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

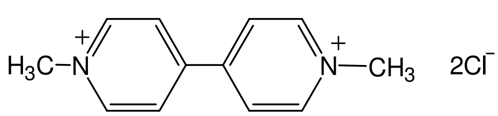
CAS Registry No.: 1910-42-5 (paraquat dichloride)
4685-14-7 (paraquat)

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:	<< $1x10^{-5}$ 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:	$4x10^{-9}$ 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

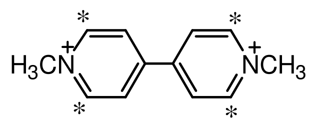
Technical material (Wollerton. 1987)

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

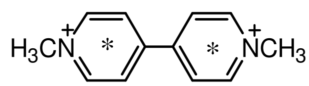
pH:	3.95 at approximately 20 °C
Flash point:	> 90 °C
Surface tension:	58.6 mN/m at 20 °C
Storage stability:	≥2 years at 25 °C in polythene
Formulations:	SL (in various concentrations alone or in combination with diquat)

METABOLISM AND ENVIRONMENTAL FATE

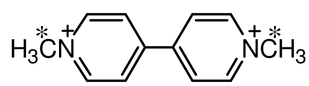
For studies of metabolism in animals and plants, [^{14}C]paraquat was labelled as shown (Figure 1). The structures of metabolites identified in these studies are shown in Figure 2.



[2,2′,6,6′-^{14}C]paraquat



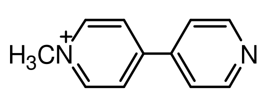
[U-^{14}C-dipyridyl]paraquat



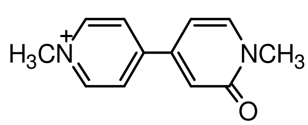
[1,1′-^{14}C-dimethyl]paraquat

(*position of ^{14}C label)

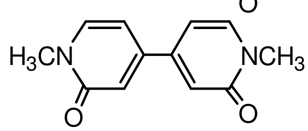
Figure 1. Radiolabelled paraquat used in metabolism studies.



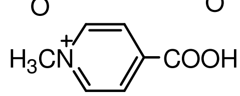
Monoquat



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

<u>Lactating cow</u>. 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.

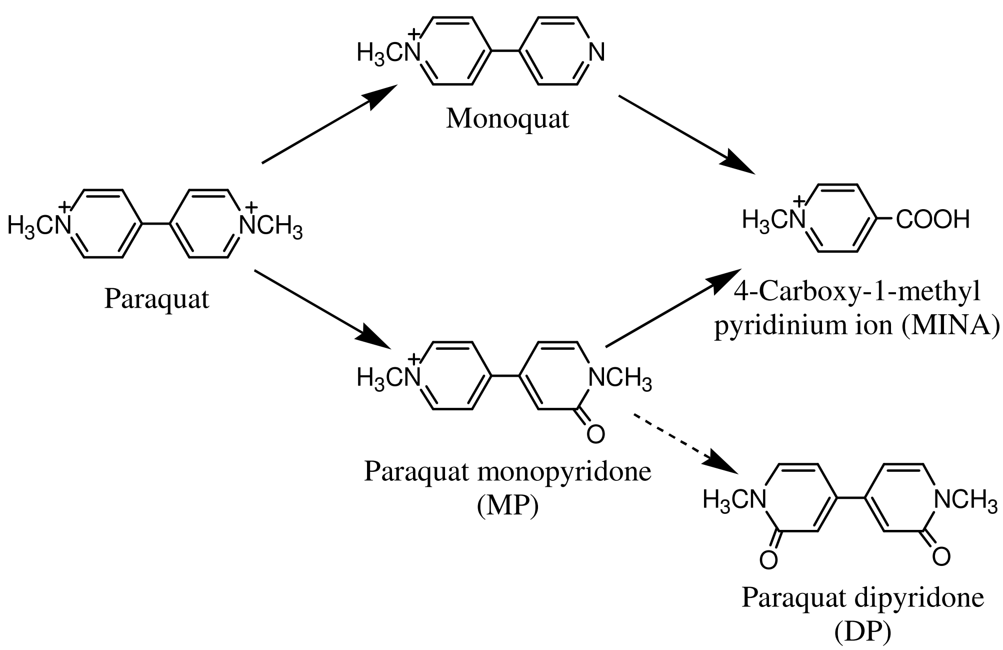


Figure 3. Proposed metabolic pathways of paraquat in animals.

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.

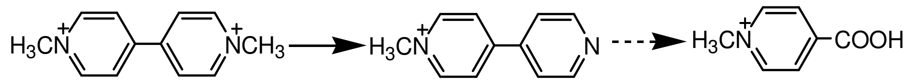


Figure 43. Proposed metabolic pathways of paraquat in plants.

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.

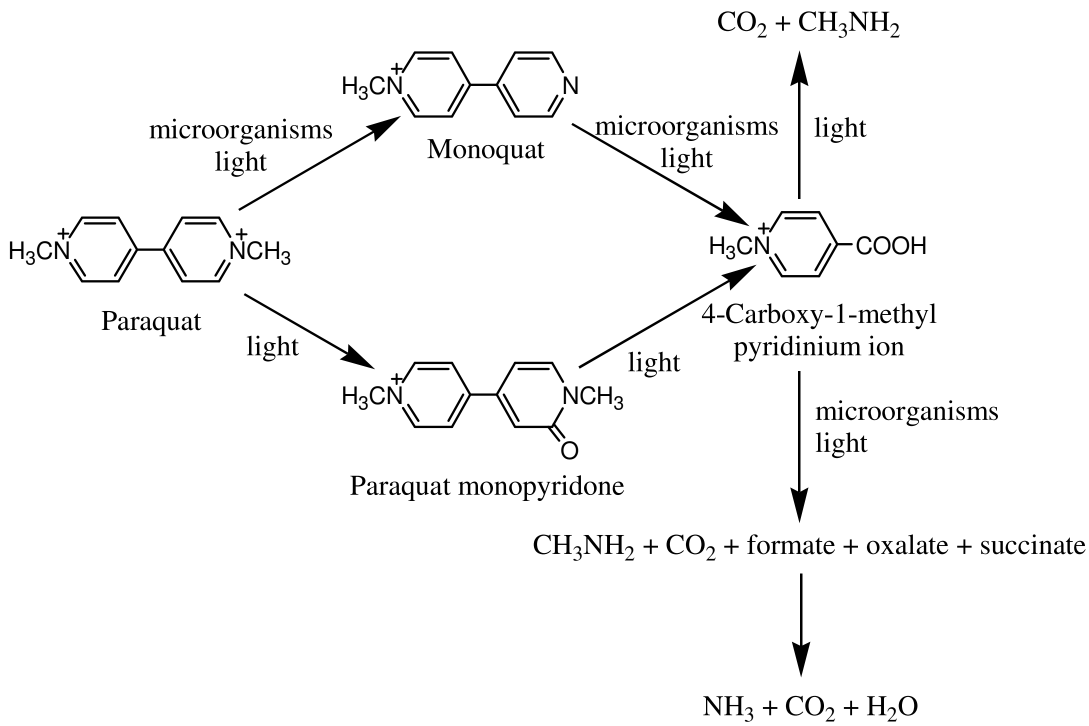


Figure 5. Proposed degradation pathways of paraquat by light and isolated microorganisms under laboratory conditions

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) (50 g)	0.02 0.05
	Grass and straw (100 g) (25 g)	0.02 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

Method & reference	Sample	LOQ, mg/kg
	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 100 g			60-75 60-75		
	Grass and straw 25 g 100 g			80-95 70-85		
	Sugar-cane juice 100 ml 100 ml			80-95 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

Citrus fruits

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				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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				1	0B*	<0.01	Spray hit lower	T-758
1965	1.12	0.12	935		3	0.08, 0.06	branches and fruit;	
(Navel)							fruit dropped on	
							sprayed weeds on day	
							0, 1, 2, and 3;	
							composite samples	
							taken on day 3	
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					0B*	<0.01		T-631
1964-66								Broadcast
Orange								spray around
(Valencia)								each tree on an
Treatments								area of 100 sq
1964: 4								ft.
1965: 4								
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	1.12			1	0B*	<0.05		Ross *et al.*
1972					14	≤0.05	Fruit	1978
(unknown)								AGA No2561
Italy, 1993					0B*	<0.02		Dick *et al.*
(Biondo)	0.80	0.080	1000	1	7	≤0.02	Fruit	1995b
								IT10-93-H348

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

Pome fruits

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

*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)					0B*	<0.01		Calderbank & McKenna 1964 Hamilton
	2.24		935	1	14	<0.01		
	4.48			1	14	<0.01		
	2.24			2	14	<0.01		
	4.48			2	14	<0.01		
	2.24			1	87	<0.01		
	4.48			1	87	<0.01		
(Veteran)					0B*	<0.01		
	1.12		749	2	44	<0.01		
(Elberta)					0B*	<0.01		
	1.12		749	2	59	<0.01		
Germany 1990 (Red Haven)	1.00		1000		0B*	<0.01		Earl & Anderson 1992a Rs9023E3
				1	11	<0.01	Fruit from tree	
						0.04	Fruit on ground	
(Red Haven)	1.00		1000		0B*	<0.01		Rs9023E4
				1	13	<0.01	Fruit from tree	
						0.02	Fruit on ground	
PLUM								
Canada, 1963 (Sapa & Dura)					0B*	<0.01		Calderbank & McKenna 1964 Guelph
	1.12		234	2	72	<0.01		

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		Calderbank & McKenna 1964
	0.22		833	1	21	<0.01	All applied direct to suckers	
					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 4.4		1130	1 2 1 2	6 19 122 19 6 19 122 19	≤0.01 <0.01 <0.01 ≤0.01 ≤0.01 <0.01 <0.01 ≤0.01		
Switzerland, 1971 (unknown)	0.3 0.4		1000	1	85 133 196	<0.01 <0.01 <0.01		Edwards 1974
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				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Germany, 1990				1	0B*	<0.01		Earl &
(Riesling)	1.0		1000		0	<0.01	From vine	Anderson
					10	<0.01	From vine	1992b
						0.13	From ground	Rs9022E1
(Scheurebe)				1	0B*	<0.01		Rs9022E2
	1.0		1060		0	<0.01	From vine	
					14	<0.01	From vine	
						0.09	From ground	
(Portogieser)				1	0B*	<0.01		Rs9022E3
	1.0		1000		0	<0.01	From vine	
					14	<0.01	From vine	
						0.10	From ground	
(Weissbur				1	0B*	<0.01		Rs9022E4
gunder)	1.0		1000		0	<0.01	From vine	
					14	<0.01	From vine	
						0.17	From ground	
(Bacchus)				1	0B*	<0.01		Rs9022E5
	1.0		1000		0	<0.01	From vine	
					14	<0.01	From vine	
						0.04	From ground	
(Morio Muskat)				1	0B*	<0.01		Rs9022E6
	1.0		1000		0	<0.01	From vine	
					14	0.07	From ground	
NY, USA, 1977 (unknown)	1.12			1	0B*	<0.05		Ross *et al.* 1978
					135	≤0.05		AGA No4953
					149	≤0.05		AGA No5039
CA, USA, 1997 (Thompson Seedless)	5.6		279	1	0B*	<0.01	Fresh grape, juice	Spillner *et al.*
						<0.05	Dried grape	1998
					0	≤0.01	Fresh grape	Broadcast
					0	<0.01	Juice	02-CA-97-601
					21	<0.05	Dried grape	
CANE FRUITS								
Ontario, Canada, 1963 Blackcurrant (Saunders Topsy)	2.24		749-935	1	0B*	<0.01		Calderbank & McKenna 1964
					35	≤0.01	Post-emergence directed	
Redcurrant (Cherry Perfection)	2.24		749-935	1	0B*	<0.01		
					35	≤0.01		
Ontario, Canada, 1964 Blackcurrant (Unknown)					0B*	<0.01		McKenna 1966 Guelph
	2.24		935	1	42	≤0.01	Post-emergence directed	
					71	<0.01		
Ontario, Canada, 1964 Redcurrants (Cherry reflection)					0B*	<0.01	Post-emergence directed	McKenna 1966 Guelph
	2.24		935	1	71	≤0.01		
BC, Canada, 1963 Blueberries (Dixie)					0B*	<0.01	Post-emergence directed	Calderbank & McKenna 1964
	0.84		899	1	80	≤0.01		
	1.40		899			≤0.01		
BC, Canada, 1963 Blueberries (Dixie)	0.84		899	1	85	≤0.01		
	1.40		899			≤0.01		
BC, Canada, 1964 Blueberries (Dixie)					0B*	<0.01	Post-emergence directed	McKenna 1966 Pitt Meadows
	0.56		748	1	65	<0.01		
	1.12					≤0.01		
	1.68					≤0.01		
	2.24					≤0.01		

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
(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					B*	<0.005		Kennedy 1985
1985							Olives picked & then	INT H 11.85
(Tsounati)							directly sprayed	
							Oil	
	1.0		500	1	5	<0.005		
Italy, 1986					0B*	<0.05	Fruit picked up from	Gatti 1987
(Coratina)	0.54		1000	1	7	<0.05	ground	60/86/1
					14	<0.05		
					21	<0.05		
	0.89		1000	1	7	<0.05		
					14	<0.05		
					21	<0.05		
	1.79		1000	1	7	<0.05		
					14	<0.05		
					21	<0.05		
Italy, 1993							Fruit picked from tree	Dick *et al.*
(Frantioio)							Fruit	1995a
	1.56		N/A	1	0B*	<0.10	Oil	IT10-93-H33
						<0.05	Fruit	8
					7	<0.10	Oil	
						<0.05		
Italy, 1993							Fruit picked from tree	IT10-93-H33
(Coratina)							Fruit	9
	1.56		N/A	1	0B*	<0.10	Oil	
						<0.05	Fruit	
					7	<0.10	Oil	
						<0.05		

Country, year Olives (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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	ES50-99-S03
							olives were on ground	3
							at treatment	
	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	3
							olives were on ground	
							at treatment	
	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					0B*	<0.05	14-37% of analysed	Devine *et al.*
2001							olives were on ground	2003
(Hojiblanca)							at treatment	ES051-01-S0
	1.09		347	1	3	0.45	Whole fruit	13
						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 kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	Reference
						<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	<u><0.01</u>		
	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					0B*	<0.01		Waimanalo
Guava	1.12		748	4	1	<0.01	Edible pulp	Farm
(Beaumont)						<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	
							Discarded stone cells	
						<0.01		
	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					0B*	<0.01		McKenna
Bananas	1.40		584	3	0	<0.01 x4	Fruit flesh	1966
(Valery)						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 (Stuttgarter Riesen)					B*	<0.01	Post-emergence directed application	Massey 1987a
	1.3		1300	1	0	0.01		RS8423E3
					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 FL, 1974 (Walter)					0B*	<0.01	Post-emergence directed application	Chevron 1975c T-2866
	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 kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
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 kg ai/ha	Application kg ai/hl	Application water, l/ha	Application no.	PHI days	Paraquat mg/kg	Notes	References
FL, 1974 Sweet pepper (Early Cal Wonder)	0.56		421	1	0	<0.01, <0.01		T-2873
					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		
LA, 1975 Sweet pepper (Keystone Giant Resistant)	0.56		187	4	0	<0.01, <0.01		T-3152
					7	<0.01, <0.01		
					14	<0.01, <0.01		
					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 Sweet pepper (Yolo Wonder)	1.12pre		374	1+				T-3332
	1.12		299	4	7	<0.01		
					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 kg ai/ha	Application kg ai/hl	Application water, l/ha	Application no.	PHI days	Paraquat mg/kg	Notes	Reference
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 Summer Squash (Unknown)	 1.12 pre 0.56			 1+ 3	0B* 8	<0.025 <0.025	1 pre + 3 post directed application	Roper 1989e 18CA-88-436
CA, USA, 1988 Summer Squash (Unknown)	 1.12 pre 0.56			 1+ 3	0B* 8	<0.025 <0.025		18CA-88-437
CA, USA, 1988 Summer Squash (Unknown)	 1.12 pre 0.56			 1+ 3	0B* 8	<0.025 <0.025		18CA-88-438
CA, USA, 1988 Summer Squash (Unknown)	 1.12 pre 0.56			 1+ 3	0B* 33	<0.025 <0.025		17CA-88-439

*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, 1964 (Mixed)	 2.24 2.24 1.12 2.24 1.12 0.49 0.97		 935 935 935 935 935 468 468	 1 1 1 1 1 1 1	0B* 36 55 55 55 55 71 71	<0.01 <0.01 0.08 0.05 0.05 0.04 0.01 0.01		McKenna 1966 Pre-emergenc e
UK, 1965 (Unknown)	 0.841 0.841 0.841		 N/A N/A N/A	 1 1 1	0B* 39 58 72	<0.01 <0.01 0.01 <0.01 0.02 <0.01 <0.01 <0.01	Head, unwashed Head, washed Head, unwashed Head, washed Head, unwashed Head, washed Head, unwashed Head, washed	
UK, 1964 (Unknown)	 1.68 pre 2.24		 N/A N/A	 1+ 2	0B* 46	<0.01 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	Massey 1987c
							directed	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 Kale (Unknown)					0B*	<0.01		McKenna 1966
	1.68 pre			1+				
	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.				
Germany, 2001 Dried field beans (Optimus)	1.0		400	1	0B*	<0.05	Post-emergence directed Dried field bean	Devine & Balluff 2002c G01W056R
					0	<0.05	Straw	
						2.6		
Germany, 2001 Beans with pods (Maja)	1.0		400	1	0B*	<0.05	Post-emergence directed Beans with pods	Devine & Balluff 2002b G01W054R
					0	<0.05	Straw	
						1.4	Beans with pods	
					3	0.10	Straw	
						0.34	Beans with pods	
					7	<0.05	Straw	
						0.91		
Spain, 2001 Beans with pods (Cleo)	1.0		400	1	0B*	<0.05	Post-emergence directed Beans with pods	Devine & Balluff 2002a S01W031R
					0	0.09	Straw	
						0.41	Beans with pods	
					3	<0.05	Straw	
						0.09	Beans with pods	
					7	<0.05	Straw	
						0.15		
The Netherlands 2002 Beans with pods (Valance)	1.0		300	1	0B*	<0.05	Post-emergence directed Beans with pods	Devine & Poppezijn 2003 CEMS-1839/01
					7	<0.05	Straw	
						0.08		
Spain, 2002 Beans with pods (Moncayo)	1.0		200	1	0B*	<0.05	Post-emergence directed Beans with pods	Devine & Orellana 2003a AF/6396/SY/1
					7	<0.05	Straw	
						0.21		
Ontario, Canada, 1963					0B*	<0.01	Pre-emergence	Calderbank & McKenna 1964
Beans (Small white)	0.56		281	1	122	<0.01	Seed	
						<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 kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes and references	
Ontario, Canada,					0B*	<0.01	Post-emergence directed	Calderbank &
1963							Seed	McKenna 1964
Beans	0.28		281	1	107	<0.01	Pods	Edwards 1974
(Small white)						<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,					0B*	<0.01	Pre-emergence	McKenna 1966
1964	1.12		468	1	60	<0.01	Seed	
Beans								
(Small white)								
VICIA								
UK, 1964					0B*	<0.01	Pre+post-emergence	McKenna 1966
Broad beans	1.68pre		N/A	1+				
(unknown)	2.24		N/A	1	71	<0.01	Seed	
						<0.01	Pod	
					85	<0.01	Seed	
						0.01	Pod	
Spain, 2000	0.69		314	1	0B*	<0.01	Post-emergence directed	Jones 2000c
Broad beans							Seed	AF/4715/ZE/1
(Reina Mora)					0	<0.01	Pod	
						<0.01		
Spain, 2002	1.0		200	1	0B*	<0.05	Post-emergence directed	Devine &
Fresh broad bean							Fresh broad bean	Orellana 2003b
(Muchamiel)					0	<0.05	Straw with empty pods	AF/6397/SY/1
						1.5		
PEAS								
Ontario, Canada,	0.56		38	1	0B*	<0.01	Pre-emergence	Calderbank &
1963					123	<0.01	Vines	McKenna 1964
(Lincoln)								

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*	<0.05	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 (Amethyst)	0.20		70	1	0B*	<0.05	Post-emergence harvest aid	Markus 1993b MAP-GRA-92
					38	0.23	Grain	
						1.0	Straw	
	0.40		70		38	0.44	Grain	
						4.0	Straw	

Country, year Crop (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes and references	
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 88JH402
	0.25		300	1	7	<0.05		
					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				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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*	 <0.05 <2 <0.05	Harvest aid Forage Hay Seed	Roper 1989n
IL (Fayette)	2.24		38	1	0 5 10 15 21	20 26 24 22 0.1	Hay Forage Forage Forage Seed	22IL-88-458 Ground application
IA (Pioneer 9271)	2.24		38	1	0 5 10 15	24 45 8 9 9 0.05	Forage Hay Forage Forage Forage Seed	36IA-88-459 Ground application
					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				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
MN (BSR 101)	2.24		38	1	0	59	Forage	30MN-88-541
						2	Hay	Aerial
					5	23	Forage	application
					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
						6	Hay	Aerial
					5	19	Forage	application
					10	8	Forage	
					15	1	Forage	
						0.08	Seed	

B*=control

Root and tuber vegetables

Residue trials were carried out on beetroot 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 sugar beet 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 carrots, 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 kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
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				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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	<0.01	Tuber	McKenna 1964
(Sebago)	0.56		281	1	123	<0.01		
	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				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Ontario, Canada, 1963					0B*	<0.01	Early post-emergence directed	Calderbank & McKenna 1964
(Sebago)	0.28		281	1	101	<0.01		
					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 Mountain)	0.28		1348	1	28	<0.01		
	0.56		1348	1	28	0.07		
	0.84		1348	1	28	0.06		
Ontario (Katahdin)	0.28		1123	1	16	0.02, 0.04		
	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				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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							Harvest aid	Roper 1989b
(Russet Burbank)					0B*	<0.05	Unwashed tuber	16ID88-400
						<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* 103	<0.05 ≤0.05 <0.05	Pre-emergence directed Stalk Fern	Calderbank & McKenna 1964
Ontario, Canada, 1964 Asparagus (Waltham)	1.12		234	1	0B* 70	<0.02 ≤0.02	Pre-emergence	Chevron 1970 T-1403
USA, 1969 Asparagus					0B*	<0.02	Pre-emergence	Chevron 1970
MI (California 711)	1.12		337	1	25	≤0.02, <0.02		T-1839 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* 36	<0.05 <0.05	Post-emergence Stalk	McKenna 1966
CA, USA					0B*	<0.05	Post-emergence directed	Lurvey 1996
1992	1.12		187	3	1	<0.05		92:CA:126
Globe Artichoke (unknown)	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				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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							Harvest aid	
(INRA260)	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 kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
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

