05 <0.05 <0.05		
CA, USA Almonds					0B*	<0.01		Chevron 2001
1964								

Country, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
(Non Pareil)	1.12		935	3	3	0.01	Whole nuts	T-603
					3	0.04	Whole terminals	Number in ():
(Texas)				4	26	<0.01	Hulls	application
					26	≤0.01	Kernels	number in 1963
					26	0.01	Terminals	
(Non Pareil)				2	52	<0.01	Hulls, less shells	
					52	≤0.01	Kernels	
(Non Pareil)	2.24		935	3(2)	3	0.02	Whole nuts	
					3	0.07	Whole terminals	
(Texas)				4(2)	26	<0.01	Kernels	
					26	<0.01	Hulls	
					26	<0.01	Terminals	
(Non Pareil)				2(2)	52	<0.01	Hulls, less shells	
					52	0.01	Kernels	
1966								T-1088
(Nonpareil)	1.12		206	4(1)	1	<0.01	Hulls	Number in ():
					1	≤0.01	Nuts	application number in 1964
(Non pariel)	1.12		34	4(1)	1	0.07	Hulls	T-1089
					1	0.02	Kernels	nuts knocked to treated ground
(Non pariel)	1.12		34	4(1)	1	0.22	Hulls	T-1090
					1	0.01	Kernels	nuts knocked to treated ground
HI, USA Macademia nuts					0B*	<0.01		Chevron 2001
1962								
(Standard)	0.90			2	44	≤0.01	Kernels	T-321
	1.23			2	44	≤0.01	Kernels	
	1.57			2	44	<0.01	Kernels	
(Keahou)	0.56			3	6	<0.01	Kernels	T-333
					26	<0.01	Kernels	
	1.40			3	6	≤0.01	Kernels	
					26	<0.01	Kernels	
1964								T-609
(Keahou)	0.56		468	3	30	<0.01	Whole nuts	Number in ():
				4	73	<0.01	Nut Kernels	application
				3(4)	65	<0.01	Whole nuts	number in 1963
				4(4)	73	<0.01	Nut Kernels	
	1.12		468	3(4)	65	0.01	Whole nuts	
				4(4)	73	≤0.01	Nut Kernels	
1985								T-6617
(Keahou)	0.56		281	1	1	<0.01	Nut meat	Dried for 14 days
				2	1	0.02	Nut meat	before shelling
	0.28		281	1	1	0.01	Nut meat	Nuts were hulled
				2	1	0.01	Nut meat	on day of sampling
AL, USA, 1962 Pecans					0B*	<0.01		Chevron 2001
(Mixed)	2.24		1870	6	49	<0.01	Nut meat	T-345
	4.48		1870	6	49	<0.01	Nut meat	
USA					0B*	<0.05		Ross *et al.* 1978
OR, 1972 Filberts (unknown)	1.12			1	134	≤0.05	Nut meat	
GA, 1977 Pecans (unknown)	1.12			1	161	≤0.05	Nut meat	
AL, 1977 Pecans (unknown)	1.12			1	171	≤0.05	Nut meat	

*B: control

Oil seed

Paraquat is recommended for use in the cultivation of cotton and sunflowers as a pre-plant or pre-emergence treatment, a post-emergence directed or guarded spray for inter-row weed control, and for harvest aid desiccation.

Several trials were conducted for over several years and locations in the USA on cotton involving pre-emergence applications at 0.14 to 1.12 kg/ha with harvest 4 to 176 days post application. In numerous trials with a pre-emergence followed by a harvest aid desiccation application, cotton was harvested after 3 to 11 days.

In 1988 trials in the USA, paraquat was applied pre-emergence to sunflowers at 1.12 or 5.6 kg/ha and with sampling 41 to 131 days post application. In other US trials in various years and locations, paraquat was applied for harvest aid desiccation at 0.28 to 1.12 kg/ha with sampling 7 to 21 days post application.