<u>Sorghum</u>. 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 G522DR Hybrid)	1.12 pre			1+				38AX-87-576
	0.56 post			2	35	<0.025	Forage	
						<0.025	Silage	
						0.04	Hay	
					61	<0.025	Fodder	
						≤0.025	Grain	
AL (Funks GB125)	1.12 pre			1+				62AL-87-578
	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 King 2660)	1.12 pre			1+				US01-87-580
	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 DK42V)	1.12 pre			1+				
	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 FE Y75)	2.8			1	3	12.5	Whole grain from field	11TX88-793
						10.4	Whole grain from 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
						9.2	Whole grain from 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 <0.5 stover	Pre-emergence followed by a harvest aid desiccation	Carringer & Yuen 2001
NC (DK36)	1.12pre		184	1+	3	14	Grain	PARA-00-MR-01-343
	1.12post		184	1		18	Stover	

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					0B*	<0.05	5 days Pre planting	Anderson *et al* 1995
(Loto)	0.92		400	1	119	<u>≤0.05</u> <0.05	grain straw	IT10-93-H370 IT10-93-H371
(Koral)	0.92		400	1	151	<u>≤0.05</u> <0.05	grain straw	

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 kg ai/ha	kg ai/hl	water, l/ha	no.	PHI days	Paraquat mg/kg	Notes	References
(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					0B*	<0.01		Chevron 2001
Macademia nuts								
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					0B*	<0.01		Chevron 2001
Pecans								
(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*	<0.01	Pre-emergence	Chevron 1967 T-383
					121	<0.01	Seed	
						<0.01	Trash	
						<0.01	Lint	
CA, 1964 (Acala 4-42)	1.12		468	1	30	<0.01, <0.01	Whole plant	T-614
					60	<0.01, <0.01		
					154	<0.01, <0.01		
CA, 1965 (Acala 4-42)	1.12		187	1	0B*	<0.02		T-771
					147	0.02, 0.04	Fuzzy seed	
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			1	9.5	0.02, 0.02, 0.03, 0.04	Fuzzy seed	
	0.56			1	9.5	0.03, 0.07, 0.14, 0.17	Fuzzy seed	
MS (DPL15)	0.28			1	10	<0.01, <0.01, 0.06, 0.07	Fuzzy seed	T-656
	0.56			1	10	0.02, 0.02, 0.02, 0.03	Fuzzy seed	
CA (Acala 4-42)	0.28			1	11	<0.01, <0.01, <0.01, <0.01	Fuzzy seed	T-657
	0.56			1	11	<0.01, <0.01, <0.01, <0.01	Fuzzy seed	
CA (Acala 4-42)	0.14			1	5	<0.01, <0.01	Fuzzy seed	T-659
					11	<0.01, <0.01		

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	0.97, 0.97, 1.28, 1.76	Cotton (including trash & bolls)	T-654
					9	0.08, 0.09, 0.10, 0.18	Fuzzy seed	
					9	<0.01, <0.01, <0.01, <0.01	Acid-delinted seed	
					9	<0.01, <0.01, <0.01, 0.01	Mechanically delinted seed	
					9	<0.01, <0.01, <0.01, 0.01	Hulls	
					9	<0.01, <0.01, <0.01, <0.01	Crude oil	
					9	<0.01, <0.01, <0.01, <0.01	Meal	
TX (Rex)	0.56			1	1 5 10	15, 15 2.1, 2.6 2.0, 2.1	Cotton (including trash & bolls)	T-653
					5 10	0.11, 0.13 0.18, 0.18	Fuzzy seed	
					10	0.05, 0.051	Acid-delinted seed	
					10	0.08, 0.08	Mechanically delinted seed	
					10	2.8, 3.3	Lint cotton	
					10	0.13, 0.13	Hulls	
					10	<0.01, <0.01	Crude oil	
					10	0.02, 0.02	Meal	
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			1+ 1	4	0.10, 0.18	Fuzzy seed	T-786
	0.56 0.28			1+ 1	5	0.34	Fuzzy seed	
	0.90			1	6	0.62	Fuzzy seed	
1993					0B*	<0.05	Pre-emergence followed by post-emergence, harvest aid	Roper 1994
NM (Paymaster 792)	1.4pre 0.14post 0.56post			1+ 2+ 1	3 5	0.16 0.11	Seed	13-NM-93-371
	1.4pre 0.84post			1+ 1	3 5	0.26 0.34	Seed	

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	

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA (DP 5461)	1.4 pre		150	1+				14-CA-95-661
	0.56		187/222	2+				
	0.14		77/78	2+				
	0.56		80	1	3	0.07	Seed	
AZ (DPL 20)	1.4 pre		104	1+				14-AZ-95-662
	0.56		126/127	2+				
	0.14		79/80	2+				
	0.56		80	1	3	0.23	Seed	
						23	Gin byproduct	
OK (Paymaster HS200)	1.4 pre		136	1+				23-OK-95-663
	0.56		185/192	2+				
	0.14		69/68	2+				
	0.56		67	1	3	0.35	Seed	
						5.3	Gin byproduct	

B=control

Table 39. Paraquat residues in sunflower seed from supervised trials in the USA.

Year, location (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
1988					0B*	<0.05	Pre-emergence	Roper 1989o
SD (Interstate 893)	5.6			1	84	<0.05	Forage	31SD-88-475
					131	<0.05	Seed	
ND (Pioneer 6445)	5.6		215	1	B*	<0.05	Forage	34ND-88-476
					74	<0.05	Seed	
					122	<0.05		
ND (Pioneer 6440)	1.1			1	74	<0.05	Forage	34ND-88-528
					122	<0.05	Seed	
SD (unknown)	1.1			1	84	<0.05	Forage	31SD-88-529
					131	<0.05	Seed	
MN (NK285)	1.1			1	76	<0.05	Forage	33MN-88-530
					111	<0.05	Seed	
TX (Texas Triumph 565)	1.1		210	1	41	<0.05	Forage	10TX-88-531
					118	<0.05	Seed	
1994					0B*	<0.05	Pre-emergence; post directed; & harvest aid	Roper 1995
ND (Pioneer DO 827)	1.12		142	1+			Seed	34ND-94-202
	0.70		59	1+				
	0.56		142	1	7	0.93		
SD, (Cargill 100)	1.12		142	1+				34SD-94-203
	0.70		59	1+				
	0.56		142	1	7	0.74	Seed	
1971					0B*	<0.01	Harvest aid	Chevron 1975a
CA (Peredovik)	0.28		374	1	0	0.08, 0.08	Seed	T-2185
					7	0.10, 0.11	Seed	
						0.23, 0.27	Hull	
						0.17, 0.12	Meal	
						<0.01, <0.01	Oil	
					14	0.11, 0.11	Seed	
	0.56		374	1	0	0.16, 0.16	Seed	
					7	0.35, 0.35	Seed	
						0.57, 0.67	Hull	
						0.54, 0.55	Meal	
						<0.01, <0.01	Oil	
					14	0.23, 0.23	Seed	
MS (NK-HO1)	0.28		46	1	0	0.05, 0.11	Seed	T-2186
					7	0.10, 0.31	Seed	
						1.3, 2.4	Hull	
						0.64, 1.2	Meal	
						<0.01, <0.01	Oil	
					14	0.38, 0.52	Seed	
	0.56		46	1	0	0.19, 0.19	Seed	

Year, location (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
					7	0.27, 0.34	Seed	
						2.2, 4.6	Hull	
						0.60, 0.71	Meal	
						<0.01, <0.01	Oil	
					14	0.49, 0.81	Seed	
1972					0B*	<0.01	Harvest aid	Chevron 1975a
MN (VNIIMK 8931)	0.28		47	1	7	0.05, 0.11	Seed	T-2392
						0.07, 0.08	Hulls	
						0.10, 0.14	Meal	
						<0.01, <0.01	Oil	
					14	0.09, 0.13	Seed	
						0.07, 0.10	Hulls	
						0.17, 0.23	Meal	
						<0.01, <0.01	Oil	
					21	0.11, 0.12	Seed	
						0.07, 0.09	Hulls	
						0.11, 0.15	Meal	
						<0.01, <0.01	Oil	
	0.56		47	1	7	0.04, 0.04	Seed	
					14	0.32, 0.52	Seed	
					21	0.81, 0.42	Seed	
MN (VNIIMK 8931)	0.28		47	1	7	0.06, 0.06	Seed	T-2393
						0.06, 0.06	Hulls	
						0.02, 0.10	Meal	
						<0.01, <0.01	Oil	
					14	0.03, 0.04	Seed	
						0.04, 0.06	Hulls	
						0.05, 0.07	Meal	
						<0.01, <0.01	Oil	
					21	0.02, 0.04	Seed	
						0.02, 0.02	Hulls	
						0.04, 0.05	Meal	
						<0.01, <0.01	Oil	
	0.56		47	1	7	0.21, 0.27	Seed	
					14	0.37, 0.39	Seed	
					21	0.32, 0.60	Seed	
CA (HO-1)	0.28		206		7	0.12, 0.14	Seed	T-2394
						0.14, 0.16	Hulls	
						0.17, 0.20	Meal	
						<0.01, <0.01	Oil	
					14	0.09, 0.11	Seed	
						0.11, 0.14	Hulls	
						0.17, 0.20	Meal	
						<0.01, <0.01	Oil	
					21	0.10, 0.11	Seed	
						0.08, 0.11	Hulls	
						0.18, 0.18	Meal	
						<0.01, <0.01	Oil	
	0.56		206		7	0.35, 0.51	Seed	
					14	0.40, 0.44	Seed	
					21	0.23, 0.26	Seed	
1973					0B*	<0.01	Harvest aid	Chevron 1975a
IA (Peredovik)	0.28		187	1	7	0.10, 0.13	Seed	T-2679
						0.30, 0.32	Hulls	
						<0.01, <0.01	Meal	
						<0.01, <0.01	Oil	
	1.1		187	1	7	0.18, 0.19	Seed	
						0.53, 0.54	Hulls	
						<0.01, 0.01	Meal	
						<0.01, <0.01	Oil	
						17, 18	Leaves	
						8.3, 8.4	Stalks	

Year, location (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
ND (Peredovik)	0.56		47	1	7	0.16, 0.16	Seed	T-2680
						0.56, 0.58	Hulls	
						<0.01, 0.01	Meal	
						<0.01, <0.01	Oil	
						8.1, 11	Leaves	
						4.8, 5.2	Stalks	
					14	0.10, 0.11	Seeds	
					21	0.05, 0.05	Seeds	
CA (RHA-271)	0.56		206	1	7	0.09	Seed	T-2681
						0.27	Hulls	
						<0.01	Meal	
						<0.01	Oil	
					14	0.05	Seed	
MS (HF-52)	0.56		47	1	7	0.12, 0.14	Seed	T-2682
						0.36, 0.40	Hulls	
						<0.01, <0.01	Meal	
						<0.01, <0.01	Oil	
					14	0.09, 0.10	Seed	
					21	0.07, 0.09	Seed	
SD (Record)	0.63		23	1	14	0.15, 0.16	Seed	T-2683
						0.42, 0.50	Hulls	
						0.01, 0.02	Meal	
						<0.01, <0.01	Oil	
MN (Cargill 101)	0.56		47	1	9	0.20, 0.22	Seed	T-2684
						0.60, 0.64	Hulls	
						0.02, 0.02	Meal	
						<0.01, <0.01	Oil	
1974					0B*	<0.01	Harvest aid	Chevron 1975a
MN (Sputnik)	0.56		47	1	7	0.12, 0.16	Seed	T-3069
						0.25, 0.30	Hulls	
						0.08, 0.09	Meal	
						<0.01, <0.01	Oil	
ND (Sputnik)	0.56		47	1	7	0.24, 0.24	Seed	T-3070
						0.50, 0.59	Hulls	
						0.11, 0.14	Meal	
						<0.01, <0.01	Oil	
SD (Peredovik)	0.56		47	1	7	0.28, 0.32	Seed	T-3071
TX (sun Hi 372)	0.56		47	1	15	0.18, 0.19	Seed	T-3126
						0.39, 0.40	Hulls	
						0.09, 0.13	Meal	
						<0.01, <0.01	Oil	
					20	0.14, 0.16	Seed	
TX (Sun Hi 372)	0.56		47	1	17	0.12, 0.15	Seed	T-3127

B=control

Hops

Paraquat is recommended for the control of weeds pre-emergence or post-emergence directed between hop rows.

In Canada, a single post-emergence directed application of 1.12 kg ai/ha was made and green hops were harvested 42 days after application.

In residue trials in the USA in the States of Idaho and Washington, using three post-emergence directed applications of paraquat at 2.8 kg ai/ha green hops were harvested 13 to 14 days after the last application and processed into dried hops.

Table 40. Paraquat residues in hops from supervised trials in Canada and the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
BC, Canada, 1964 (Unknown)	2.24		702-935	1	0B*	<0.01	Post-emergence directed	McKenna 1966
					53	<0.01	Green hops	
ID, USA, 1988 (Hallertau Mittlefrueh)	2.8	9.03	31	3	B*	<0.05	Green hops	Roper 1989d 15ID88-591
						<0.1	Dried hops	
					14	<0.05	Green hops	
						<0.1	Dried hops	
WA, USA, 1988 (L-1 Clusters)	2.8	9.03	31	3	B*	<0.05	Green hops	15WA88-592
						<0.1	Dried hops	
					13	<0.05	Green hops	
						<0.1	Dried hops	
OR, USA, 1973					B*	<0.01	Green hops	Anon. 1975b
						<0.01	Dried hops	
(Cascade)	0.56			3	14	0.04	Green hops	T-2639
						0.05	Dried hops	
	1.12			3	14	0.05	Green hops	
						0.01	Dried hops	
(Fuggle)	0.56		374	1+				T-2640
	1.12			1	14	0.03	Green hops	
						0.03	Dried hops	
	1.12			1+				
	2.24			1	14	0.01	Green hops	
						0.02	Dried hops	
(Bullion)	0.56		467	3	14	0.04	Green hops	T-2958
						0.05	Dried hops	
	1.12			3	14	0.03	Green hops	
						0.07	Dried hops	
(Bullion)	1.12		187	3	31	<0.01	Dried hops	T-2967
						<0.01	Refuse	
	2.24			3	31	<0.01	Dried hops	
						0.06	Refuse	

*B: control

Tea. Table 41 shows application rates per season. Paraquat was applied as one initial blanket spraying plus 1, 3 or 5 spot treatments for weed-infested areas over a period of 5-7 months. Green leaf samples from each plot were taken 0-21 days after the first blanket treatment and at intervals after subsequent spot treatments, and processed into black tea by the orthodox (4NET) or CTC method (other than 4NET). The orthodox method consists of withering the leaves until the moisture is reduced to 20-25% and then repeatedly rolling the leaf in conventional three crank rollers. Leaves are then fermented at normal temperature. The fermentation is stopped by firing the leaves. In the CTC (crushing, tearing and curling) method the withered leaves as above are fed into a commercial machine consisting of two milled and chased rollers running at a ratio of 1:10. The leaves are then fermented under controlled temperature and humidity before firing in a drying machine.

Table 41. Paraquat residues in black tea from supervised trials in India.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha		water, l/ha	no.				
Jorhat, 1994 (Khorijan & Timgamira Jat)	0		500 (blanket)		7	<0.05		Anderson & Agarwal 1996 1 NET
					21	<0.05		
					7	<0.05		
					21	<0.05		
					7	<0.05		
	0.57	1 blanket			7	<0.05	after blanket treatment	
		3 spot			21	<0.05	after 1st spot treatment	
					7	<0.05	after last spot	
					21	<0.05	treatment	
					7	<0.05	after blanket treatment	
							after 1st spot treatment	
	1.6	1 blanket			7	0.07	after last spot	
		3 spot			21	<0.05	treatment	
					7	<0.05		
					21	<0.05		
					7	<0.05		
Rajmai, 1994 (Betjan clone TVI)	0		500 (blanket)		7	<0.05		2 NET
					21	<0.05		
					7	<0.05		
					21	<0.05		
					7	<0.05		
	0.68	1 blanket			7	<0.05	after blanket treatment	
		3 spot			21	<0.05	after 1st spot treatment	
					7	<0.05	after last spot	
					21	0.07	treatment	
					7	<0.05	after blanket treatment	
							after 1st spot treatment	
	2.0	1 blanket			7	<0.05	after last spot	
		3 spot			21	<0.05	treatment	
					7	<0.05		
					21	0.05		
					7	<0.05		
Nagrakata, India 1994 (biclonal selections)	0		500 (blanket)	1	7	<0.05		3 NET
					21	<0.05		
					7	<0.05		
					21	0.05		
	0.56	1 blanket		1	7	<0.05	after blanket treatment	
		1 spot			21	<0.05	after 1st (last) spot	
					7	<0.05	treatment	
					21	<0.05	after blanket treatment	
	1.7	1 blanket		1	7	<0.05	after 1st (last) spot	
		1 spot			21	<0.05	treatment	
					7	<0.05		
					21	<0.05		
Darjeeling, 1994 (China hybrid)	0		500 (blanket)		7	<0.05		4 NET
					21	<0.05		
					7	<0.05		
					21	<0.05		
					7	<0.05		
	0.57	1 blanket			7	<0.05	after blanket treatment	
		3 spot			21	<0.05	after 1st spot treatment	
					7	<0.05	after last spot	
					21	<0.05	treatment	
					7	<0.05	after blanket treatment	
							after 1st spot treatment	
	1.7	1 blanket			7	<0.05	after last spot	
		3 spot			21	<0.05	treatment	
					7	<0.05		
					21	<0.05		
					7	<0.05		

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and references	
	kg ai/ha		water, l/ha	no.				
Valpari, India	0		500		7	<0.05		5 ST
1994			(blanket)		21	<0.05		
(Upasi-17 clone)					7	0.13		
	0.56	1 blanket			7	0.09	after blanket treatment	
		5 spot			21	0.08	after last spot	
					7	0.07	treatment	
							after blanket treatment	
	1.7	1 blanket			7	0.09	after last spot	
		5 spot			21	0.08	treatment	
					7	0.07		
Munnar, India	0		500		7	<0.05		6 ST
1994			(blanket)		21	<0.05		
(China hybrid)					7	<0.05		
	0.56	1 blanket			7	<0.05	after blanket treatment	
		3 spot			21	0.12	after last spot	
					5	<0.05	treatment	
							after blanket treatment	
	1.7	1 blanket			7	<0.05	after last spot	
		3 spot			21	<0.05	treatment	
					5	<0.05		
Assam, India	0.25	0.06	400	1	5	0.05		Indian
(Clone T3E3)					7	<0.05		submission,
Site I								2004
	0.19	0.05	400	1	5	<0.05		
					7	<0.05		
	0.19	0.05	400	1	5	<0.05		
					7	<0.05		
	0.19	0.05	400	1	5	<0.05		
					7	<0.05		

Animal feedingstuffs

Soya forage and hay or fodder

Table 42. Paraquat residues in soya beans from supervised trials in the USA.

Year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no				
1988					0B*	<0.025, <0.05	Pre-emergence	Roper 1989l
IN (Decalb CX324)	1.1				79	≤0.025	Forage	23IN-88-584
					96	≤0.05	Hay	
MS (Asgrow)	1.1				113	≤0.025	Forage	48MS-88-585
					113	≤0.05	Hay	
MN (Evans)	1.1				132	≤0.025	Forage	38MN-88-787
					147	≤0.05	Hay	
OH (unknown)	1.1				106	≤0.025	Forage	27OH-88-788
					106	≤0.05	Hay	
1987					OB*	<0.025	Pre-emergence, post-emergence directed	Roper 1989m
NE (Asgrow 3127)	1.1 pre			1+				92NB-87-560
	0.14 post			2	52	≤0.025	Forage	
					63	≤0.025	Hay or fodder	
					88	<0.025	Seed	
IL (William 82)	1.1 pre			1+				US04-87-561
	0.14 post			2	59	≤0.025	Forage	
					59	≤0.025	Hay or fodder	
					90	<0.025	Seed	

Year (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no	PHI days	Paraquat mg/kg	Notes	References
IA (Pioneer 9271)	1.1 pre 0.14 post			1+ 2	 37 84 84	 <0.025 0.2 0.03	 Forage Hay or fodder Seed	A1IA-87-562
LA (Yield King 613)	1.1 pre 0.14 post			1+ 2	 19 48 63	 0.05 0.1 <0.025	 Forage Hay or fodder Seed	36LA-87-563
MS (Centennial)	1.1 pre 0.14 post			1+ 2	 65 79 79	 <0.025 0.05 <0.025	 Forage Hay or fodder Seed	US05-87-564
MO (Asgrow 3544)	1.1 pre 0.14 post			1+ 2	 53 102 102	 <0.025 <0.025 <0.025	 Forage Hay or fodder Seed	48MO-87-565
AR (DPL 504)	1.1 pre 0.14 post			1+ 2	 74 41 109	 <0.025 <0.025 <0.025	 Forage Hay or fodder Seed	06AR-87-566
AL (Braxton)	1.1 pre 0.14 post			1+ 2	 70 138 138	 <0.025 <0.025 <0.025	 Forage Hay or fodder Seed	62AL-87-567
GA (Kirby)	1.1 pre 0.14 post			1+ 2	 34 79 79	 <0.025 0.04 <0.025	 Forage Hay or fodder Seed	83GA-87-568
De (Pioneer 9441)	1.1 pre 0.14 post			1+ 2	 3 30 30	 1.8 0.3 <0.025	 Forage Hay or fodder Seed	44DE-87-569
1997					0B*	<0.05	Pre-emergence	Spillner *et al.* 1999
NC(Hyperformer 574)	1.4			1	36	0.08	Forage	01-NC-97-610
TN(Hutachson)					30	0.28		50-TN-97-611
AR(AG5901)					23	<0.05		49-AR-97-612
LA(Delta Pine					29	<0.05		69-LA-97-613
DP3478)					36	0.07		63-IA-97-615
IA(Pella)					36	0.15		63-IA-97-616
IA(D260)					42	<0.05		63-IA-97-617
IA(L2233)					44	<0.05		04-IL-97-618
IL(Asgrow A3237)					42	0.06		60-IL-97-619
IL(Asgrow 4401)					44	<0.05		60-IL-97-620
IL(Asgrow 2704 STS)					53	0.06		67-IN-97-621
IN(Pioneer 9342)					47	<0.05		67-IN-97-622
IN(Alder 373)					36	<0.05		37-KS-97-623
KS(Ciba 373)					40	<0.05		36-MN-97-624
MN(ICI D162)					42	<0.05		37-MO-97-625
MO(Ciba 3362)					50	<0.05		89-OH-97-627
OH(Asgrow 3701)					47	<0.05		34-SD-97-628
SD(Garst D210)					36	<0.05		79-WI-97-629
WI(Asgrow XP19505)					27	0.06		05-MS-97-631
MS(Asgrow 5979)					30	0.06		68-NE-97-632
NE(Pioneer 9281)					36	<0.05		79-WI-97-633
WI(Asgrow AG-2501)								
					0B*	<0.05	Pre-emergence, then two post-emergence directed then one spot application	Spillner *et al.* 1999

Year (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	no	PHI days	Paraquat mg/kg	Notes	References
	1.40 pre			1+				
	0.56 post			2+				
NC(Hyperformer 574)	0.05 spot			1	46	<0.05	Hay	01-NC-97-610
TN(Hutachson)					28	0.70		50-TN-97-611
AR(AG5901)					21	1.36		49-AR-97-612
LA(Delta Pine					10	4.10		69-LA-97-613
DP3478)					14	0.79		63-IA-97-615
IA(Pella)					14	0.99		63-IA-97-616
IA(D260)					11	1.74		63-IA-97-617
IA(L2233)					8	3.21		04-IL-97-618
IL(Asgrow A3237)					11	1.15		
					14	1.19		
					18	0.74		
					25	0.49		
					26	0.88		60-IL-97-619
IL(Asgrow 4401)					22	0.67		60-IL-97-620
IL(Asgrow 2704 STS)					18	2.69		67-IN-97-621
IN(Pioneer 9342)					10	5.56		67-IN-97-622
IN(Alder 373)					18	0.09		37-KS-97-623
KS(Ciba 373)					22	0.82		36-MN-97-624
MN(ICI D162)					16	0.29		37-MO-97-625
MO(Ciba 3362)					27	1.04		68-NE-97-626
NE(Pineer 9281)					20	1.95		89-OH-97-627
OH(Asgrow 3701)					22	1.33		34-SD-97-628
SD(Garst D210)					8	0.33		05-MS-97-631
MS(Asgrow 5979)					29	0.34		
					32	0.57		
					35	0.18		
					43	0.49		
					18	0.33		79-WI-97-633
WI(Asgrow AG-2501)								
					0B*	<0.05	Pre-emergence; two post-emergence directed; one spot; one desiccation application	Spillner *et al.* 1999
1988					B*	<0.05	Forage	Roper 1989n
						<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	Forage	
						<15	Hay	
						<0.05	Seed	
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	

Year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no				
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 application
					10	24	Forage	
					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 application
					5	10	Forage	
					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 application
						23	Hay	
					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 application
					5	27	Forage	
					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 application
					5	10	Forage	
					10	10	Forage	
					15	<5	Forage	
					19	0.1	Seed	
MN (BSR 101)	2.24		38	1	0	59	Forage	30MN-88-541
						2	Hay	Aerial application
					5	23	Forage	
					10	23	Forage	
					15	22	Forage	
					22	0.08	Seed	

Year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no				
					B*	<1	Forage	
						<2	Hay	
						<0.05	Seed	
OH (Asgrow 3427)	2.24		38	1	0	15	Forage	27OH-88-542
						6	Hay	Aerial application
					5	19	Forage	
					10	8	Forage	
					15	1	Forage	
						0.08	Seed	

B*: control

Sugar beet tops

Table 43. Paraquat residues in beet from supervised trials in the UK and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
UK, 1964 Beetroot (unknown)	1.68 pre		N/A	1+	112	<0.01	Root	McKenna 1966
	2.24 direct			2		0.01	Tops	
UK, 1964 Sugar Beet (Klein)	1.68 pre		N/A	2+	72	0.01	Root	McKenna 1966
	2.24 direct			1		0.08	Tops	
	1.68 pre		N/A	2+	84	<0.01	Root	
	2.24 direct			1		0.06	Tops	
USA, 1988 Sugar Beet (unknown)	1.12		N/A	1	0B*	<0.025	Pre-emergence	Roper 1989c
					136	<0.05	Root	33MN88-405
						≤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	

*B: control

Maize forage and fodder

Table 44. Paraquat residues in maize forage and fodder from supervised trials in Canada, Italy, South Africa, the UK and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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	
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	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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 35IN-88-440
IA (Garst 8383)	0.56			1	0	2	Forage	
					7	2		
					14	0.5		
					21	0.6		
					22	0.3	Silage	
	0.56			2	48	<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	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
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	
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	

*B: control

Sorghum forage (green) and straw and fodder, dry

Table 45. Paraquat residues in sorghum forage (green) and straw and fodder, dry, from supervised trials in the USA.

Year, location (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	No.				
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	
1971					0B*	<0.01	Pre-emergence followed by post-emergence directed	Kalens *et al.* 1971
MS (Funks BR 79)	0.28 pre 0.28 post		234	1+ 1	36	<0.01	Forage	T-2155
					86	<0.01	Grain	
						<0.01	Fodder	

Year, location (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	No.	PHI days	Paraquat mg/kg	Notes	References
	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	
TX (DeKalb E 56)	0.56 pre		206	1+	40	<0.01	Forage	T-2157
	0.28 post			1	131	<0.01	Grain	
						<0.01	Fodder	
TX (NK 222)	0.56 pre		206	1+	40	<0.01	Forage	T-2159
	0.56 post			1	67	<0.01	Grain	
						<0.01	Fodder	
1973					0B*	<0.01	Harvest aid	Anon 1975a
IA (unknown)	0.43		28	1	7	2.0	Grain	T-2778
						10	Fodder & Forage	(air)
NE (Pioneer 878)	0.43		28	1	8	2.5	Grain	T-2779
						0.10	Flour	(air)
						6.0	Bran	
						8.4	Shorts	
						0.86	Germ	
						5.6	Fodder	
IL (unknown)	0.43		131	1	7	28	Fodder	T-2780
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)	
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)
1987					0B*	<0.025	Pre-emergence and then post-emergence directed	Roper 1989k
TX (Pioneer 8493)	1.12 pre 0.56 post			1+ 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 0.56 post			1+ 2	48	<0.025	Forage	92NB-87-571
						0.025	Silage	
					62	0.06	Hay	
					73	0.03	Fodder	
						<0.025	Grain	

Year, location (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	No.				
KS (Paymaster	1.12 pre			1+				48KS-87-572
1022)	0.56 post			2	20	0.025	Forage	
						0.04	Silage	
					25	<0.025	Hay	
					72	0.06	Fodder	
						<0.025	Grain	
SD (Sokota	1.12 pre			1+				64SD-87-573
910GS)	0.56 post			2	22	0.025	Forage	
						0.025	Silage	
						<0.025	Hay	
					67	0.03	Fodder	
						<0.025	Grain	
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	
MO (Stauffer	1.12 pre			1+				06MO-87-575
530)	0.56 post			2	44	0.04	Forage	
						0.2	Hay	
					56	<0.025	Fodder	
						<0.025	Grain	
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	1.12 pre			1+				06AR-87-579
530)	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	
2000					0B*	<0.02 grain <0.5 stover	Pre-emergence followed by a harvest aid desiccation	Carringer & Yuen 2001
NC (DK36)	1.12pre		184	1+	3	14	Grain	PARA-00-MR
	1.12post		184	1		18	Stover	-01-343

Year, location (variety)	Application kg ai/ha	kg ai/hl	water, l/ha	No.	PHI days	Paraquat mg/kg	Notes	References
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				PARA-00-MR -01-347
					1	8.4 24	Grain Stover	
					3	6.7 19	Grain Stover	
					7	6.0 15	Grain Stover	
					14	4.1 9.9	Grain Stover	
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 straw and fodder, dry

Table 46. Paraquat residues in rice straw and fodder, dry, from supervised trials in Guatemala, Italy and the USA.

Location, 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	5 days Pre planting	Anderson *et al* 1995
(Loto)	0.92		400	1	119	<0.05 <u><0.05</u>	grain straw	IT10-93-H370 IT10-93-H371
(Koral)	0.92		400	1	151	<0.05 <u><0.05</u>	grain straw	
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 <u><0.02</u>	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 <u><0.03</u>	Grain Straw	
(Labelle)	1.12		187	1	106	<0.01 <u><0.02</u>	Grain Straw	M209-5583

*B: control

Almond hulls

Table 47. Paraquat residues in almond hulls from supervised trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes and reference	
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, USA					0B*	<0.01		Chevron 2001
1964								
(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 fruit	
					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	Meat	nuts knocked to treated ground
(Non pariel)	1.12		34	4(1)	1	0.22	Hulls	T-1090
					1	0.01	Meat	nuts knocked to treated ground

*B: control

Cotton

Table 48. Paraquat residues in cotton 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)					0B*	<0.01	Pre-emergence	Chevron 1967 T-383
	1.12		468	1	121	<0.01	Seed	
						<0.01	Trash	
						<0.01	Lint	
CA, 1964 (Acala 4-42)	1.12		468	1	30	<0.01, <0.01	Whole plant	T-614
					60	<0.01, <0.01		
					154	<0.01, <0.01		
TX (Blightmaster)	0.56			1	9	0.97, 0.97, 1.28, 1.76	Cotton (including trash & bolls)	T-654
					9	0.08, 0.09, 0.10, 0.18	Fuzzy seed	
					9	<0.01, <0.01, <0.01, <0.01	Acid-delinted seed	
					9	<0.01, <0.01, <0.01, 0.01	Mechanically delinted seed	
					9	<0.01, <0.01, <0.01, 0.01	Hulls	
					9	<0.01, <0.01, <0.01, <0.01	Crude oil	
					9	<0.01, <0.01, <0.01, <0.01	Meal	

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
TX (Rex)	0.56			1	1	15, 15	Cotton (including trash & bolls)	T-653
					5	2.1, 2.6		
					10	2.0, 2.1		
					5	0.11, 0.13	Fuzzy seed	
					10	0.18, 0.18		
					10	0.05, 0.051	Acid-delinted seed	
					10	0.08, 0.08	Mechanically delinted seed	
					10	2.8, 3.3	Lint cotton	
					10	0.13, 0.13	Hulls	
					10	<0.01, <0.01	Crude oil	
					10	0.02, 0.02	Meal	
1989							Harvest aid	Roper 1990
					0B*	<1.0	Gin trash	
TX (Paymaster 145)	0.56			1	14	11	Gin trash	10TX-89-481
TX (Paymaster 145)	0.56			1	14	7.3	Gin trash	10TX-89-482
TX (DPL 50)	0.56			1	17	6.2	Gin trash	11TX-89-483
TX (DPL 50)	0.56			1	17	5.9	Gin trash	12TX-89-484
OK (Tamcot CD-3H)	0.56			1	14	12	Gin trash	13OK-89-485
AZ (D&PL 61)	0.56			1	14	5.2	Gin trash	14TX-89-486
AZ (D&PL 61)	0.56			1	14	9.4	Gin trash	14TX-89-487
CA (GC510)	0.56			1	13	32	Gin trash	19CA-89-488
CA (GC510)	0.56			1	13	34	Gin trash	19CA-89-489
USA, 1995					0B*	<0.05	Pre-emergence followed by post-emergence, harvest aid	Roper & Elvira 1996
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	
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	
AZ (DPL 20)	1.4 pre		104	1+				14-AZ-95-662
	0.56		126/127	2+				
	0.14		79/80	2+				
	0.56		80	1	3	0.23	Seed	
						23	Gin byproduct	
OK (Paymaster HS200)	1.4 pre		136	1+				23-OK-95-663
	0.56		185/192	2+				
	0.14		69/68	2+				
	0.56		67	1	3	0.35	Seed	
						5.3	Gin byproduct	

B: control

FATE OF RESIDUES IN STORAGE AND PROCESSING

In processing

The Meeting received information on processing studies on the following **commodities.**

Crop	**Studied processed products**
Orange:	Juice
Plum:	Dried prunes
Grape:	Dried grapes and grape juice
Olive:	Washed fruit, oil and press cake
Tomato:	Juice, wet pomace, dry pomace and ketchup
Sugar Beet:	Molasses and refined sugar
Potato:	crisps, dried potato and granules
Maize:	germ, starch, grits, meal, flour and oil
Sorghum:	Bran, starch, grits and flour
Cotton seed:	Trash/gin by-products and oil
Sunflower seed:	Meal and oil
Hop:	Dried hop and beer

In order to investigate the degradation of paraquat residues during processing, typical processing studies were conducted. As the standard analytical methods for paraquat involve a rigorous acid reflux extraction (0.5M sulphuric acid reflux for 5 hours), the stability of paraquat to hydrolysis has been demonstrated. Studies showed paraquat to be stable the pH range of 5-9.

For those crops where paraquat is applied pre-emergence, post-emergence, or directly between crops, paraquat must not have direct contact with the crop, so and for this reason, under these applications, the extent the exposure of the crop to paraquat is minimal. The supervised field trials demonstrated the absence of, or very low residues of, paraquat in these crops, which would make processing studies unnecessary.

However, with harvest aid desiccant uses, the direct application of paraquat to the crop may result in much higher levels of residues, while in some cases orchard fruit under unusual conditions may come in contact with sprayed weeds. In these cases, processing studies were needed, to determine whether residues of paraquat are transferred and concentrated in the processed products.

The transfer factors are calculated by dividing the residues measured in the processed commodity by the residues measured in the raw agricultural commodity. The residue data used for the calculations are uncorrected for recovery values and expressed in mg paraquat cation/kg.

<u>Processing of oranges</u>

The fate of paraquat residue in oranges during juicing was investigated in studies in California and Florida, USA, with exaggerated application rates of 4.48 to 20.2 kg ai/ha as directed broadcast between the rows (Chevron, 2001). These rates are 4 to 18 times the highest permitted rate in US GAP. Oranges were collected between 0 and 177 days after application and processed to juice as described in Figure 6.

Table 49 shows that even at an exaggerated rate of application, no quantifiable residues of paraquat were found in any processed sample (limit of quantification: 0.01 mg/kg for peel and juice).

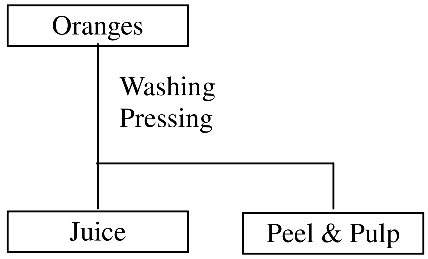


Figure 6. Processing of oranges to juice.

Table 49. Paraquat residues in oranges and processed products from trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, 1962	2.8	0.12		2	0B*	<0.01		Chevron 2001
(Navel)								T-326
					0	<0.01	Juice (procedural	
					7	<0.01	recovery, 45%)	
					15	<0.01		
					28	<0.01		
					0	<0.01		
					7	<0.01	Pulp (procedural	
					15	<0.01	recovery, 67%)	
					28	<0.01		
FL, 1965					0B*	<0.01		T-631
(Valencia)	1.12	0.054		4	177	<0.01, <0.01	Mature fruit	Broadcast
						<0.01, <0.01	Juice	spray around
	2.24	0.054		9	31	<0.01, <0.01	Mature fruit	each tree on an
						<0.01, <0.01	Juice	area of 100 sq
		0.11		4	177	<0.01, <0.01	Mature fruit	ft.
						<0.01, <0.01	Juice	
FL, 1965	2.44	0.12		1	0B*	<0.01		T-903
(Hamlin)					3	0.01, <0.01	Mature fruit	
						<0.01, <0.01	Juice	

B*: control

Since the residues of paraquat in all samples were below the limit of quantification, processing factors could not reliably calculated.

<u>Processing of plums</u>

Two plum trials were used to obtain field-incurred residues in plums for processing into dried plums. In two trials conducted in the USA, paraquat was applied to the ground round plum trees as a broadcast directed spray three times during the season at 4.48 kg/ha (Roper, 1989a). This rate is 4 times the highest label rate in the USA. The fruit were harvested 28 days after treatment. Some of these fresh prunes were dried for 16 hours in a commercial fruit drier to produce dried prunes (Figure 7). Residues were measured in fresh plums and dried prunes and the results are shown in Table 50.

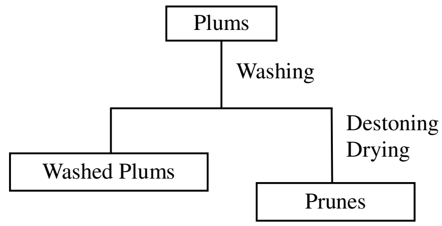


Figure 7. Processing of plums to prunes.

Table 50. Paraquat residues in plums and dried prunes from trials in the USA.

Location, year Crop (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, 1987 (Prune, French)	4.48	1.93		3	B*	<0.01 <0.05	Fresh Dried	Roper 1989a 45CA-87-523
					28	<0.01 <0.05	Fresh Dried	
	4.48	1.93		3	B*	<0.01 <0.05	Fresh Dried	45CA-87-599
					28	<0.01 <0.05	Fresh Dried	

B*:control

Since residues of paraquat in all the samples were below the limit of quantification, processing factors could not reliably be calculated.

<u>Processing of grapes</u>

One residue trial in grapes was conducted during 1997 in California, USA (Spillner, 1998). Paraquat was applied once at an exaggerated rate of 5.6 kg/ha as a broadcast between the rows. This rate is 5 times the highest application rate on labels. Grapes were collected on the day of application and processed into sun-dried grapes (sun-dried for 21 days) and grape juice simulating industrial practice as closely as possible. The paraquat residues in grapes, dried grapes and juice were determined. The processing of fresh grapes into dried grapes and juice is shown in Figure 8. Residues measured in grapes, raisins, and juice are shown in Table 51. The limit of quantification was 0.01 mg/kg for grapes and grape juice, and 0.05 mg/kg for dried grapes.

No quantifiable residues of paraquat were found in any treated or untreated sample.

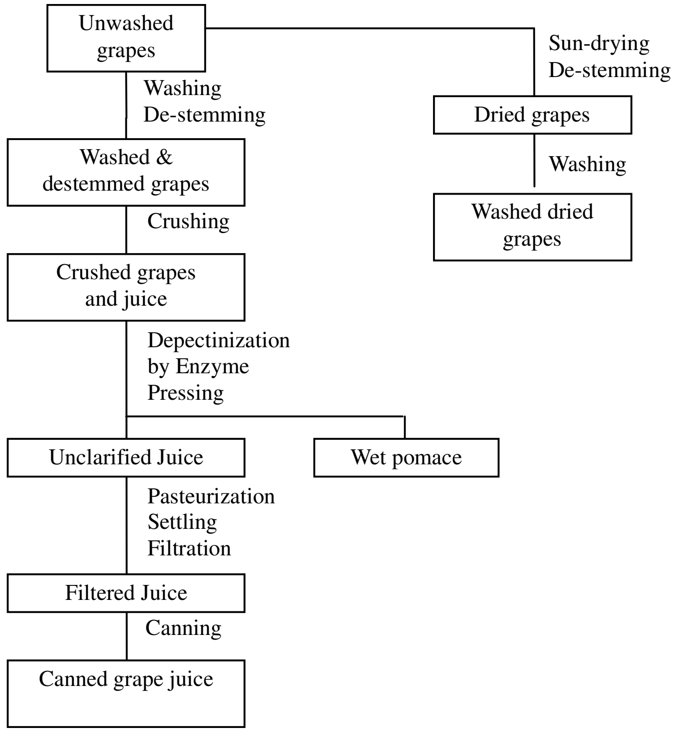


Figure 8. Processing of grapes to dried grapes and grape juice.

Table 51. Paraquat residues in grapes, dried grapes and juice from trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	no.				
CA, 1997 (Thompson Seedless)	5.6		45.6	1	B*	<0.01 <0.01 <0.05	Berries Juice Dried grapes	Spillner *et al.* 1998 02CA-97-601
					21	<0.01 <0.01 <0.05	Berries Dried grapes Processed Juice	

B*=control

Since residues of paraquat in all samples were below the limit of quantification, processing factors could not reliably be calculated.

Processing of olives

Olives destined for oil production are often harvested from the ground and paraquat may occasionally be applied directly to the fallen fruit when used to control weeds growing through the collection nets on the ground. These whole fruits will contain some paraquat residue, either through transfer from treated vegetation or through direct exposure. Studies were therefore conducted to investigate paraquat residues in oil and cake processed from olive fruits.

In a US trial in 1988, paraquat was applied four times at 5.6 kg ai/ha (a total of 22.4 kg ai/ha) to the soil at the base of the trees and olives were harvested 13 days after the last application. The application rate is five times the highest application rate on US labels (Roper, 1989i).

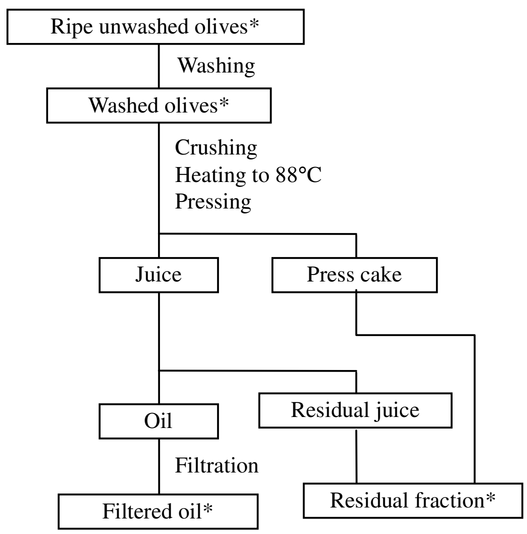
Two residue trials were carried out on olives in Italy in 1993 in which a single application of paraquat at a rate of 1.56 kg ai/ha and diquat at 0.78 kg ai/ha was applied for inter-row weed control. Olives were harvested 7 days after treatment to determine residues in olives and oil (Dick *et al.*, 1995a).