Table 38. Paraquat residues in cotton and sunflowers from supervised trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, 1963 (Acala 4-42)	1.12		468	1	0B* 121	<0.01 <0.01 <0.01 <0.01	Pre-emergence Seed Trash Lint	Chevron 1967 T-383
CA, 1964 (Acala 4-42)	1.12		468	1	30 60 154	<0.01, <0.01 <0.01, <0.01 <0.01, <0.01	Whole plant	T-614
CA, 1965 (Acala 4-42)	1.12		187	1	0B* 147	<0.02 0.02, 0.04	Fuzzy seed	T-771
MS, 1966 (Stoneville 213)	1.12		187	1	172	<0.01, <0.01	Fuzzy seed	T-1123
LA, 1966 (DPL smootleaf)	1.12		187	1	176	<0.01, <0.01	Fuzzy seed	T-1124
AR, 1966 (Rex)	1.12		374	1	171	<0.01, <0.01	Fuzzy seed	T-1125
1971					0B*	<0.01	Pre-emergence followed by harvest aid desiccation	Whipp & Kalens 1972
MS (Delta pine land 16)	0.56 pre 0.14 post		187 187	1+ 1	4	0.21, 0.25	Fuzzy seed	T-2151
MS (Stoneville 213)	0.56 pre 0.14 post		187 187	1+ 1	7	0.12, 0.12	Fuzzy seed	T-2152
LA (Coker 201)	0.56 pre 0.14 post		187 187	1+ 1	7	0.07, 0.12	Fuzzy seed	T-2153
LA (Rex smooth leaf 66)	0.56 pre 0.14 post		187 187	1+ 1	4	0.11, 0.18	Fuzzy seed	T-2154
1964					0B*	<0.01	Harvest aid desiccation	Chevron 1966 T-655
TX (Delta pine)	0.28 0.56			1 1	9.5 9.5	0.02, 0.02, 0.03, 0.04 0.03, 0.07, 0.14, 0.17	Fuzzy seed Fuzzy seed	
MS (DPL15)	0.28 0.56			1 1	10 10	<0.01, <0.01, 0.06, 0.07 0.02, 0.02, 0.02, 0.03	Fuzzy seed Fuzzy seed	T-656
CA (Acala 4-42)	0.28 0.56			1 1	11 11	<0.01, <0.01, <0.01, <0.01 <0.01, <0.01, <0.01, <0.01	Fuzzy seed Fuzzy seed	T-657
CA (Acala 4-42)	0.14			1	5 11	<0.01, <0.01 <0.01, <0.01	Fuzzy seed	T-659

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
TX (Blightmaster)	0.56			1	9 9 9 9 9 9 9	0.97, 0.97, 1.28, 1.76 0.08, 0.09, 0.10, 0.18 <0.01, <0.01, <0.01, <0.01 <0.01, <0.01, <0.01, 0.01 <0.01, <0.01, <0.01, 0.01 <0.01, <0.01, <0.01, <0.01 <0.01, <0.01, <0.01, <0.01	Cotton (including trash & bolls) Fuzzy seed Acid-delinted seed Mechanically delinted seed Hulls Crude oil Meal	T-654
TX (Rex)	0.56			1	1 5 10 5 10 10 10 10 10 10 10	15, 15 2.1, 2.6 2.0, 2.1 0.11, 0.13 0.18, 0.18 0.05, 0.051 0.08, 0.08 2.8, 3.3 0.13, 0.13 <0.01, <0.01 0.02, 0.02	Cotton (including trash & bolls) Fuzzy seed Acid-delinted seed Mechanically delinted seed Lint cotton Hulls Crude oil Meal	T-653
1965					0B*	<0.01	Harvest aid desiccation	Chevron 1966
TX (Stoneville 7A)	0.28			1	10	0.03, 0.04	Fuzzy seed	T-742
TX (Stoneville 7A)	0.28			1	10	0.10, 0.15	Fuzzy seed	T-743
OK (Lankart 23-3)	0.28			1	9	0.03, 0.13	Fuzzy seed	T-745
TX (Stoneville 7A)	0.28			2	10	0.28, 0.31	Fuzzy seed	T-746
TX (Stoneville 7A)	0.28			2	7	0.13, 0.16	Fuzzy seed	T-747
OK (Lankart 23-3)	0.28			2	7	0.33, 0.40	Fuzzy seed	T-749
CA (Acala 4-42)	0.56			1	3 5	0.09, 0.12 0.18, 0.30	Fuzzy seed	T-938
CA (Acala 4-42)	0.56			1	3 5	0.11, 0.11 0.12, 0.15	Fuzzy seed	T-939
TX (Lankart 57)	0.42 0.28 0.56 0.28 0.90			1+ 1 1+ 1 1	 4 5 6	 0.10, 0.18 0.34 0.62	 Fuzzy seed Fuzzy seed Fuzzy seed	T-786
1993					0B*	<0.05	Pre-emergence followed by post-emergence, harvest aid	Roper 1994
NM (Paymaster 792)	1.4pre 0.14post 0.56post 1.4pre 0.84post			1+ 2+ 1 1+ 1	 3 5 3 5	 0.16 0.11 0.26 0.34	 Seed Seed	13-NM-93-37 1