In these studies none of the samples of olives or contained paraquat residues above the limit of quantification.

Two new trials were conducted on olive trees in Spain during 2001 and 2002 (Devine *et al.*, 2003). Three or seven days before normal harvest, paraquat was applied once at a nominal rate of 1.1 kg ai/ha to fallen olives and the harvesting area around the base of the trees in two treated plots. Olive fruit samples for residue analysis were taken at normal harvest. Olive fruits for processing were taken from the untreated plant and the plots treated 3 days before harvest. These samples (unwashed olives) were processed into washed olives, virgin oil and refined oil, which were then analysed.

A flow chart for olive processing is shown in Figure 9 and the results of analysis in Table 52.

In the trial in the USA, paraquat was applied four times at an exaggerated rate (5.6 kg paraquat/ha; 22.4 kg/ha total) and the fruit were harvested from the trees for processing into oil and cake. In other trials in Spain, mature olives were sprayed directly on the ground with paraquat at rates from 0.36 to 1.3 kg/ha. The fruit were analysed after 3-17 days and the residue of paraquat ranged from 0.08 to 4.4 mg/kg.



* Analysed samples

Figure 9. Processing of olives to oil.

Table 52. Paraquat residues in olives and their processed products from trials conducted in Italy, Spain, and the USA.

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
USA 1988 (Manzanilla)	5.6			4	B*	<0.05, <0.05	Fruit	Roper 1989i 73CA88-526
						<0.05	Residual fraction	
						<0.05	Oil	
					13	<0.05, <0.05	Fruit	
						<0.05	Residual fraction	
						<0.05	Oil	
Latina, Italy, 1993 (Frantoio)	1.56		1000	1	B*	<0.10	Fruit	Dick *et* al. 1995a IT10-93-H338
						<0.05	Oil	
					7	<0.10	Fruit	
						<0.05	Oil	
Foggia, Italy 1993 (Coratina)	1.56		1000	1	B*	<0.10	Fruit	IT10-93-H339
						<0.05	Oil	
					7	<0.10	Fruit	
						<0.05	Oil	

Country, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	References
	kg ai/ha	kg ai/hl	water, l/ha	no.				
Andalucia, Spain, 2001/2002 (Hojiblanca)	1.09		347	1			Mean % of treated olives: 24%	Devine *et* al. 2003 ES051-01-S013
					B*	<0.05		
					3	0.45	Fresh fruit	
					3	0.18	Unwashed fruit	
					3	0.11	Washed fruit	
					3	<0.05	Virgin oil	
					3	<0.05	Refined oil	
Catalonia, Spain, 2001/2002 (Arbequina)	1.05		192				Mean % of treated olives: 10%	ES060-01-S113
					B*	<0.05		
					3	0.09	Fresh fruit	
					3	0.06	Unwashed fruit	
					3	<0.05	Washed fruit	
					3	<0.05	Virgin oil	
					3	<0.05	Refined oil	

B*: control

The procedural recoveries in the analysis of virgin oil and refined oil were relatively low at 66 and 62% respectively.

Processing factors were calculated from the Spanish trials where residues in the fresh fruit were above the limit of quantification. The results are shown in Table 53.

Table 53. Processing factors from olives to oil.

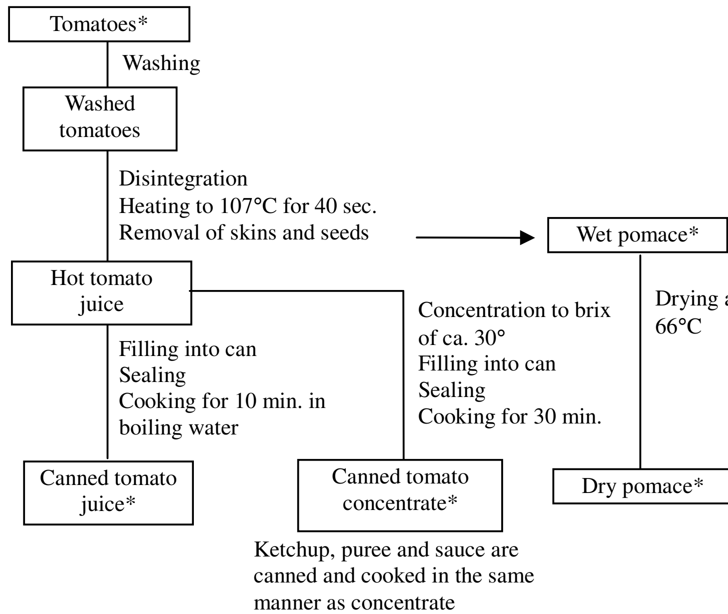
Product	ES051-01-S013		ES051-01-S113	
	Paraquat (mg/kg)	Processing factor	Paraquat (mg/kg)	Processing factor
Fresh Olive	0.38		0.09	
Unwashed olives before processing	0.18	0.47	0.06	0.67
Washed olives before processing	0.11	0.29	<0.05	<0.56
Virgin Oil	<0.05	<0.13	<0.05	<0.56
Refined oil	<0.05	<0.13	<0.05	<0.56

Paraquat is not transferred into the oil. Washing reduces paraquat residues to a certain extent.

<u>Processing of tomatoes</u>

In a study in the USA in 1988 whole tomatoes were treated with one pre-emergence broadcast application of paraquat at a rate of 1.12 kg ai/ha followed by three directed applications at 2.8 kg ai/ha (about 5 times the highest current application rate). Ripe tomatoes were harvested 30 days after the last application and processed according to normal commercial practice. The limits of quantification were 0.005 mg/kg for whole tomatoes and juice; 0.025 mg/kg for ketchup and wet pomace, and 0.05 mg/kg for dry pomace (Roper, 1989q).

A flow diagram outlining the processing is shown in Figure 10 and the results of residue analysis in Table 54. All residues of paraquat in all samples were below the limit of quantification.



* analysed samples

Figure 10. Processing of tomatoes to canned juice, canned tomatoes, canned concentrate, and wet and dry pomace

Table 54. Paraquat residues in tomatoes and processed products from 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, 1988 (Jackpot)					B*	<0.005	Unwashed tomato	Roper 1989q 18CA88-789
						<0.005	Juice	
						<0.025	Ketchup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	
	1.12		38.2	1				
	2.8			3	30	<0.005	Unwashed tomato	
						<0.005	Juice	
						<0.025	Ketchup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	
CA, USA, 1988 (Jackpot)					B*	<0.005	Unwashed tomato	18CA88-790
						<0.005	Juice	
						<0.025	Ketchup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	
	1.12		38.2	1				
	2.8			3	30	<0.005	Unwashed tomato	
						<0.005	Juice	
						<0.025	Ketchup	
						<0.025	Wet pomace	
						<0.05	Dry Pomace	

B*=control

Since residues of paraquat in all samples were below the limit of quantification, processing factors could not reliably be calculated.

<u>Processing of sugar beet</u>

A study was conducted in the USA to determine paraquat residues in dehydrated pulp, molasses and refined sugar produced from sugar beet treated with one pre-emergence broadcast application of paraquat at a rate of 5.6 kg ai/ha, which is five times the normal rate in the USA. The beets were harvested at normal harvest, 137 days after treatment, and processed according to normal commercial practice. The limits of quantification were 0.05 mg/kg for roots, dry pulp and molasses, and 0.025 mg/kg for wet pulp and sugar (Roper, 1989c). A flow chart for sugar beet processing is shown in Figure 11 and the results of residue analysis are shown in Table 55.

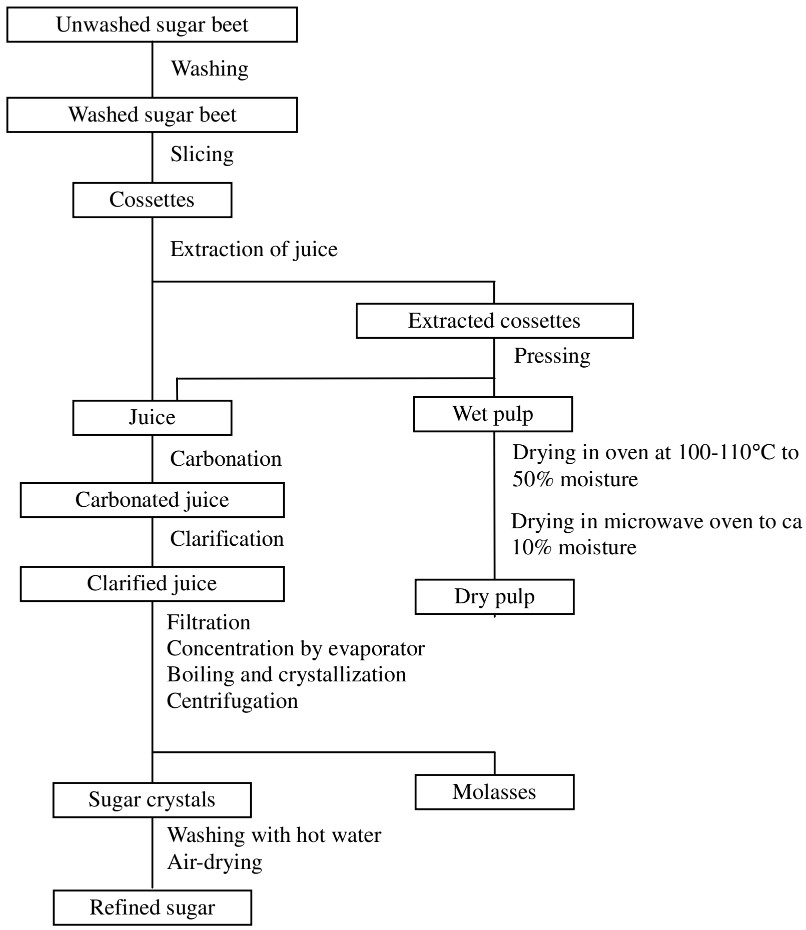


Figure 11. Processing of sugar beet to refined sugar, molasses and wet and dry pulp.

Table 55. Paraquat residues in sugar beet and processed products from a trial in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
ID, 1988	5.6		31	1	B*	<0.05	Unwashed roots from field	Roper 1989c 16ID88-599
						<0.05	Washed roots	
						<0.025	Wet pulp	
						<0.05	Dry pulp	
						<0.05	Molasses	
						<0.025	Sugar	
					137	<0.05	Unwashed roots from field	
						<0.05	Washed roots	
						<0.025	Wet pulp	
						<0.05	Dry pulp	
						<0.05	Molasses	
						<0.025	Sugar	

B*: control

Since residues of paraquat in all samples were below the limit of quantification, processing factors could not reliably be calculated.

Processing of potatoes

A study was conducted in Idaho and Maine, USA, to determine paraquat residues in potato tubers, wet and dried peel, crisps (chips) and granules from potatoes from plants treated with one broadcast spray of paraquat as a pre-harvest desiccant at 2.8 kg ai/ha seven days prior to harvest. Samples of unwashed potato tubers were washed and processed into potato crisps (chips) and granules according to the process described in Figure 12. The limits of quantification were 0.025 mg/kg for washed potatoes, peeled potatoes and potato crisps, 0.05 mg/kg for unwashed potatoes, peel and granules, and 0.025 mg/kg for dried peel (Roper, 1989b). The analytical results are shown in Table 56.

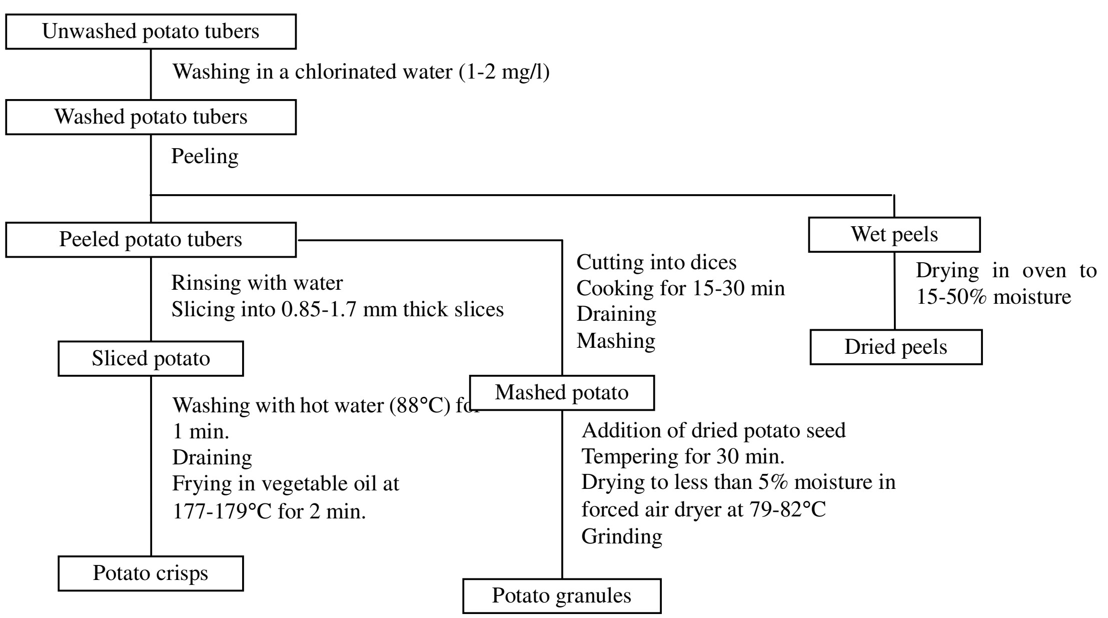


Figure 12. Processing of potatoes to crisps, granules and wet and dried peels.

Table 56. Paraquat residues in potatoes and processed products from trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
ID, 1988 (Russet Burbank)	2.8		31	1	B*	<0.05	Unwashed tuber from field	Roper 1989b 16ID88-400
						<0.025	Washed tuber	
						<0.05	Wet peels	
						<0.125	Dry peels	
						<0.025	Peeled potatoes	
						<0.025	Crisps	
						<0.05	Granules	
					7	<0.05	Unwashed ber from field	
						0.05	Washed tuber	
						0.13	Wet peels	
						0.45	Dry peels	
						<0.025	Peeled potatoes	
						0.05	Crisps	
						0.15	Granules	
ME, 1988 (Superior)	2.8		31	1	B*	<0.05	Unwashed tuber from field	56ME88-401
						<0.025	Washed tuber	
						<0.05	Wet peels	
						<0.125	Dry peels	
						<0.025	Peeled potatoes	
						<0.025	Crisps	
						<0.05	Granules	
					7	0.11	Unwashed tuber from field	
						0.10	Washed tuber	
						0.13	Wet peels	
						1.3	Dry peels	
						0.03	Peeled potatoes	
						0.10	Crisps	
						0.26	Granules	

B*=control.

Processing factors calculated are shown in Table 57.

Table 57. Processing factors for processed products of potatoes.

Product	16ID88-400		56ME88-401	
	Paraquat (mg/kg)	Processing factor	Paraquat (mg/kg)	Processing factor
Whole unwashed tuber from field	<0.05	-	0.11	
Whole washed tuber from processor	0.05	>1	0.10	0.91
Wet peel	0.13	>2.6	0.13	1.2
Dry peel	0.45	>9	1.3	12
Peeled potato	<0.025	-	0.03	0.27
Crisps	0.05	>1	0.1	0.09
Granules	0.15	>3	0.26	2.4

Processing of maize

A study was conducted in Iowa, USA, in 1988 to determine paraquat residues in crude and refined oils and milled fractions from maize treated with one broadcast application (harvest aid use) of paraquat at a rate of 2.8 kg ai/ha and harvested 7 days after the application. Maize grains (kernels) were processed as shown in Figure 13. The results of residue analysis are shown in Table 58. The limit of quantification was 0.05 mg/kg for all samples (Roper, 1989g).

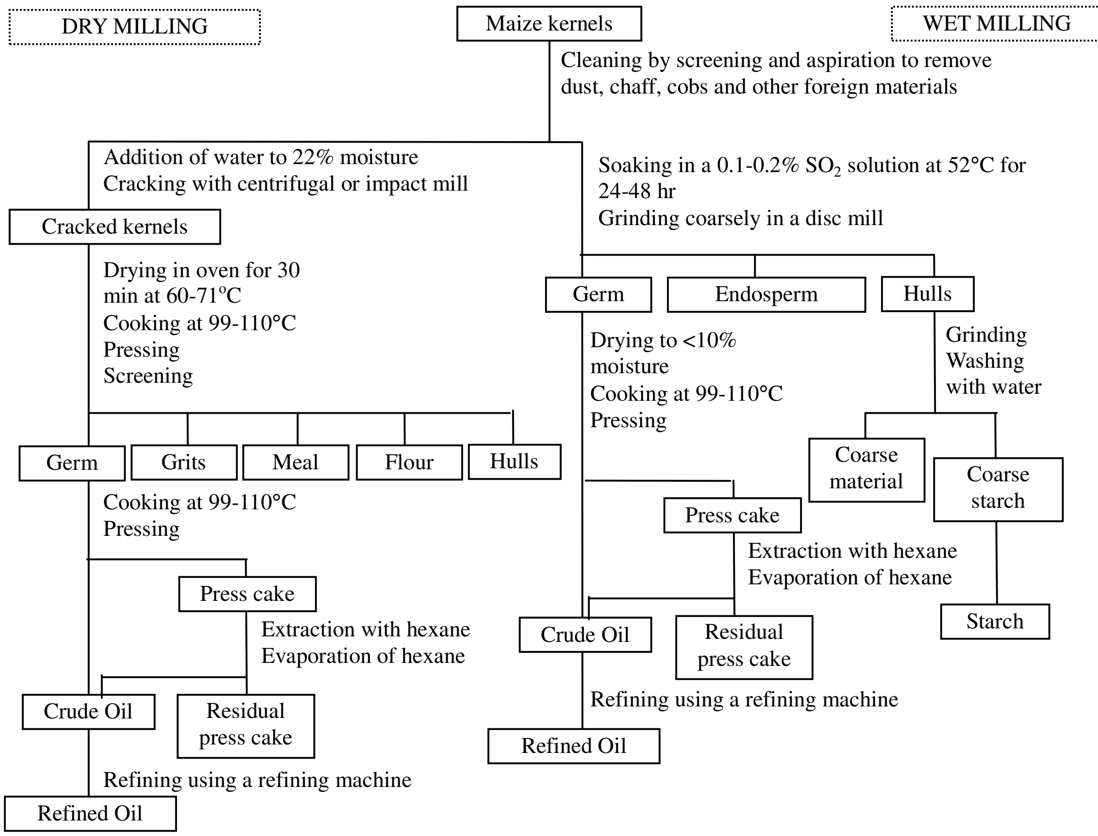


Figure 13. Processing of maize to oil, starch and milling fractions.

Table 58. Paraquat residues in maize and processed products from 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.				
IA, 1988 (Pioneer 3471)	2.8		31	1	B*	<0.05	All the uncontrolled samples	Roper 1989g
					7	0.4	Kernels from field	36IA88-791
							DRY MILLING	
						0.2	Kernels from processor	
						0.05	Large grits	
						0.09	Medium grits	
						0.1	Small grits	
						0.2	Coarse meal	
						0.1	Meal	
						0.3	Flour	
						1	Hulls	
						0.06	Germ	
						0.1	Expeller press cake	
						0.1	Extraction press cake	
							Expeller crude oil	
						<0.05	Refined oil	
						<0.01	WET MILLING	
							Kernels from	
						0.2	processor	
							Hulls	
						<0.05	Germ	
						<0.05	Course starch	
						<0.05, 0.05	Starch	
						<0.05	Expeller press cake	
						0.06	Extraction press cake	
						<0.05	Expeller crude oil	
							Refined oil	
						<0.05		
						<0.05		

B*: control

Processing factors calculated are shown in Table 59. There was no detectable transfer to oil.

Table 59. Processing factors for maize products.

Product	Wet milling		Dry milling	
	Paraquat (mg/kg)	Processing Factor	Paraquat (mg/kg)	Processing Factor
Whole kernel from processor	0.2		0.2	
Hulls	<0.05	<0.25	1	5
Germ	<0.05	<0.25	0.06	0.3
Large grits			0.05	0.25
Medium grits			0.09	0.45
Small grits			0.1	0.5
Coarse meal			0.2	1
Meal			0.1	0.5
Flour			0.3	1.5
Coarse starch	<0.05	<0.25		
Starch	<0.05	<0.25		
Expeller press cake	0.06	0.30	0.1	0.5
Extraction press cake	<0.05	<0.25	0.1	0.5
Expeller Crude oil	<0.05	<0.25	<0.05	<0.25
Refined oil	<0.05	<0.25	<0.01	<0.05

Processing of sorghum

Studies were conducted in Texas, California and Nebraska, USA in 1973/1974 to determine paraquat residues in milling fractions of sorghum. Sorghum was treated with one aerial application as a post-emergence harvest aid at a rate of 0.21 kg ai/ha (Texas and California) or 0.43 ka ai/ha and harvested 7-24 days after treatment. Grain was processed to flour, bran and shorts (byproduct of milling consisting of bran, germ and course meal). The results of residue analysis are shown in Table 60 (Anon., 1975a).

In more recent studies in Texas and Nebraska in 1988 and 1989 sorghum was treated with one broadcast application as a post-emergence harvest aid at a rate of 2.8 kg ai/ha, equivalent to five times the normal rate permitted in the USA, and harvested 3 or 7 days after treatment. Whole sorghum grain was processed into hulled grain, wet and dry milled bran, coarse grits, starch, and flour by both dry and wet milling as indicated in Figure 14. The results of residue analysis are shown in Table 60. The limits of quantification were 1 mg/kg for whole grain and grits, 10 mg/kg for bran and 0.5 mg/kg for starch and flour (Roper, 1989j).

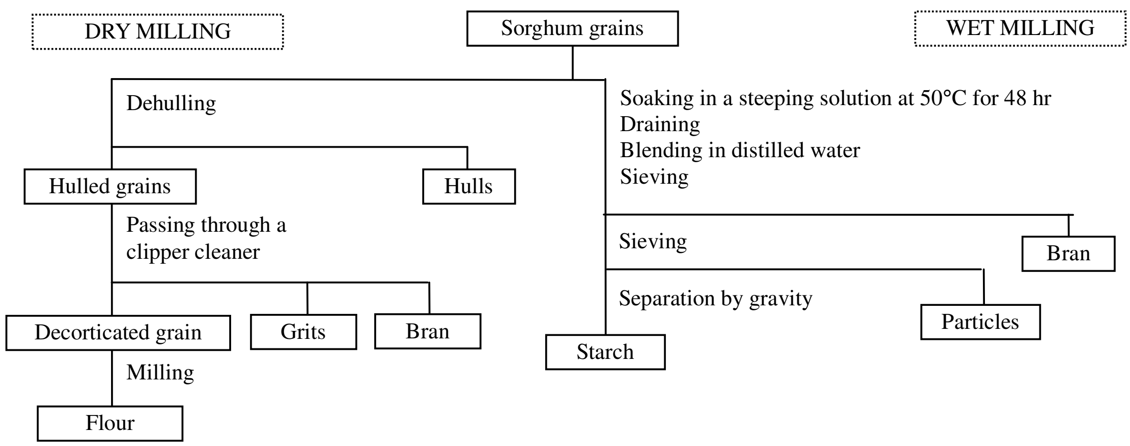


Figure 14. Processing of sorghum to hulled grains, bran, grits and flour.

Table 60. Paraquat residues in sorghum and processed products from trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
TX, 1988	2.8				B*	<1	Grain, whole & hulled	Roper, 1989j
(Golden Acres T-E							Coarse grits	11TX88-793
Y-75)						<1	Bran	
						<10	Starch	
						<0.5	Flour	
						<0.5	Grain from field	
					3	12.5	Grain from processor	
						10.4	Dry milled bran	
							Coarse grits	
						69.7	Flour	
						3.3	Wet milled bran	
						3.6	Starch	
						44.8		
						1.4		

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
NE, 1989	2.8				B*	<1	Grain, whole & hulled	41NB88-794
(NK 2230)							Grits	
						<1	Bran	
						<10	Starch	
						<0.5	Flour	
						<0.5	Grain from field	
					7	26.4	Grain from processor	
						9.2	Hulled grain	
							Dry milled bran	
						1.8	Coarse grits	
						51.6	Flour	
						2.2	Wet milled bran	
						2.5	Starch	
						23.8		
						0.7		
TX, 1970	0.21		7.7	1	7	0.61	Grain	Anon 1975a
						0.08	Flour	T-2004
						3.3	Bran	
						1.1	Shorts	
					24	0.33	Grain	
						0.07	Flour	
						1.4	Bran	
						0.53	Shorts	
CA, 1970	0.21		7.7	1	7	0.83	Grain	T-2005
						0.41	Flour	
					21	0.50	Grain	
						0.30	Flour	
NE, 1973	0.43		4.6	1	8	2.7	Grain	T-2779
						0.10	Flour	
						6.8	Bran	
						9.1	Shorts	
						1.4	Germ	

B*: control

Processing factors calculated are shown in Table 61.

Table 61. Processing factors for sorghum .

Product	Paraquat (mg/kg)	Processing factor	Paraquat (mg/kg)	Processing factor
	11TX88-793		41NB88-794	
Whole grain from field	12.5		26.4	
Whole grain from processor	10.4	0.83	9.2	0.35
Hulled grain			1.8	0.07
Dry milled bran	69.7	5.6	51.6	2.0
Coarse grits	3.3	0.26	2.2	0.08
Flour	3.6	0.29	2.5	0.09
Wet milled bran	44.8	3.6	23.8	0.90
Starch	1.4	0.11	0.7	0.03
	T-2004 (PHI: 7 days)		T-2779	
Grain	0.61		2.7	
Flour	0.08	0.13	0.10	0.04
Bran	3.3	5.4	6.8	2.5
Shorts	1.1	1.8	9.1	3.4
Germ			1.4	0.52

<u>Processing of cotton</u>

In a study Texas in 1964 cotton was treated once with paraquat as a harvest aid desiccant at a rate of 0.56 kg ai/ha, harvested 1-10 days after application, and processed. Processed fractions were analysed with the results shown in Table 62. The limit of quantification was 0.01 mg/kg (Chevron, 1966).

Another study was conducted in Texas, Arizona, Oklahoma and California to determine the paraquat residue levels of cotton gin trash. Mature cotton received one broadcast application of paraquat at a rate of 0.56 kg ai/ha as a harvest aid desiccant. In one site in Texas, cotton was treated by aerial application. Cotton bolls were harvested after 13 days (2 trials in California), 14 days (5 trials in Texas, Arizona and Oklahoma) and 17 days (2 trials in Texas). Cotton bolls were passed through a cotton gin and the gin trash collected for analysis. The residues in the gin trash were 32 and 34 mg/kg 13 days after treatment; 5.2, 7.3, 9.4, 11 and 12 mg/kg 14 days after treatment; 7.3 and 11 mg/kg from aerial application; and 5.9 and 6.2 mg/kg 17 days after treatment. However, no information on the paraquat levels in cotton was available for estimating processing factors.

A flow chart for cotton processing is shown in Figure 15.

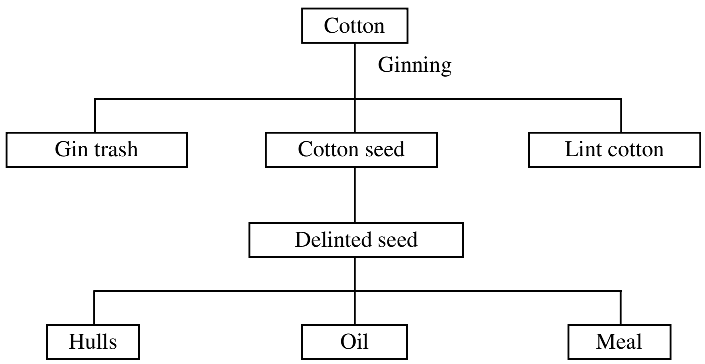


Figure 15. Flow chart for cotton processing.

Table 62. Paraquat residues in cotton and processed products from trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
TX, 1964	0.56			1	B*	<0.05		Chevron 1966
(Blightmaster)					10	2.03	Cotton (including trash & bolls)	T-653
						0.18	Fuzzy seed	
						0.05	Acid-delinted seed	
						0.08	Mechanically reginned seed	
						3.07	Lint cotton	
						0.13	Hulls	
						<0.01	Crude oil	
						0.02	Meal	

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
TX, 1964 (Rex)	0.56			1	9	1.37	Cotton (including trash & bolls)	T-654
						0.09	Fuzzy seed	
						<0.01	Acid-delinted seed	
						<0.01	Mechanically reginned seed	
						0.01	Hulls	
						<0.01	Crude oil	
						<0.01	Meal	
							BIS(METHYSULFATE) SALT**	
						1.13	Cotton (including trash & bolls)	
						0.14	Fuzzy seed	
						<0.01	Acid-delinted seed	
						0.01	Mechanically reginned seed	
						<0.01	Hulls	
						<0.01	Crude oil	
						<0.01	Meal	

B*: control ** dichloride salt used

Processing factors calculated are shown in Table 63.

Table 63. Processing factors for cotton products.

Product	Paraquat (mg/kg)	Processing factor	Paraquat (mg/kg)	Processing factor
	T-653		T-654	
Cotton (trash & bolls)	2.03		1.37	
Fuzzy seed	0.18	0.09	0.09	0.07
Acid delinted seed	0.05	0.02	<0.01	<0.007
Mechanically delinted seed	0.05	0.02	<0.01	<0.007
Lint cotton	3.07	1.5		
Hulls	0.13	0.06	0.01	0.007
Crude oil	<0.01	<0.005	<0.01	<0.007
Meal	0.02	0.01	<0.01	<0.007

Sunflower

A study was conducted in California, Iowa, Minnesota, Mississippi, North Dakota, South Dakota and Texas, USA, to determine paraquat residues in sunflower oil and meal prepared from sunflower seed. Sunflowers received one application of paraquat as a harvest aid desiccant at rates from 0.28 to 1.12 kg ai/ha (ground application in 5 of 16 tests and aerial application in the others). Mature seeds were harvested 1-3 weeks after treatment and processed to oil, meal and hulls. The results of residue analysis are given in Table 64. The LOQ was 0.01 mg/kg (Chevron, 1975a).

Table 64. Paraquat residues in sunflower products from trials in the USA.

Location , year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
CA, 1971 (Peredovik)	0.28		61	1	B*	<0.01		Chevron 1975a T-2185 (ground appl.)
					7	0.11	Mature seed	
						0.25	Hulls	
						0.15	Meal	
						<0.01	Oil	
	0.56		61			0.35	Mature seed	
						0.62	Hulls	
						0.55	Meal	
						<0.01	Oil	

Location , year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
MS, 1971 (NK-HO1)	0.28		7.5	1	7	0.21	Mature seed	T-2186 (ground appl.)
						1.9	Hulls	
						0.92	Meal	
						<0.01	Oil	
	0.56		7.5			0.31	Mature seed	
						3.4	Hulls	
						0.66	Meal	
						<0.01	Oil	
MN, 1972 (VNIIMK 8931)	0.28		7.7	1	7	0.08	Mature seed	T-2392 (aerial appl)
						0.08	Hulls	
						0.12	Meal	
						<0.01	Oil	
					14	0.11	Mature seed	
						0.09	Hulls	
						0.20	Meal	
						<0.01	Oil	
					21	0.12	Mature seed	
						0.08	Hulls	
						0.13	Meal	
						<0.01	Oil	
MN, 1972 (VNIIMK 8931)	0.28		7.7	1	7	0.06	Mature seed	T-2393 (aerial appl)
						0.06	Hulls	
						0.06	Meal	
						<0.01	Oil	
					14	0.04	Mature seed	
						0.05	Hulls	
						0.06	Meal	
						<0.01	Oil	
					21	0.03	Mature seed	
						0.02	Hulls	
						0.05	Meal	
						<0.01	Oil	
CA, 1972 (HO-1)	0.28		34	1	7	0.13	Mature seed	T-2394 (ground appl)
						0.15	Hulls	
						0.19	Meal	
						<0.01	Oil	
					14	0.10	Mature seed	
						0.13	Hulls	
						0.19	Meal	
						<0.01	Oil	
					21	0.11	Mature seed	
						0.10	Hulls	
						0.18	Meal	
						<0.01	Oil	
IA, 1973 (Peredovik)	0.56		31	1	7	0.12	Mature seed	T-2679 (ground appl.)
						0.31	Hulls	
						<0.01	Meal	
						<0.01	Oil	
	1.12		31			0.19	Mature seed	
						0.54	Hulls	
						0.01	Meal	
						<0.01	Oil	
ND, 1973 (Peredovik)	0.56		7.7	1	7	0.16	Mature seed	T-2680 (aerial appl.)
						0.57	Hulls	
						0.01	Meal	
						<0.01	Oil	
CA, 1973 (RHA-271)	0.56		34	1	7	0.09	Mature seed	T-2681 (ground appl.)
						0.27	Hulls	
						<0.01	Meal	
						<0.01	Oil	
MS, 1973 (HF-52)	0.56		7.7	1	7	0.13	Mature seed	T-2682 (aerial appl)
						0.38	Hulls	
						<0.01	Meal	
						<0.01	Oil	

Location , year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
SD, 1973 (Record)	0.63		3.8	1	14	0.16 0.46 0.02 <0.01	Mature seed Hulls Meal Oil	T2683 (aerial appl)
MN, 1973 (Cargill 101)	0.56		7.7	1	9	0.21 0.62 0.02 <0.01	Mature seed Hulls Meal Oil	T-2684 (aerial appl)
MN, 1974 (Sputnik)	0.56		7.7	1	7	0.14 0.28 0.09 <0.01	Mature seed Hulls Meal Oil	T-3069 (aerial appl)
ND, 1974 (Sputnik)	0.56		7.7	1	7	0.24 0.55 0.13 <0.01	Mature seed Hulls Meal Oil	T-3070 (aerial appl)
TX, 1974 (Sun Hi 372)	0.56		7.7	1	15	0.19 0.40 0.11 <0.01	Mature seed Hulls Meal Oil	T-3126 (aerial appl)

B*: control

Processing factors calculated from the results obtained with an application rate of 1.12 kg ai/ha are shown in Table 65.

Table 65. Processing factors from sunflower seed to processed commodities

Product	Paraquat (mg/kg)	Processing factor
	T-2679	
Mature seed	0.19	
Hulls	0.54	2.8
Meal	0.01	0.05
Oil	<0.01	<0.05

In some trials with lower application rates, higher paraquat residues (0.35, 0.31 and 0.24 mg/kg) were observed in mature seeds. However, the paraquat concentrations in the oil samples, prepared from these mature seeds with higher paraquat residues, were below the limit of detection of 0.01 mg/kg.

Hops

A study was conducted in the states of Idaho and Washington, USA, to determine paraquat residues in spent hops and a methylene chloride extract from dried hops. Hop vines were treated three times with a directed spray of paraquat at a rate of 2.8 kg ai/ha, five times the normal rate in the USA. Green hop cones were harvested 13 or 14 days after the last treatment. Bulk samples of green hops were dried according to commercial practice. Dried hops were processed into spent hops and methylene chloride extract as shown in Figure 16. The results of residue analysis are shown in Table 66. The limit of quantification was 0.05 mg/kg for green hops, 0.1 mg/kg for dried and spent hops, and 0.0125 mg/kg for methylene chloride extract (Roper, 1989).

Another study was conducted in Oregon, USA, to determine paraquat residues in beer. The hop vines received three applications except one trial in which only two applications were made, at 0.56, 1.12 or 2.24 kg ai/ha each time. Green cones were harvested 14 days after the last application. A portion of the cones were dried and used to make beer. No detailed description of beer brewing process was provided. The results of residue analysis are given in Table 67. The LOQ was 0.01 mg/kg for green hops, dried hops and beer (Anon., 1975).

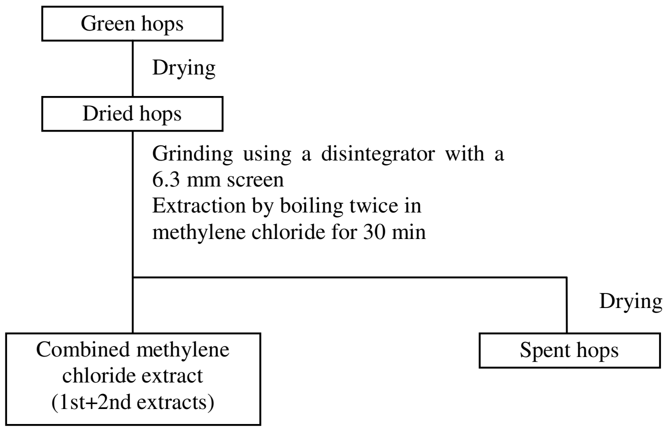


Figure 16. Processing of green hops to dried hops, spent hops and methylene chloride extract of hops.

Table 66. Paraquat residues in hops and processed products from trials in the USA.

Location, year (variety)	Application				PHI days	Paraquat mg/kg	Notes	Reference
	kg ai/ha	kg ai/hl	water, l/ha	No.				
ID, USA, 1988 (Hallertau Mittelfrueh)	2.8		31	3	B*	<0.05	Green hops	Roper 1989d 15ID88-591
						<0.1 (0.04)	Dried hops	
						<0.1 (0.05)	Spent hops	
						<0.0125	Mehylene chloride extract	
					14	<0.05 (0.04)	Green hops	
						<0.1 (0.06)	Dried hops	
						<0.1 (0.06)	Spent hops	
						<0.0125	Mehylene chloride extract	
WA, USA, 1988 (L-1 Clusters)	2.8		31	3	B*	<0.05	Green hops	15WA88-592
						<0.1	Dried hops	
						<0.1 (0.04)	Spent hops	
						<0.0125	Mehylene chloride extract	
					13	<0.05 (0.02)	Green hops	
						<0.1 (0.06)	Dried hops	
						<0.1 (0.03)	Spent hops	
						<0.0125	Mehylene chloride extract	
OR, USA, 1973 (Cascade)					B*	<0.01	Green hops	Anon. 1975b T-2639
						<0.01	Dried hops	
						<0.01	Beer	
	0.56			3	14	0.04	Green hops	
						0.05	Dried hops	
						0.01	Beer	
	1.12			3	14	0.05	Green hops	
						0.01	Dried hops	
						<0.01	Beer	
OR, USA, 1973	1.12			2	14	0.03	Green hops	T-2640
						0.03	Dried hops	
						<0.01	Beer	
	2.24			2	14	0.01	Green hops	
						0.02	Dried hops	
						<0.01	Beer	
OR, USA, 1973	0.56			3	14	0.04	Green hops	T-2958
						0.05	Dried hops	
						<0.01	Beer	
	1.12			3	14	0.03	Green hops	
						0.07	Dried hops	
						<0.01	Beer	

B*: control

In the study on processing green hops to dried hops, spent hops and methylene chloride extract, residues were all below the limit of quantification, so processing factors could not be reliably calculated. Processing factors were calculated for brewing beer and are shown in Table 67. Drying green hops to dried hops does not cause much increase in the concentration of paraquat which indicates some degradation of paraquat during drying.

Table 67. Processing factors from green hops to hops and beer.

Product	Paraquat (mg/kg)	Processing factor	Paraquat (mg/kg)	Processing factor	Paraquat (mg/kg)	Processing factor
	T-2639 (0.56 kg ai/ha)		T-2958 (0.56 kg ai/ha)		T-2639 (1.12 kg ai/ha)	
Green cones	0.04		0.04		0.05	
Dry cones	0.05	1.3	0.05	1.3	0.01	0.2
Beer	0.01	0.25	<0.01	<0.25	<0.01	<0.2
	T-2958 (1.12 kg ai/ha)		T-2640 (1.12 kg ai/ha)		Mean processing factor	
Green cones	0.03		0.03			
Dry cones	0.07	2.3	0.03	1	1.2	
Beer	<0.01	<0.33	<0.01	<0.33	<0.28	

Maximum application rate in the USA: 0.55 kg ai/ha.

RESIDUES IN ANIMAL COMMODITIES

Farm animal feeding studies

In animal metabolism studies on a goat and hens, paraquat residue concentrations were measured in tissues, milk and eggs (see Tables 7-9). No additional animal feeding studies were submitted.

RESIDUES IN FOOD IN COMMERCE OR AT CONSUMPTION

In the residue monitoring data from the Australian National Residue Survey (2001-2002), 18 samples of macadamia nuts were analysed for paraquat by an HPLC method. No residues were detected above the limit of reporting of 0.02 mg/kg.

NATIONAL MAXIMUM RESIDUE LIMITS

National MRLs in Argentina, Brazil, Czech Republic, European Union, Peru and the USA were reported by the manufacturer. The information on MRLs in Japan was obtained from the official web site of the Ministry of Environment. The information on MRLs in Australia and tolerances in the USA was provided by the governments of Australia and the USA respectively.

Table 68. National maximum residue limits.

Country	**Commodity**	**MRL (mg/kg)**
Argentina	Cotton oil	0.05
	Cotton seed	0.2
	Potato	0.2
Australia	Cereal grains [except maize; rice]	0.05*
	Cotton seed	0.2
	Cotton seed oil, edible	0.05
	Edible offal (mammalian)	0.5
	Eggs	0.01*
	Fruits (except olives)	0.05*
	Hops, dry	0.2
	Maize	0.1

Country	**Commodity**	**MRL (mg/kg)**
	Meat (mammalian)	0.05*
	Milks	0.01*
	Olives	1
	Peanut	0.01*
	Peanut, whole	0.01*
	Potato	0.2
	Poultry, Edible offal of	0.05*
	Poultry meat	0.05*
	Pulses	1
	Rice	10
	Rice, polished	0.5
	Sugar cane	0.05*

Country	Commodity	MRL (mg/kg)
	Tree nuts	0.05*
	Vegetables (except potato; pulses)	0.05*
Brazil	Banana	0.05
	Corn	0.1
	Cotton	0.2
	Fruits (various)	0.05
	Grapes	0.05
	Potato	0.2
	Rice	0.5
	Sorghum	0.5
	Soya bean	0.1
	Vegetables (various)	0.05
	Wheat	0.01
Czech R.	Hop, Dried	0.2
European Union	Fruits (various; including tree fruits, vine and strawberries)	0.05
	Hops, dry	0.1
	Oilseeds (various)	0.05
	Tea	0.1
	Tree nuts (various)	0.05
	Vegetables (various; including some herbs)	0.05
Japan (withholding limits)	Asparagus	0.05
	Barley	0.05
	Broccoli	0.05
	Burdock	0.05
	Cabbage	0.05
	Carrot	0.05
	Cauliflower	0.05
	Cucumber	0.05
	Eggplant	0.05
	Fruits (of any fruit tree)	0.05
	Japanese radish	0.05
	Konjac	0.05
	Lettuce	0.05
	Melons	0.05
	Oat	0.05
	Onion, bulb	0.05
	Peppers, sweet	0.05
	Potato	0.05
	Pumpkin	0.05
	Rice, hulled	0.1
	Rye	0.05
	Spinach	0.05
	Strawberry	0.05
	Sweet potato	0.05
	Tomato	0.05
	Watermelon	0.05
	Welsh onion	0.05
	Wheat	0.05
	Yam	0.05
Peru	Banana	0.05
	Cocoa	0.5
	Coffee	0.05
	Grape	0.05
	Oil palm	0.05
	Orange	0.05
	Potato	0.05
	Rice	0.05

Country	Commodity	MRL (mg/kg)
	Sugar cane	0.5
	Tea	0.05
USA	Acerola	0.05
	Alfalfa	5
	Almond, hulls	0.5
	Apple	0.05
	Apricot	0.05
	Artichoke, globe	0.05
	Asparagus	0.5
	Avocado	0.05
	Banana	0.05
	Barley, grain	0.05
	Bean, dry, seed	0.3
	Bean, forage	0.1
	Bean, hay	0.4
	Bean, lima, succulent	0.05
	Bean, snap, succulent	0.05
	Beet, sugar	0.5
	Beet, sugar, tops	0.5
	Birdsfoot trefoil	5
	Broccoli	0.05
	Cabbage	0.05
	Cabbage, Chinese	0.05
	Cacao bean	0.05
	Carrot, roots	0.05
	Cattle, fat	0.05
	Cattle, kidney	0.3
	Cattle, meat	0.05
	Cattle, meat byproducts, except kidney	0.05
	Cauliflower	0.05
	Cherry	0.05
	Clover	5
	Coffee bean	0.05
	Collards	0.05
	Corn, field, forage	3.0
	Corn, field, grain	0.1
	Corn, field, stover	10.0
	Corn, fresh (inc sweet corn), kernel plus cob with husks removed	0.05
	Corn, pop, grain	0.1
	Corn, pop, stover	10.0
	Cotton, undelinted seed	0.5
	Cucurbits	0.05
	Egg	0.01
	Endive	0.05
	Fig	0.05
	Fruit, citrus	0.05
	Goat, fat	0.05
	Goat, kidney	0.3
	Goat, meat	0.05
	Goat, meat byproducts, except kidney	0.05
	Grass, pasture	5
	Grass, range	5
	Guar bean	0.5
	Guava	0.05
	Hog, fat	0.05
	Hog, kidney	0.3
	Hog, meat	0.05

Country	Commodity	MRL (mg/kg)
	Hog, meat byproducts, except kidney	0.05
	Hop, dried cone	0.2
	Horse, fat	0.05
	Horse, kidney	0.3
	Horse, meat	0.05
	Horse, meat byproducts, except kidney	0.05
	Kiwifruit	0.05
	Lentil, seed	0.3
	Lettuce	0.05
	Milk	0.01
	Mint, hay	0.5
	Mint, hay, spent	3.0
	Nectarine	0.05
	Nut	0.05
	Olive	0.05
	Onion, dry bulb	0.05
	Onion, green	0.05
	Papaya	0.05
	Passionfruit	0.2
	Pea, dry, seed	0.3
	Peach	0.05
	Peanut	0.05
	Peanut, hay	0.5
	Pear	0.05
	Pea (succulent)	0.05
	Pea, field vines	0.2
	Pea, field, hay	0.8

Country	Commodity	MRL (mg/kg)
	Persimmon	0.05
	Pineapple	0.05
	Pistachio	0.05
	Plum, prune, fresh	0.05
	Potato	0.5
	Rhubarb	0.05
	Rice, grain	0.05
	Rice, straw	0.06
	Safflower, seed	0.05
	Sheep, fat	0.05
	Sheep, kidney	0.3
	Sheep, meat	0.05
	Sheep, meat byproducts, except kidney	0.05
	Small fruit	0.05
	Sorghum, forage	0.05
	Sorghum, grain	0.05
	Soybean	0.05
	Soybean forage	0.05
	Strawberry	0.25
	Sugarcane, cane	0.5
	Sunflower, seed	2
	Turnip, greens	0.05
	Turnip, roots	0.05
	Vegetable, fruiting	0.05
	Wheat	0.05

APPRAISAL

Paraquat, a non-selective contact herbicide, was first evaluated by the JMPR for toxicology and residues in 1970. Subsequently, it was reviewed for toxicology in 1972, 1976, 1982, 1985 and 1986 and for residues in 1972, 1976, 1978 and 1981. The Meeting reviewed paraquat toxicologically within the periodic review programme in 2003 and established an ADI of 0–0.005 mg/kg bw and an ARfD of 0.006 mg/kg bw as paraquat cation. Currently, there are 22 Codex MRLs for plant commodities, their derived products and animal commodities.