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
TX (Paymaster 145)	1.4pre			1+				13-TX-93-372
	0.14post			2+				
	0.56post			1	3	<0.05	Seed	
					6	0.09		
	1.4pre			1+				
	0.84post			1	3	0.10	Seed	
					5	0.12		
TX (DPL 5415)	1.4pre			1+				25-TX-93-373
	0.14post			2+				
	0.56post			1	3	1.0	Seed	
					5	0.55		
	1.4pre			1+				
	0.84post			1	3	0.75	Seed	
					5	0.18		
1995					0B*	<0.05	Pre-emergence followed by post-emergence, harvest aid	Roper & Elvira 1996
NC (Deltapine 90)	1.4pre		140	1+				01-NC-95-651
	0.56		187	2+				
	0.14		93	2+				
	0.56		93	1	3	0.38	Seed	
LA (DPL 5415)	1.4 pre		124	1+				69-LA-95-652
	0.56		214	2+				
	0.14		90	2+				
	0.56		91	1	3	0.46	Seed	
					3	18	Gin byproduct	
MS (Stoneville 453)	1.4 pre		187	1+				05-MS-95-653
	0.56		234	2+				
	0.14		89/86	2+				
	0.56		84	1	1	0.23	Seed	
					3	0.16		
					7	0.21		
					14	0.14		
TN (DPL 50)	1.1 pre		128	1+				50-TN-95-654
	0.56		279	2+				
	0.14		86/88	2+				
	0.56		88	1	3	0.44	Seed	
TX (DPL 51)	1.4 pre		94	1+				25-TX-95-655
	0.56		186/194	2+				
	0.14		93/92	2+				
	0.56		88	1	3	0.58	Seed	
NM (Paymaster 145)	1.4 pre		128	1+				23-NM-95-656
	0.56		216/212	2+				
	0.14		93	2+				
	0.56		93	1	3	0.16	Seed	
TX (Paymaster 145)	1.4 pre		137	1+				23-TX-95-658
	0.56		215/218	2+				
	0.14		79/76	2+				
	0.56		80	1	3	2.0	Seed	
						12	Gin byproduct	
TX (Paymaster HS200)	1.4 pre		137	1+				23-TX-95-659
	0.56		215/225	2+				
	0.14		79/78	2+				
	0.56		75	1	3	0.50	Seed	
						8.0	Gin byproduct	
CA (Acala GC510)	1.4 pre		139	1+				02-CA-95-660
	0.56		270/257	2+				
	0.14		90/92	2+				
	0.56		89	1	3	0.49	Seed	
						69	Gin byproduct	