The CCPR at its Thirty-second Session identified paraquat as a priority for periodic review by the 2002 JMPR, but residue evaluation was postponed to the present Meeting.

Paraquat is usually available in the form of paraquat dichloride or paraquat bis(methylsulfate). The Meeting received data on metabolism, environmental fate, analytical methods, storage stability, supervised field trials, processing and use patterns.

Metabolism

Animals

The WHO Expert Group of the 2003 JMPR reviewed studies on the the excretion balance of paraquat in *rats* given a single dose of 1 or 50 mg/kg bw [1,1´-^{14}C-dimethyl]paraquat dichloride or 14 daily doses of 1 mg/kg bw unlabelled paraquat dichloride followed by 1 mg/kg bw of the labelled compound. They also evaluated studies of the biotransformation of paraquat in rats given the same doses of radiolabelled paraquat and other studies of metabolism and toxicity in rats. They concluded that orally administered paraquat is not well absorbed. Excretion was rapid, with 60–70% in faeces and 10–20% in urine; 90% was excreted within 72 h. Paraquat was eliminated largely unchanged: 90–95% of radiolabelled paraquat in urine was identified as the parent compound.

When 23 mg/kg [1,1´-^{14}C-dimethyl]paraquat dichloride were administered through a rumen fistula to one *sheep*, all the administered radiolabel was excreted within 10 days in urine (4%) and faeces (96%), indicating that residues of orally administered paraquat would not remain or accumulate in sheep tissues. Most of the radiolabel in urine and faeces was attributed to unchanged paraquat and 2–3% to paraquat monopyridone. Less than 1% 4-carboxy-1-methylpyridinium ion, paraquat dipyridone and monoquat were found.

When 0.92 mg/kg [1,1´-^{14}C-dimethyl]paraquat dichloride was administered subcutaneously to a sheep, paraquat was again excreted rapidly. Over 80% of the administered radioactivity was excreted in urine, 69% 1 day after treatment. Unchanged paraquat accounted for most of the radiolabel. The monopyridone was present at 2–3% and monoquat as a trace metabolite. The excretion patterns in the two sheep were virtually identical, regardless of the route of administration.

A *pig* weighing about 40 kg was fed twice daily with a diet containing [1,1´-^{14}C-dimethyl]paraquat ion at a rate equivalent to 50 mg/kg for 7 days. At sacrifice, 69% of the administered radiolabel had been excreted in faeces and 3.4% in urine; 13% was present in the stomach contents and viscera. All the radiolabel found in tissues, except in liver, was attributed to paraquat. About 70% of the radiolabel in the liver was identified as paraquat, with 7% as monoquat ion and about 0.6% as monopyridone ion. This result indicates that there is no significant metabolism of paraquat in pigs.

In a similar study, a pig was fed a diet containing [2,2´,6,6´-^{14}C]paraquat ion at a rate equivalent to 50 mg/kg for 7 days. At sacrifice, 72.5% of the administered radiolabel had been excreted in faeces and 2.8% in urine. In the liver, about 70% of the radiolabel was identified as paraquat and 4% as monoquat ion.

A Friesian *cow* weighing 475 kg given a single dose of about 8 mg/kg [1,1´-^{14}C-dimethyl]paraquat dichloride from a balling gun excreted 95.6% of the administered radioactivity in faeces within 9 days; 89% was excreted within the first 3 days. Analysis indicated that 97–99% of the radioactivity in 1–4-day faeces and 100% of that in 5–6-day faeces co-chromatographed with paraquat. A total of 0.7% of the administered dose was excreted in urine, 80% of which was excreted within the first 2 days. Paraquat accounted for 90% of the radiolabel in urine on day 1, 70% on day 3 and 62% on day 5. The remaining activity was attributed to paraquat monopyridone and monoquat. Only 0.0032% of the administered radiolabel was recovered from milk within 9 days. The traces of radioactivity in milk (a maximum of 0.005 mg/l as paraquat ion equivalent milk taken in the morning of day 2) were attributed mainly to paraquat and its monopyridone and to a naturally occurring compound which appeared to be lactose. The residue level of any one compound in milk was ≤ 0.002 mg/kg.

When 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 equivalent to approximately 100 mg/kg in the diet, 50.3% of the administered radioactivity was excreted in faeces, 2.4% in urine and 33.2% in stomach contents by the time of sacrifice. The total radioactivity, expressed in paraquat ion equivalents, in milk increased during the experimental period, reaching a maximum of 0.0092 mg/kg (equivalent to 0.003% of the daily dose) 4 h before slaughter. Of this radioactivity, 75.7% was attributed to paraquat, and 15.8% did not show a cationic character. There appeared to be no significant metabolism of paraquat in any tissue, except liver and peritoneal fat, where about half the radiolabel was attributed to paraquat, < 5% as monopyridone ion and 5% as monoquat ion.

Warren laying *hens* given [2,2´,6,6´-^{14}C]paraquat ion in gelatin capsules at a rate equivalent to 30 mg/kg normal diet for 10 days had excreted 99% of the administered radiolabel in faeces at the time of sacrifice; 96.6% of the radiolabel was attributed to unchanged paraquat. The amount of radiolabel in egg albumen did not exceed 0.0014 mg/kg in paraquat ion equivalents throughout the experimental period, while that in the yolk was < 0.001 mg/kg on day 1 and increased gradually to 0.18 mg/kg (in one bird) on day 8. All the radiolabel in yolk was identified as paraquat.

The studies on the fate of orally administered paraquat show that most is excreted unchanged, mainly in faeces and to a much smaller extent in urine. Excretion of paraquat was rapid in all the species studied, hens showing the most efficient excretion. Little paraquat was absorbed from the gastrointestinal tract, and the small amount absorbed was not significantly metabolized. Less than 0.05 mg/kg of paraquat was found in muscle, milk and eggs, even at the high dose rates used in these studies. These findings indicate that no significant bioaccumulation of paraquat is expected to occur in these species.

The metabolism of paraquat in these species was similar. Four metabolites were identified: monoquat, paraquat monopyridone, 4-carboxy-1-methylpyridinium ion and paraquat dipyridone. In all tissues except liver of all the species tested and in goat peritoneal fat, 80–100% of the total radiolabel was attributable to the parent compound, paraquat. In liver and goat peritoneal fat, 50–80% of the radiolabel was associated with paraquat, and absorbed paraquat was metabolized to monoquat and paraquat monopyridone and to a much smaller extent to 4-carboxy-1-methylpyridinium ion. The metabolism of paraquat involves oxygenation of one pyridine ring to form paraquat monopyridone and desmethylation of one pyridine ring to form monoquat. Cleavage of the pyridine–pyridine linkage produces 4-carboxy-1-methylpyridinium ion. The other *N*-methylpyridine moiety would produce carbon dioxide and methylamine.

Plants

When paraquat is used as a directed spray before sowing, before planting, before emergence and after emergence, it is present in soil as residues, but no direct contact occurs with crops. Sandy loam soil in pots in which *lettuce* and *carrots* were sown was sprayed with [U-^{14}C-bipyridyl]paraquat ion immediately after sowing at rates equivalent to 14.3 kg ai/ha for lettuce and 14.7 kg ai/ha for carrots, which are 13 times the highest current application rates for those crops, and maintained in a greenhouse. The radiolabel in mature lettuce and carrots harvested 65 and 96 days after treatment represented 0.0034 and 0.0048 mg/kg in paraquat ion equivalents, respectively. This result confirms the lack of significant translocation of residues of paraquat from treated soil to lettuce leaves or carrot roots.

Paraquat is also used as a crop desiccant and harvest aid, when it is in direct contact with crops. The foliage of *potatoes* and *soya beans* growing in pots in a greenhouse was treated with ^{14}C-paraquat at rates equivalent to 8.7 or 8.8 kg ai/ha (potato) and 8.2 kg ai/ha (soya beans), 14–16 times the highest current use for desiccation on potato and soya beans. The average TRR, expressed in paraquat ion equivalents, in soya and potato plants harvested 4 days after treatment were 638 mg/kg in soya foliage, 0.747 mg/kg in soya beans and 0.082 mg/kg in potato tuber. In all the samples, 89–94% of the TRR was identified as paraquat. The rest of the radioactive residue consisted of two or three fractions, none of which exceeded 10% of the respective TRR. In soya foliage extracts, small amounts of 4-carboxy-1-methylpyridinium ion (0.3% TRR) and monoquat (0.3 % TRR) were found. The latter is a known photodegradation product of paraquat.

As paraquat is strongly adsorbed by soil (see above), its uptake by plants after pre-emergence or post-emergence directed use is insignificant, even at exaggerated application rates. When paraquat was applied as a desiccant to potato and soya bean at a rate > 10 times the highest recommended application rate, with a 4-day PHI, the main component in potato tuber, soya beans and soya foliage was paraquat. In soya foliage, monoquat and 4-carboxy-1-methylpyridinium ion were also found. Although the latter is a known photodegradation product and was not found in soya beans or potato tuber, biotransformation cannot be excluded because the TRR was too low for reliable identification. As the fate of paraquat in soya foliage appears to involve photodegradation, its fate is considered to be common among plants.

The metabolism of paraquat involves desmethylation of one pyridine ring to form monoquat. 4-Carboxy-1-methylpyridinium ion appears to be produced by photolysis of monoquat, with breakdown of the pyridine–pyridine linkage, but involvement of biotransformation cannot be excluded. Paraquat monopyridone and dipyridone, which are found in animals, were not found in plants even at much higher than normal application rates. The transformation of paraquat in plants is similar to its metabolism in animals.

Environmental fate

Soil

Paraquat was applied to slurries of loam, loamy sand, silty clay loam or coarse sand in 0.01 mol/l aqueous calcium chloride at rates higher than normal, to give 0.01 mg/l in the equilibrium solution after a 16-h equilibration. The calculated adsorption coefficients ranged from 480 in the coarse sand to 50 000 in the loam. At normal application rates, the concentration of paraquat in the equilibrium solution could not be determined (< 0.0075 mg/l). No significant desorption was observed.

A field survey of 242 agricultural soils in Denmark, Germany, Greece, Italy, The Netherlands and the United Kingdom showed that paraquat was strongly adsorbed to all the soil types studied. The adsorption coefficients calculated at application rates much higher than normal ranged from 980 to 400 000, and those adjusted for the organic carbon content of soil were 8400–40 000 000. Adsorption coefficients could not be calculated at normal application rates because the concentration in equilibrium solution was below the limit of determination (0.01 mg/l). On the McCall scale, paraquat was classified as ‘immobile’ in all these soils, without leaching.

[2,6-^{14}C]Paraquat was applied to sandy loam soil in pots at a nominal rate of 1.05 kg/ha and incubated in the dark at 20 ± 2 °C under aerobic conditions in order to study the aerobic degradation of paraquat. After 180 days of incubation, paraquat accounted for > 93% of the applied radiocarbon, with no detected degradation products. Less than 0.1% of the applied radioactivity evolved as $^{14}CO_2$ over the 180-day incubation period. The half-life of paraquat in soil under aerobic conditions could not be estimated, although a long half-life in soil was implied by the results of the study.

In long-term field dissipation studies conducted on cropped plots in Australia, Malaysia, The Netherlands, Thailand, the United Kingdom and the USA, the location had no major effect on the field dissipation rate. Generally, paraquat residue levels had declined to about 50% 10–20 years after the start of the studies. This implies a DT_{50} of 10–20 years after application of single, large doses of paraquat to soil. The DT_{90} could not be estimated in these studies, however, as the experimental periods were too short.

Conventional laboratory studies could not provide useful information on the route or rate of degradation of paraquat in soil because of its strong adsorption to soil minerals and organic matter. In order to obtain information, microbiological degradation studies were conducted with microorganisms isolated from soil. The most effective soil organism for decomposing paraquat was a yeast species, *Lipomyces starkeyi*. When incubated with radiolabelled paraquat, the yeast culture or cultures originating from two sandy loam soils decomposed most of the paraquat, released CO_2 and formed oxalic acid at 24–25 °C.

An unidentified bacterium isolated from soil metabolized [1,1´-^{14}C]paraquat to monoquat and 4-carboxy-1-methylpyridinium ion. Extracts of *Achromobacter* D were found to produce CO_2, methylamine, succinate and formate as metabolites of 4-carboxy-1-methylpyridinium ion. The results showed that the CO_2 originated from a carboxyl group, methylamine from the *N*-methyl group and the carbon skeletons of formate and succinate from the C-2 and C-3–C-6 atoms of the pyridine ring, respectively. These results indicate that the pyridine ring is split between C-2 and C-3.

The degradation rate of paraquat in soil was determined by cultivating 10 mg/kg [U-^{14}C-dipyridyl]paraquat with *Lipomyces* and mixed cultures derived from two soils. The degradation of paraquat was rapid, with a DT_{50} between 0.02 and 1.3 days after a lag phase of about 2 days, accompanied by rapid mineralization to CO_2 and the formation of several unidentified minor polar metabolites.

The photolysis of [2,2´,6,6´-^{14}C]-paraquat was studied by applying it to the surface of a highly sandy soil which was exposed to natural sunlight. The proportion of paraquat in samples declined during 85 weeks, at which time paraquat represented 86.6–89.5% of the total radiolabel found in unmixed and mixed soil samples. Thin-layer chromatographic analysis of the 6 mol/l HCl extracts of mixed and unmixed soils contained monoquat ion, paraquat monopyridone ion and an uncharacterized compound, which accounted for 1.4–2.4%, 1.2–1.3% and 1.8–2.4%, respectively, of the total radioactivity after 85 weeks. Photodegradation on the soil surface is not considered to be a major environmental degradation process for paraquat.

Water–sediment systems

Aqueous photolysis of paraquat was examined by maintaining ring-labelled paraquat in sterilized 0.01 mol/l phosphate buffer solution (28 mg/l) at 25 °C under light. After 36 days of irradiation simulating summer sunlight in Florida (USA), most of the recovered radioactivity was attributed to paraquat, with 0.13% as CO_2 and no photodegradation products. When solutions of radiolabelled paraquat were exposed to unfiltered ultraviolet light, no paraquat remained after 3 days, with formation of CO_2, methylamine and 4-carboxy-1-methylpyridinium ion; the last metabolite further degraded to CO_2 and methylamine. These results indicate that, while paraquat appears to be stable to photolysis at pH 7, it readily degrades into CO_2 and methylamine when exposed to unfiltered ultraviolet light.

[U-^{14}C-dipyridyl]Paraquat in deionized water was applied to the water surface of two continuously aerated sediment–water systems at a rate equivalent to 1.1 kg ai/ha. Paraquat was strongly adsorbed to the sediment in both systems, even immediately after treatment. After 100 days of incubation, 0.1–0.2% of the applied radioactivity was found in the aqueous phase, 92.9–94.9% in extracts from sediment fractions and 4.2–4.5% in unextracted sediment fractions. Most of the radiolabel recovered from the aqueous phase and sediment extract was attributed to paraquat, while no degradation products were detected. The DT_{50} or the DT_{90} could not be estimated as no significant degradation of paraquat was observed during the experimental period.

Residues in succeeding crops

Seeds of wheat, lettuce and carrot were sown into individual pots containing a sandy loam soil 0, 30, 120 and 360 days after treatment of the soil with [2,2´,6,6´-^{14}C]paraquat at an application rate equivalent to 1.05 kg ai/ha, and were maintained in a glasshouse until maturity. Over the course of the study, the TRR in soil represented an average of 99.2% of the applied radioactivity. ^{14}C-Paraquat accounted for 72.7–99.3% of the TRR in soil extracts and no other radioactive compounds were detected in any soil sample. Radioactive residues, expressed in paraquat ion equivalents per kilogram, were below the LOQ in most crop samples sown 0, 30 and 120 days after treatment. The highest radioactive residue level, 0.009 mg/kg in paraquat ion equivalents, was found in wheat straw sown 30 days after treatment.

Seeds of lettuce and carrot were sown in pots containing sandy loam soil, and the soil was treated immediately afterwards with [U-^{14}C-dipyridyl]paraquat at exaggerated rates of 14.3 and 14.7 kg/ha respectively, corresponding to approximately 13 times the highest current application rate. The lettuce was harvested 65 days after treatment and the carrots 96 days after treatment. The levels of radioactive residues in lettuce leaf and carrot root at harvest were 0.0034 and 0.0048 mg/kg in paraquat ion equivalents, respectively. There is therefore no significant uptake of paraquat into rotational crops, even when the soil is treated at exaggerated rates.

Methods of analysis

With the long history of registration of paraquat in many countries, many analytical methods have been developed and used for measuring residues in plant and animal commodities. All the methods provided to the Meeting were for analysis of paraquat only. Some analytical methods allow separate determination of paraquat and diquat in a sample.

Samples of plant origin

Six analytical methods for the determination of paraquat in plant commodities and oil and oil cake were submitted.

Three of the methods involve extraction of paraquat by refluxing homogenized or comminuted samples in 0.5 mol/l sulfuric acid for 5 h; filtration, cation-exchange chromatography from which paraquat is eluted with saturated ammonium chloride, conversion of paraquat to its coloured free radical with 0.2% (w/v) sodium dithionite in 0.3 mol/l NaOH and spectrophotometric measurement. The methods differ only in the spectrophotometric measures used: absorption of the free radical in the range 360–430 nm measured against a control solution or absorption in the range of 380–430 nm measured in second derivative mode against a paraquat standard.

In the most recent method, the eluate from cation-exchange chromatography is further cleaned up on a C18 SepPak solid phase extraction cartridge, and the second 5-ml eluate is analysed by reverse-phase ion-pair HPLC with ultraviolet detection at 258 nm.

Two other methods developed for the determination of paraquat in liquid samples, such as oil, also involve second derivative spectrophotometry (360–430 nm), but they do not involve extraction with sulfuric acid. Reverse-phase ion-pair HPLC is also used as the confirmatory method.

All these methods were validated in one or several laboratories for vegetables and fruits, cereal grains and seed, grass and straw, sugar-cane juice, oil seeds, oil and oil cake. The LOQ of these methods ranged from 0.01 to 0.05 mg/kg, except for oil cake, for which the LOQ was 0.5 mg/kg. The mean procedural recoveries were 61–107% at fortification rates reflecting both the LOQ and the actual levels of incurred residues. In general, lower recoveries were made from oil and oil cake. The mean recovery from rape-seed oil cake and olive oil was 67% and that from coffee beans was 61%; those from other commodities were > 70%. The relative standard deviation of recoveries ranged from 2% to 19%.

Samples of animal origin

Three analytical methods for the determination of paraquat in animal products were submitted.

Two methods, including the most recent, for determining paraquat in milk, eggs and animal tissues involve extraction of paraquat by homogenizing samples in 10% trichloroacetic acid, centrifugation, dilution with water, application to a cation-exchange column, sequential washing, elution of paraquat with saturated ammonium chloride, determination by reverse-phase ion-pair HPLC with ultraviolet detection at 258 nm. Fat in milk, skin with subcutaneous fat and fat samples must be removed by hexane extraction before cation exchange.

A method for analysing liquid samples, including milk, does not involve acid extraction or defatting, and milk is mixed directly with cation exchange resin before packing. Otherwise, this method is the same as those described above.

The LOQs were reported to be 0.005 mg/kg for milk, eggs and bovine, ovine and chicken tissues. The mean procedural recoveries were 75–105%, with a relative standard deviation of 2–13%.

The currently used methods for plant and animal samples were found to be suitable for quantification of paraquat in plant and animal commodities for enforcement purposes. The methods are fully validated and include confirmatory techniques. The earlier methods for quantification of paraquat in plant and animal samples were also found to be suitable in validation; however, a mean recovery < 70% was seen for rape-seed cake, olive oil and coffee beans analysed by one of the methods.

Stability of residues in stored analytical samples

Investigations were reported of the stability of residues in ground samples of prunes, banana, cabbage, potato, carrot, tomato, maize (grain, forage, fodder and silage), wheat grain, coffee beans, birdsfoot trefoil (forage and hay), meat, milk and eggs stored in a deep freezer at a temperature < –15 °C for 1–4 years.

No decrease in residue levels of paraquat, whether fortified or incurred, was observed in any of the crop matrices during the test period, the longest being 46 months. The exception was a slight decrease in birdsfoot trefoil forage that had been treated at a rate equivalent to 0.54 kg ai/ha and contained incurred residues at 57 mg/kg.

No decrease in the levels of residues of paraquat in animal commodity matrices over time was observed under storage for up to 28 months. The test matrices represented a diverse selection of animal tissues, and the studies demonstrate the stability of paraquat under various storage conditions.

Definition of the residue

Paraquat is usually available as the dichloride salt or the bis(methylsulfate) salt but is determined as paraquat ion in analysis. Paraquat is known to adsorb strongly to soil, and most of the small amount incorporated into plant remains as paraquat (90%). Its metabolites were not found when paraquat was applied at normal rates. When it was applied post-emergence, most of the applied compound remained, with minimal amounts of photodegradation products, indicating the involvement of photolysis in the transformation of paraquat. The residue of concern in plants is paraquat ion.

In studies of metabolism in rats, cattle, goats, pigs and hens, the metabolic pathway was similar, producing minor levels of oxidized metabolites. The metabolic pathways in animals and plants are similar. In animals, the residue of concern is also paraquat ion.

The definition of the residue in all countries that provided national MRLs to the Meeting was paraquat ion.

All the identified metabolites have been covered by toxicological evaluations, owing either to their occurrence in rats or in independent studies. The ADI recommended by the JMPR is for paraquat cation.

The Meeting therefore agreed that the definition of residues for plant and animal commodities should be: Paraquat cation (for both compliance with MRLs and estimation of dietary intake).

Results of supervised trials on crops

When used for weed control, paraquat is not sprayed directly onto crops and is strongly adsorbed to soil. Therefore, little paraquat is expected to be found in harvested crops. After pre-emergence application, no residues were expected to be detected in the harvested crops, although some samples contained residues. After use as a harvest aid desiccant, however, paraquat is in direct contact with crops, and the residue levels tend to be much higher than when it is used for weed control.

The Meeting agreed that data from trials of pre-plant and pre-emergence application should be evaluated against any GAP available to the Meeting, regardless of the country or region; while data on trials of post-emergence application and harvest aid desiccation should be evaluated against GAP of the country in which the trials were conducted or of a neighbouring country.

As degradation of paraquat on the surface of crops appears to involve photolysis, residue levels are expected to be similar in all crops, justifying estimation of group MRLs for paraquat.

For estimating STMR from the results of two or more sets of trials with different LOQs in which no residues exceeding the LOQs are reported, the lowest LOQ should be used, as stated in the 2002 *FAO Manual*, unless the residue level can be assumed to be essentially zero. The size of the trial database supporting the lowest LOQ was taken into account in making decisions in these cases.

Since maximum residue levels were estimated for a number of vegetable groups in which the levels were below the LOQ, the Meeting decided to withdraw the previous recommendation for vegetables (except as otherwise listed) of 0.05 * mg/kg.

In Germany, information is required on the possible contamination of fruits that have fallen onto ground treated with pesticides. Therefore, tests were carried out on apples, stone fruits, grapes and olives to simulate the residue situation in fruit used for juice and other processed products. Nevertheless, direct consumption of fruit picked up from the ground is regarded as inappropriate.

Citrus fruit

Numerous supervised residue trials have been carried out over several seasons and in several locations on orange in Italy and in California and Florida, USA, and on lime, lemon and grapefruit in Florida.

Paraquat is registered for the control of weeds around the base of citrus fruit trees at a maximum rate of 1 kg ai/ha as an inter-row spray, with no PHI, in Italy and at a maximum rate of 1.14 kg ai/ha as a directed spray, with no PHI, in the USA.

The residue levels of paraquat in whole mature *oranges* in trials in Italy and the USA were below the LOQs of 0.01, 0.02 or 0.05 mg/kg, even when paraquat was applied at twice or 30 times the maximum application rate, except in two trials. In one trial with an application rate of 2.44 kg ai/ha, mature fruit from one plot contained paraquat residues at a level of 0.01 mg/kg. In a trial with an application rate of 1.12 kg ai/ha, residue levels of 0.06 and 0.08 mg/kg were found in whole fruit. In this trial, however, the lower fruit-bearing branches were deliberately sprayed, the fruit fell onto sprayed weeds, and they were picked up from the ground within 3 days of spraying for analysis. Even though this represents the worst-case scenario, it does not reflect GAP in any country and is therefore inappropriate for use in estimating a maximum residue level. The residue levels in whole mature oranges in valid trials were, in ranked order: < 0.01 (15), 0.01, < 0.02 (two) and < 0.05 mg/kg (one).

In one trial in the USA, both juice and pulp were analysed for paraquat residues. Although the levels were below the LOQ of 0.01 mg/kg, the procedural recovery was too low for the results to be regarded as reliable.

In trials in the USA on *grapefruit*, *lemon* and *lime* in 1970 and 1972, with application rates reflecting GAP in the USA, the paraquat residue levels were < 0.01 (one) and < 0.05 mg/kg (three).

As the residue situation in oranges and other citrus fruits is similar and GAP is recommended for citrus fruits as a group in Italy and the USA, the Meeting considered it appropriate to establish a group maximum residue level for citrus fruits. The combined residue levels, in ranked order, were: < 0.01 (16), 0.01, < 0.02 (two) and < 0.05 (four) mg/kg. The Meeting estimated a maximum residue level of 0.02 mg/kg, an STMR of 0.01 mg/kg and a highest residue level of 0.02 mg/kg for paraquat in citrus fruits. The value of 0.02 mg/kg covers only the finite residue level found at 0.01 mg/kg.

Pome fruit

Trials were carried out on apples in Canada, Germany and the United Kingdom and on pears in Canada and Germany.

Paraquat is registered for use to control weeds around the base of pome fruit trees at a maximum rate of 0.66 kg ai/ha with one application and no PHI in the United Kingdom and at a maximum rate of 1.14 kg ai/ha with no PHI in the USA. No information on GAP was available for Canada or Germany, but the results of trials conducted in those countries were reviewed against the GAP of the USA and United Kingdom, respectively.

Trials on *apple* were conducted at rates of 1.12–4.48 kg ai/ha, and in one trial in the United Kingdom at a highly exaggerated rate of 12.3 kg ai/ha, about 20 times the maximum rate permitted in that country. In the latter trial, paraquat was applied directly to the bark of the trees to simulate worst-case conditions. In some cases, two applications were made, in the same or subsequent years. Apples were harvested 0–780 days after the last application. In trials on *pear*, paraquat was applied at rates of 1.0–4.48 kg ai/ha once or twice, and pears were harvested 0–77 days after the last application. Paraquat residue levels were below the LOQ of 0.01 mg/kg in all apples and pears taken from trees, even after treatment at rates as high as 20 times the maximum GAP rate.

In the trials in Germany, apples and pears taken from the trees were placed on the ground 6–7 days after application and collected about 7 days later for analysis. Residue levels of paraquat of 0.02–0.19 mg/kg were found in the apples, which could be attributed to the transfer of paraquat from the sprayed weed. The Meeting concluded that these data are not appropriate for use in estimating a maximum residue level.

As the residue situations in apples and pears are similar, and GAP is recommended for pome fruits or orchard fruits as a whole in all the countries that provided information on GAP, the Meeting considered it appropriate to establish a group maximum residue level for pome fruits. As the paraquat residue levels in all the valid trials were below the LOQ, even after application at exaggerated rates, the Meeting estimated a maximum residue level for pome fruits of 0.01* mg/kg, an STMR of 0 mg/kg and a highest residue level of 0 mg/kg.

Stone fruit

Trials were carried out on peaches, plums, apricots and cherries in Canada, Germany, the United Kingdom and the USA.

Paraquat is registered for use to control weeds around the base of stone fruit trees at a maximum rate of 0.66 kg ai/ha, with one application and no PHI for stone fruits in the United Kingdom and at a maximum rate of 1.14 kg ai/ha, with three applications and a 28-day PHI for stone fruits other than peaches in the USA; the PHI for use on peach trees in the USA is 14 days. No information on GAP was available from Canada or Germany, and the results of trials conducted in those countries were reviewed against the GAP of the USA and the United Kingdom, respectively.

The application rates in the supervised trials ranged from 0.22 to 4.48 kg ai/ha, applied to the base of the fruit trees up to three times in a season; the fruit was harvested from the trees 0–103 days after the last application. No residues of paraquat above the LOQ of 0.01 or 0.05 mg/kg were found in fruit harvested directly from the trees in any trial, even after spraying three times at a rate four times the maximum permitted rate. In most of the US trials, paraquat was applied one or two times instead of the maximum of three, but because of the higher application rates, the total amount applied was higher than the maximum allowed by GAP.

In trials on plums in the United Kingdom, paraquat was applied directly to suckers at rates of 0.22–1.34 kg ai/ha. No residues were found above the LOQ of 0.01 mg/kg in fruit harvested 21 or 55 days later.

In the trials in Germany, fruit were placed on sprayed weeds and collected for analysis about 1 week later. Small amounts of paraquat residues were found (0.02 and 0.04 mg/kg on peach, < 0.01 mg/kg on plum and 0.07 mg/kg on cherry) in the fruit samples, due to transfer from the sprayed weeds. As stone fruit intended for juice production is usually grown in orchards in which herbicides are rarely used, these data were not used for estimating a maximum residue level.

As the residue situations in stone fruits are similar and GAP is recommended for stone fruits or similar GAPs are established for peach and stone fruits excluding peach, the Meeting considered it appropriate to establish a group maximum residue level for stone fruits. As the paraquat residue levels were below the LOQ, even when applied at exaggerated rates and the methods of analysis in most of the trials had a LOQ of 0.01 mg/kg, the Meeting estimated a maximum residue level for stone fruits of 0.01* mg/kg and STMR and highest residue values of 0 mg/kg.

Berries and small fruit

Grape

Trials on residues in grapes have been conducted in Canada, Japan, Switzerland and the USA at rates of 0.3–4.4 kg ai/ha applied one to five times. Grapes were harvested from the vines at maturity 0–196 days after the last application. Four trials were conducted in Germany in which paraquat was applied between the rows of established vines at a rate of 1.0 kg ai/ha and grapes were sampled from the vines 0–14 days after application.

Paraquat is registered for weed control around grape vines at a maximum rate of 0.72 kg ai/ha, with five applications and a 30-day PHI in Japan and a maximum rate of 1.14 kg ai/ha, with the number of applications and the PHI unspecified in the USA. No information on GAP was available from Canada, Germany or Switzerland, but the results of trials in Canada were reviewed against US GAP.

In all trials in Canada, Japan and the USA reviewed against respective GAP, grapes obtained directly from the vine did not contain paraquat residues at levels above the LOQ of 0.01 or 0.02 mg/kg, even when applied at five times the recommended rate or with a shorter PHI.

In the German trials, bunches of grapes were also placed on the sprayed weed a few days after application and collected 7 days later for analysis. Small amounts of paraquat residues (0.04, 0.07, 0.09, 0.10, 0.13 and 0.17 mg/kg) were found in the grapes due to transfer from the sprayed weeds. When the fruits were sampled directly from the vine, the levels of residues were always below the LOQ of 0.01 mg/kg (six trials), which supports the results of the trials conducted in Canada, Japan and the USA.

The residue levels of paraquat in grapes in the trials that met the respective GAP or were conducted at higher rates were: < 0.01 (16), < 0.02 (three) and < 0.05 (two) mg/kg.

Cane fruit

Trials on residues were conducted in Canada on red and blackcurrants, blueberries, loganberries, gooseberries and raspberries at rates of application of paraquat of 0.56–2.24 kg ai/ha. Paraquat was applied once and the fruit was harvested 20–111 days after application.

GAP for cane fruit in the USA is a maximum rate of 1.14 kg ai/ha, with the number of applications and PHI unspecified.

Even at double the application rate, cane fruit did not contain paraquat residues at levels above the LOQ of 0.01 mg/kg. The residue levels in 25 trials following GAP or conducted at higher rates were < 0.01 mg/kg.

Strawberry

Supervised trials were conducted in France, Germany and the United Kingdom in which paraquat was used to control runners of strawberry plants at rates of 0.42–1.32 kg ai/ha once or twice. Berries were harvested 47–226 days after the last application. Three trials in Germany were conducted in plastic greenhouses.

GAP in the United Kingdom for strawberries is a maximum rate of 0.66 kg ai/ha, with one application and PHI unspecified.

The residue levels of paraquat in strawberries in trials following GAP or conducted at higher application rates were < 0.01 (six) and < 0.05 mg/kg.

As the samples analysed in all the trials except that in which grapes were kept and taken from the ground did not contain paraquat residues at levels above the LOQs and the application rate in the respective GAP is similar, the Meeting decided to propose a group maximum residue level for small fruits and berries. The residue levels in these fruits, in ranked order, were: < 0.01 (47), < 0.02 (three) and < 0.05 mg/kg (three). The Meeting, considering that use of modern analytical methods would enable lower LOQs, agreed to disregard residue levels of < 0.05 mg/kg and < 0.02 mg/kg and estimated a maximum residue level of 0.01* mg/kg and STMR and highest residue values of 0 mg/kg.

Olive

Trials on residues in olives have been carried out in Greece, Italy, Spain and the USA (California).

Paraquat is registered for controlling weeds around the base of olive trees at a maximum rate of 1 kg ai/ha, with the number of applications unspecified and a 40-day PHI in Italy and at a maximum rate of 1.14 kg ai/ha, with four applications and a 13-day PHI in the USA. The results of trials conducted in Greece and Spain were reviewed against GAP in Italy.

In trials in Italy, paraquat was applied at rates of 0.54–1.8 kg ai/ha to the base of trees, and olives were harvested from the ground or trees 7–21 days after application. Although the delay was shorter than the recommended PHI of 40 days, the residue levels in the olives were < 0.05 and < 0.1 (two) mg/kg, indicating that at a PHI of 40 days the levels are likely to be < 0.1 mg/kg. No residues (< 0.05 mg/kg) of paraquat were detected in the oil from these fruits.

In one trial in the USA, paraquat was applied four times at an exaggerated rate (5.6 kg ai/ha; 22.4 kg/ha total) and the fruit was harvested from the trees 13 days later for analysis. The residue levels of paraquat were below the LOQ of 0.05 mg/kg, as were the levels in oil and cake prepared from the olives.

In six trials in Spain, olives were harvested from the ground 0, 1 and 7 days after application of paraquat at 0.60 kg ai/ha, simulating the worse-case scenario of collecting olives intended for oil production. In these trials, the application rate was 60% of the maximum allowed in Italy, but the olive fruit were harvested much earlier than the PHI of 40 days. The residue levels in whole fruit were 0.64–10 mg/kg, indicating that there had been transfer of paraquat from the sprayed weeds to the olives. In all the oil produced from these samples, however, the maximum residue levels of paraquat were 0.06 mg/kg, indicating that paraquat is not extracted into oil, as might be expected from its chemical nature.

In other trials in Spain, mature olives were sprayed directly on the ground with paraquat at rates of 0.36–1.3 kg/ha, and the fruit was analysed 3–17 days after application. The residue levels of paraquat in the olives were 0.08–4.4 mg/kg. Residues of paraquat did not transfer to extracted oil, and washing appeared to reduce the levels on the fruit.

In one trial in Greece, mature olives were sprayed directly with paraquat at a rate of 1.0 kg ai/ha to simulate direct spraying on fallen fruit in collection nets during weed control. No residues were found at levels above the LOQ (0.05 mg/kg) in oil extracted from treated fruit harvested 5 days after application.

Olives for oil production are often harvested from the ground and paraquat used for weed control may occasionally be applied directly to the fallen fruit on the ground. The whole fruit will contain some paraquat residue, either through transfer from treated vegetation or through direct spraying. Although the olives may contain relatively high levels of paraquat, no transfer of paraquat to oil occurs. This practice is not in compliance with GAP for olives.

The residue levels in olives taken directly from trees were: < 0.05 and < 0.10 mg/kg (two). In another trial, the level was < 0.05 mg/kg in olives taken from ground that had not been directly sprayed. The residue levels in one US trial conducted at five times the usual rate were below the LOQ of 0.05 mg/kg, indicating that when paraquat is applied in accordance with GAP no residues are expected to occur in olive fruit. The Meeting estimated a maximum residue level of 0.1 mg/kg to replace the previous recommendation for olive at 1 mg/kg. The Meeting also estimated an STMR of 0.05 mg/kg and a highest residue level of 0.1 mg/kg.

Assorted tropical fruits minus inedible peel

Trials on residues were carried out on *passion fruit* in Hawaii, USA, at an application rate of 1.12–4.48 kg ai/ha, to control weeds. Fruit was harvested 1–28 days after application. GAP in the USA for use on passion fruit is a maximum rate of 1.05 kg ai/ha, with an unspecified number of applications and PHI. The residue level in whole fruit in a trial complying with the maximum GAP was 0.13 mg/kg. After application at a rate higher than the maximum GAP, residue levels of up to 0.19 mg/kg were found in whole fruit. The levels in the edible pulp of all passion fruits analysed in the trials, regardless of PHI, ranged from < 0.01 to 0.02 mg/kg at 1.12 kg ai/ha and from < 0.01 to 0.06 mg/kg at higher rates. Higher levels were found in peel than in the edible portion.

Trials on residues were carried out on *kiwifruit* in California, USA, at an application rate of 0.56–2.24 kg ai/ha, three times, to control weeds. Fruit was harvested 7–14 days after the last application. The US GAP for kiwifruit is a maximum rate of 1.14 kg ai/ha, with the number of applications unspecified and a 14-day PHI. The residue level in kiwifruit in one trial conducted in accordance with the maximum US GAP was < 0.01 mg/kg. Even at a higher application rate or a shorter PHI, the levels were below the LOQ of 0.01 mg/kg.

Trials on *guava* were carried out in two locations in Hawaii, USA, with three different application rates of 1.12–4.48 kg ai/ha at each location. Fruit was harvested 1–28 days after application. The US GAP for guava is identical to that for passion fruit. The residue levels of paraquat in all edible pulp and peel analysed were below the LOQ of 0.01 mg/kg at the maximum GAP rate and at rates up to four times the maximum GAP. No residue was found at levels above the LOQ of 0.01 or 0.02 mg/kg in juice, discarded skin or seed obtained from guava treated at 1.12 or 4.48 kg/ha with a 6-day PHI. Although no information was available on residues in whole fruit, levels above the LOQ were not expected in whole fruit in view of the residue situation in pulp, peel and other fractions.

Trials were carried out on *banana* in Honduras, with three applications of paraquat at 1.4 kg ai/ha or a single application at double this rate, to control weeds in established plantations. Fruit was harvested 0–90 days after the last application. As no information was available on GAP in Honduras, the data were reviewed against GAP of the USA (maximum rate of 1.14 kg ai/ha). The residue levels of paraquat in flesh (0- and 3-day PHI) and whole fruit (≥ 7-day PHI) were below the LOQ (0.01 mg/kg) in three trials, except in skin from fruit harvested immediately after application.

Except in the trials on passion fruit, the residue levels in tropical fruits in 10 trials conducted according to the respective GAP were all below the LOQ (< 0.01 mg/kg). The Meeting estimated a maximum residue level for paraquat in assorted tropical fruits with inedible peel, excluding passion fruit, of 0.01* mg/kg. The Meeting decided to withdraw the previous recommendation for passion fruit.

The residue levels in edible portions of these fruit were below the LOQ: < 0.01 (11) mg/kg. The Meeting estimated STMR and highest residue values for paraquat in assorted tropical fruits minus inedible peel, excluding passion fruit, of 0.01mg/kg.

Bulb vegetables

Trials on residues were conducted on *onion* in Canada, Germany and the United Kingdom in the 1960s. Paraquat is registered in the USA for pre-plant or pre-emergence application to onion in a limited number of states at a maximum rate of 1.14 kg ai/ha, with one application and a 60-day PHI (200 days in California). Uses on bulb vegetables are not included in the label in the United Kingdom.

In one Canadian trial at twice the GAP rate and with a shorter PHI (36 days), the residue levels were below the LOQ of 0.01 mg/kg. In another Canadian trial at an application rate of 1.12 mg/kg, the levels were also < 0.01 mg/kg, but the PHI was 143 days.

Trials were conducted in Germany for post-emergence directed application and for harvest aid uses, but there was no related GAP.

In one trial conducted in the United Kingdom of pre-emergence application on spring onion, the residue level was 0.02 mg/kg, but the application rate was > 30% higher than the maximum rate allowed in the USA. A further trial on spring onion involved directed post-emergence application, for which no information on GAP was available.

The Meeting concluded that there were insufficient data to recommend a maximum residue level for paraquat in onion bulb or bulb vegetables.

Brassica vegetables

Residue trials were carried out on *broccoli* in Canada; *Brussels sprouts* in The Netherlands (harvest aid); *cabbage* in Canada, Japan, Spain and the USA; and *cauliflower* in Canada. Paraquat was applied once or twice at 0.67–2.2 kg ai/ha for inter-row weed control, and the crop was harvested 5–52 days after the last application.

Paraquat is registered for use in the cultivation of *Brassica* vegetables 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. GAP in Japan is a maximum rate of 0.36 kg ai/ha, with three applications and a 30-day PHI, for broccoli, cabbage, cauliflower and Chinese cabbage as pre-plant inter-row applications. GAP in the USA is a maximum rate of 1.14 kg ai/ha, with the number of applications and PHI unspecified, for *Brassica* vegetables as pre-plant, pre-emergence treatment.

In trials conducted on broccoli, cabbage and cauliflower in Canada, the residue levels were below the LOQ of 0.01 mg/kg, even when applied at double the rate. The exception was one trial in Canada in which cabbage harvested 51 days after treatment at twice the rate contained a residue level of 0.06 mg/kg. The residue levels were < 0.01 (two) and 0.06 mg/kg.

In two trials conducted on cabbage in Japan, the residue levels were below the LOQ of 0.03 mg/kg even after application at a higher rate of 0.96 kg ai/ha and a shorter PHI of 5 days. At a highly exaggerated rate of 19.2 kg ai/ha but with only one application and a longer PHI of 52 days, the residue levels were also < 0.03 mg/kg.

No information was available on GAP that would allow evaluation of trials conducted in Spain.

Trials on Chinese cabbage were conducted in the USA in which paraquat was applied once as pre-emergence treatment at 1.05 kg ai/ha, followed by three post-emergence directed applications at 0.56 kg ai/ha. The residue levels were < 0.05 and 0.07 mg/kg. The US label allows only pre-plant and pre-emergence applications.

Trials on Brussels sprouts in The Netherlands involved a direct harvest aid application to the vegetable. In these trials, the unwashed vegetable contained a residue level of 7.3 mg/kg after 31 days, while washed vegetable had a reduced level of 1.6 after 31 days. Harvest aid desiccation was not, however, included in the labels provided to the Meeting.

The residue levels in these crops in trials that followed GAP and in trials that showed residue levels below the LOQ were, in ranked order: < 0.01 (two), <u>< 0.03</u> (two) and 0.06 mg/kg. The Meeting concluded that there were insufficient data for estimating a maximum residue level for *Brassica* vegetables.

Fruiting vegetables

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

Paraquat is registered in the USA for use on tomatoes for pre-plant or pre-emergence application at a maximum rate of 1.14 kg ai/ha, with an unspecified number of applications and a 30-day PHI; on tomatoes for post-emergence directed spray at a maximum rate of 0.55 kg ai/ha, with an unspecified number of applications and a 30-day PHI; on peppers by directed spray application at a maximum rate of 0.55 kg ai/ha, with three applications and no PHI; and on other fruiting vegetables for pre-plant or pre-emergence application at a maximum rate of 1.14 kg ai/ha, with unspecified number of applications and PHI.

The trials in Canada on *tomatoes* were for pre-emergence or pre-planting weed control, in which paraquat was used at a low rate of 0.11 kg ai/ha. Trials on tomatoes in the USA involved post-emergence directed application at 0.56–2.24 kg/ha and an exaggerated single high pre-emergence application at a rate of 11.2 kg ai/ha or pre-emergence application of 1.12 kg ai/ha followed by three inter-row directed applications at 2.8 kg ai/ha. Although samples were harvested 21 days after treatment, 30% shorter than the PHI in US GAP of 30 days, the residue levels in tomatoes were below the LOQ of 0.01 mg/kg after application at 0.56 kg ai/ha for post-emergence directed application, except in one trial in which levels up to 0.04 mg/kg were found. After application at exaggerated rates, the residue levels were still below the LOQ of 0.005 or 0.01 mg/kg or at a maximum of 0.02 mg/kg.

The residue levels in trials following GAP or conducted at higher application rates were, in ranked order: < 0.005 (two), <u>< 0.01</u> (seven) and 0.04 mg/kg.

The trials on *sweet peppers* were for use of paraquat in inter-row weed control at 0.56–2.2 kg ai/ha. The residue levels in trials at maximum GAP were < 0.01 and 0.01 mg/kg. The levels after exaggerated application rates were either below the LOQ of 0.01 mg/kg, 0.03 mg/kg (once at 1.12 kg ai/ha pre- emergence and four times at 1.12 or 2.24 kg ai/ha post-emergence applications) or 0.02 mg/kg (one trial).

The Meeting considered it appropriate to evaluate residues in tomato and peppers together for estimating the maximum residue level for fruiting vegetables, other than cucurbits. The combined levels were: < 0.005 (two), <u>< 0.01</u> (eight), 0.01 and 0.04 mg/kg. The Meeting estimated a maximum residue level for fruiting vegetables, other than cucurbits, of 0.05 mg/kg, an STMR of 0.01 mg/kg and a highest residue level of 0.04 mg/kg.

In trials on *cucumbers*, *melons* and *summer 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. While US GAP allows pre-emergence application at a maximum of 1.12 kg ai/ha, the residue levels of paraquat in all 12 trials were below the LOQ of 0.025 mg/kg. The Meeting estimated a maximum residue level for cucurbits of 0.02 mg/kg and STMR and highest residue values of 0 mg/kg.

Leafy vegetables

Trials for residues were conducted on lettuce in Canada, Germany, Spain, the United Kingdom and the USA, on kale in France, Italy and the United Kingdom and on turnip greens in the USA.

Paraquat is registered for pre-emergence application on collard and lettuce in the USA at a maximum rate of 1.14 kg ai/ha, with the number of applications and PHI unspecified. Uses on leafy vegetables are not included on labels in Italy or the United Kingdom.

Trials on residues on *lettuce* were conducted in Canada, Germany, Spain, the United Kingdom and the USA at application rates of 0.42–2.24 kg/ha; lettuce was sampled 0–147 days after application. In trials conducted in Canada and the USA following US GAP, the residue levels in untrimmed head or bunch were 0.01, 0.04 and 0.05 mg/kg.

The results of trials in the United Kingdom were evaluated against US GAP, as the uses were similar in trials in the two countries. The residue levels in unwashed lettuce head in trials following US GAP were < 0.01, 0.01 and 0.02 mg/kg.

Residue levels up to 1.4 mg/kg were found in German trials on lettuce harvested immediately after one or two applications of paraquat for post-emergence inter-row weed control. The residues were believed to have derived from spray drift onto the outer leaves. In most of these trials, the whole lettuce head was analysed without removal of outer wrapper leaves that were yellow and withered. The residue levels had declined to close to the LOQ (< 0.01 mg/kg) by 21 days after harvest. The results of trials in Germany and Spain could not be evaluated as no information on GAP in Europe was available.

Residue trials on *kale* were carried out in France, Italy and the United Kingdom at rates of 1.0–2.24 kg/ha, and kale was sampled 0–147 days after application. As no information was available on GAP in Europe, these data were not evaluated.

Six trials on *turnip greens* were carried out in the USA at a rate of 1.12 kg/ha, with sampling 55–128 days after application. The levels of paraquat residue were < 0.025 (three), 0.03, 0.04 and 0.05 mg/kg.

As the US GAPs for collard and lettuce are identical and the residue situations for these crops were similar, the Meeting considered it appropriate to combine the results for estimating a maximum residue level for leafy vegetables. The combined residue results, in ranked order were: < 0.01, 0.01 (two), 0.02, <u>< 0.025</u> (three), 0.03, 0.04 (two) and 0.05 (two) mg/kg. The Meeting estimated a maximum residue level for paraquat in leafy vegetables of 0.07 mg/kg, an STMR of 0.025 mg/kg and a highest residue level of 0.05 mg/kg.

Legume vegetables and pulses

Residue trials were conducted on beans (with pod and dry) in Canada, Germany, Italy, The Netherlands and Spain, on broad beans in Spain, on peas in Australia, Canada and the USA, and on soya beans in Brazil and the USA.

Paraquat is registered for weed control and harvest aid on legume vegetables and pulses in Australia, Brazil and the USA as follows:

Country	Maximum rate (kg ai/ha)	No. of applications	PHI (days)	Crop	Type of application
Australia	0.2		14	Chickpea	Over-the-top spray
	0.2		14	Field pea	Over-the-top spray
	0.43			Soya bean	Pre-plant
Brazil	0.6	1	7	Soya bean	Pre-plant
	0.5	1	7	Soya bean	Desiccation

Country	Maximum rate (kg ai/ha)	No. of applications	PHI (days)	Crop	Type of application
USA	1.14		–	Beans (lima, snap)	Pre-plant, pre-emergence
	1.14		–	Pea	Pre-plant, pre-emergence
	0.55	2	7	Pulses	Harvest aid
	1.14		–	Soya bean	Pre-plant or pre-emergence
					Should not exceed 1.9 l per season
	0.14	2	–	Soya bean	Post-emgence directed spray
					Second and final application 7–14 days later if needed
	0.28		15	Soya bean	Harvest aid

Uses on legumes and pulses were not included in the European labels provided to the current Meeting.

Residue trials were carried out on *dry beans* (genus *Phaseolus*) in Germany, Italy, The Netherlands and Spain, in which paraquat was used for pre-emergence weed control at single application of 0.56 or 2.24 kg ai/ha or post-emergence directed inter-row weeding at rates of 0.28–1.12 kg ai/ha. In trials in Europe, young pods were harvested 0–7 days after treatment and analysed. The residue levels in beans in pods were < 0.05–0.10 mg/kg (five trials). As no related GAP was available, these results were not used in estimating a maximum residue level. The Meeting concluded that there were insufficient data to estimate a maximum residue level for legume vegetables.

The residue levels of paraquat in dry beans in Canadian trials after pre-emergence application following GAP were < 0.01 (two), < 0.05 and 0.07 mg/kg.

Residue trials were conducted on *broad beans* in Spain after post-emergence directed spray. The residue levels in seeds harvested on the day of application were < 0.05 mg/kg (two); however, no information was available on related GAP.

Residue trials were carried out on *peas* in Canada and the United Kingdom with paraquat used for pre-emergence weed control at single applications or post-emergence directed inter-row weeding at rates of 0.14–1.68 kg ai/ha and harvesting 55–152 days after application. The residue levels of paraquat in seeds were below the LOQ of 0.01 or 0.05 mg/kg in trials with post-emergence application; however, no GAP was available for post-emergence application on peas.

Paraquat was applied at 0.20 or 1.12 kg ai/ha to field peas and chick peas as a harvest aid desiccant in Australia and the USA, with samples taken 1–38 days after application. The resulting residues of paraquat in seed in trials following GAP were found at levels of: 0.05, 0.15, 0.23, 0.25, 0.31 and 0.41 mg/kg.

A number of trials were conducted on *soya beans* in Brazil between 1981 and 1983 with a harvest aid desiccation application of paraquat at 0.25–0.80 kg/ha and sampling 2–21 days after application. The residue levels of paraquat in seed in trials following GAP in Brazil were: < 0.02, 0.03 (two), < 0.05 (two), 0.07, 0.08, 0.09, 0.10, 0.11 (two), 0.13, 0.16 (two) and 0.28 (three) mg/kg.

In trials conducted in the USA with pre-emergence application with or without a post-emergence directed application at 0.14–1.4 kg/ha, the residue levels of paraquat in soya beans harvested 3–147 days after the last application in trials following GAP were < 0.025 (nine) and 0.03 mg/kg.

Other trials were conduced in the USA on harvest aid desiccation application at 0.28 or 0.56 kg/ha and sampling 6–36 days after application. The residue levels of paraquat in seeds in trials following GAP were: < 0.01, 0.02 (four), 0.03 (two), 0.04 (two), 0.05, 0.06, 0.07, 0.08 (two), 0.09, 0.12 and 0.13 mg/kg. The hulls of treated soya beans contained higher residues than seeds.

The results of these trials clearly indicate that the levels of residues arising from harvest desiccant uses are higher than those from pre-emergence or post-emergence application.

The Meeting considered it appropriate to combine the results of trials on field peas and chick peas in Australia and on soya beans in Brazil and the USA in which paraquat was used as a harvest aid desiccant to estimate a group maximum residue level for pulses. The combined residue levels in seeds were, in ranked order: < 0.01 (two), < 0.02, 0.02 (four), 0.03 (four), 0.04 (two), < 0.05 (two), 0.05 (two), 0.06, 0.07 (two), 0.08 (three), 0.09 (two), 0.10, 0.11 (two), 0.12, 0.13 (two), 0.15, 0.16 (two), 0.23, 0.25, 0.28 (three), 0.31 and 0.41 mg/kg. The Meeting estimated a maximum residue level of 0.5 mg/kg to replace the previous recommendation for soya bean and an STMR of 0.08 mg/kg and a highest residue level for pulses of 0.41 mg/kg.

Root and tuber vegetables

Paraquat is registered for use at a maximum rate of 0.36 kg ai/ha with three applications and a 30-day PHI in Japan for pre-plant, inter-row application on carrot and in the USA at a maximum rate of 1.14 kg ai/ha for pre-emergence treatment of root and tuber vegetables excluding potatoes.

Two residue trials carried out on *beetroot* in Canada and the United Kingdom for pre-emergence application in compliance with US GAP resulted in residue levels of < 0.01 and 0.03 mg/kg.

Residue trials were conducted in the United Kingdom on beetroot and *sugar-beet* in which paraquat was used pre-sowing or pre-emergence at 1.68 kg ai/ha, followed by two directed inter-row applications at 2.24 kg ai/ha after crop emergence. No information was available, however, on GAP for post-emergence application from Europe.

In trials conducted in four states of the USA with pre-emergence application at 1.12 kg ai/ha, the residue levels in sugar-beet roots harvested 136–178 days after application were < 0.05 mg/kg (six) after a single pre-emergence application at 1.12 kg ai/ha. After application at an exaggerated rate of 5.6 kg ai/ha, the residue levels in unwashed root were < 0.05 mg/kg.

Residue trials on *carrots* with use of paraquat for pre-emergence or inter-row weed control have been carried out in Canada, Japan, Germany and the United Kingdom. The residue levels of paraquat in carrot in the Japanese trials after both pre-emergence and inter-row applications were all below the LOQ of 0.03 mg/kg, despite a shorter PHI or use of a highly exaggerated rate of 19.2 kg ai/ha. The residue levels in carrot in four trials following GAP or conducted at higher rates or shorter PHI were < 0.03 mg/kg. In Canadian trials, the residue levels were below the LOQ of 0.01 mg/kg, even in one trial in which the rate was doubled and the PHI shorter.

As no information was available on GAP in Europe, the data from German trials with post-emergence application were not considered in estimating the maximum residue level.

Residue trials were carried out on *parsnips* and *swedes* in the United Kingdom and on *turnips* in Canada and United Kingdom with use of paraquat for pre-emergence weed control (Canada) or pre-emergence followed by inter-row weed control (United Kingdom). The rates of application were 0.56–2.24 kg ai/ha. Turnip, swede and parsnip roots were harvested 49–122 days after application. The residue levels of paraquat in turnips in two Canadian trials that followed US GAP were < 0.01 mg/kg. No information on GAP was available for post-emergence application in Europe.

One trial was conducted in France on *black salsify*, in which paraquat was applied as an inter-row treatment at 0.5 and 0.8 kg ai/ha. There were no residues (< 0.02 mg/kg) in salsify roots harvested 8 and 80 days after treatment; however, no information on GAP was available.

The combined residue levels in beetroot, sugar-beet, carrots and turnips were, in ranked order: < 0.01 (four), < 0.03 (four), 0.03 (two) and < 0.05 (six) mg/kg.

Potato

Trials were carried out on potatoes in Canada, Germany, the United Kingdom and the USA for pre-emergence, post-emergence and harvest aid applications of paraquat.

Paraquat is registered in the United Kingdom for pre-emergence use at a maximum rate of 0.66 kg ai/ha with one application. It is registered in the USA for pre-plant and pre-emergence broadcast application at a maximum rate of 0.55 kg ai/ha and for broadcast application for pre-harvest vine killing and weed dessication at a maximum rate of 0.42 kg ai/ha with a 3-day PHI. The latter application is restricted to fresh market produce, with a restriction of 2.3 l/ha per season; split applications must be applied a minimum of 5 days apart.

Trials were carried out in Germany with post-emergence directed application. The residue levels were below the LOQ of 0.01 mg/kg.

Several residue trials were carried out in Canada and the USA in which paraquat was applied for weed control by pre-emergence or post-crop emergence application at a rate of 0.20–1.12 kg ai/ha. The residue levels in the tubers in trials following US GAP were < 0.01 (eight) and 0.02 mg/kg. At double the application rate, the residue levels were below the LOQ of 0.01 mg/kg.

Trials were also carried out on harvest aid desiccant use in Canada, the United Kingdom and the USA. The US label allows use of paraquat for vine killing and weed desiccation at a maximum of 0.42 kg ai/ha, with a PHI of 3 days, but in these trials rates equivalent to or higher than twice the maximum rate or a much longer PHI were used. Harvest aid use is not included in the United Kingdom label.

The residue levels in trials of pre- and post-emergence application were < 0.01 (eight) and 0.02 mg/kg. The levels in trials with double the application rate in the USA and in trials conducted in Germany were all below the LOQ.

The Meeting decided to combine the results from trials on beetroot, sugar-beet, carrot, turnip and potato. The combined residue levels, in ranked order, were: < 0.01 (12), 0.02, < 0.03 (four), 0.03 (two) and < 0.05 (six) mg/kg. The Meeting estimated a maximum residue level of 0.05 mg/kg, an STMR of 0.02 mg/kg and a highest residue level of 0.05 mg/kg for root and tuber vegetables. The maximum residue level replaces the previous recommendation for potato.

Stem vegetables

Residue trials have been carried out on asparagus, celery and globe artichokes in Canada and the USA with use of paraquat for post-emergence directed inter-row weeding at rates of 1.12–3.25 kg ai/ha in a single application. Three applications of 1.12 or 1.35 kg/ha on artichokes were also tested.

Paraquat is registered in the USA for *asparagus* at a maximum rate of 1.14 kg ai/ha for pre-plant and pre-emergence broadcast or banded over-row application and at the same maximum rate with a 6-day PHI for asparagus more than 2 years old by broadcast or banded over-row application. The residue levels were < 0.02 (two) and < 0.05 mg/kg.

Although trials were conducted on *celery* in Canada and on *artichoke* in the USA, no information on GAP for these crops was available. The Meeting concluded that the data were insufficient for estimating a maximum residue level for asparagus.

Cereal grains

1.1 Maize

Residue trials were conducted on maize in Canada, Italy, the United Kingdom and the USA with pre- and post-emergence applications and harvest aid uses.

Paraquat is registered for use in the USA at a maximum rate of 1.14 kg ai/ha for pre-plant or pre-emergence broadcast of banded over-row applications and at a maximum rate of 0.55 kg ai/ha for post-emergence directed spray. Residue trials were conducted with use of paraquat for pre-emergence weed control or for post-emergence directed spray in Canada and the USA at rates of 0.28–1.12 kg ai/ha.

In a series of trials in the USA in 1987, one pre-emergence application at 1.12 kg ai/ha and two post-emergence applications at 0.31 kg ai/ha were made. Although the post-emergence application rate was not as high as the maximum rate, the pre-emergence application rate was the maximum allowed for pre-emergence application. The Meeting considered that these trials were conducted in accordance with US GAP. The residue levels in trials in Canada and the USA conducted in accordance with US GAP were: < 0.01 (eight) and < 0.025 mg/kg (16). In trials with higher application rates (up to four times), the residue levels were below the LOQ. The levels in maize cobs were also below the LOQ of 0.01 mg/kg (two trials).

In two residue trials in Italy, paraquat was applied pre-emergence at 0.92 kg ai/ha. The residue levels in cob were < 0.05 mg/kg; however, no analysis of kernels or grain was reported.

Trials were conducted in South Africa and the United Kingdom with post-emergence application; however, owing to the lack of relevant GAP for South Africa and the fact that post-emergence application is not included on the label in the United Kingdom, the results of these trials could not be evaluated by the Meeting.

Several trials were conducted in the USA on use of paraquat as a harvest aid desiccator at rates of 0.56–1.12 kg/ha. This use is not included in US GAP, although it is allowed in Argentina, Brazil and Uruguay.

On the basis of the residue levels in maize grain in trials with paraquat applied pre- or post-emergence in Canada and the USA, < 0.01 (eight) and < 0.025 mg/kg (16), the Meeting estimated a maximum residue level of 0.03 mg/kg to replace the previous recommendation for maize and STMR and highest residue values of 0.025 mg/kg.

Sorghum

A number of residue trials were conducted in the USA, where paraquat is registered for use on sorghum at a maximum rate of 1.14 kg ai/ha, with a PHI of 48 days for grain and 20 days for forage, for pre-plant or pre-emergence broadcast application, and at a maximum rate of 0.55 kg ai/ha in two applications with the same PHIs for post-emergence directed spray. In the latter application, the applications must not exceed 2.5 l per season.

Several residue trials were carried out in the USA in several years and locations, in which paraquat was applied for weed control, either pre-emergence, post-crop emergence directed or as a harvest aid, at rates of 0.21–7.8 kg ai/ha. Samples were taken 20–131 days after pre-emergence or post-emergence directed application. The residue levels in grain in 12 trials conducted in accordance with maximum GAP for pre-emergence or post-emergence applications were all ≤ 0.025 mg/kg. When both pre- and post-emergence applications were made, if the post-application rate was in compliance with GAP, the residue results were taken into consideration in estimating the maximum residue level. In one trial with one pre-emergence application at 0.56 kg ai/ha followed by a post-emergence application at 0.56 kg ai/ha, a residue level of 0.01 mg/kg was found.

In harvest aid desiccation applications, paraquat was applied at a rate of 0.21–2.8 kg/ha, and sorghum was sampled 7–49 days after application. Harvest aid desiccant use is not included on the US label.

The Meeting estimated a maximum residue level of 0.03 mg/kg to replace the previous recommendation and STMR and highest residue values of 0.025 mg/kg for sorghum.

Rice

Trials on residues of paraquat on rice were conducted in Guatemala, Italy and the USA. Paraquat is registered for use on rice in the USA by pre-plant or pre-emergence broadcast at a maximum rate of 1.14 kg ai/ha, with no PHI specified.

Two trials were conducted in Italy in 1993, in which paraquat was applied at a rate of 0.92 kg ai/ha to the seed bed 5 days before rice was sown. Rice grain and straw samples taken at harvest did not contain residues of paraquat at levels above the LOQ of 0.05 mg/kg.

Three residue trials were conducted in Guatemala in 1983 in which paraquat was applied as a pre-emergence treatment at rates of 0.30 and 1.0 kg ai/ha to rice. Rice grain and straw samples were taken at harvest. The residues in de-husked rice in one trial conducted in compliance with the maximum rate in US GAP were < 0.05 mg/kg, but residues in rice grain were not analysed.

Residue trials were conducted in the USA in 1978 and 1982 in which paraquat was applied as a pre-emergence treatment at rates of 0.56 and 1.12 kg ai/ha to rice. In trials conducted at the maximum GAP, the residue levels in rice grain were below the LOQ of 0.01 (two) or 0.02 mg/kg. No trials were conducted at rates higher than the maximum allowed in US GAP for rice.

The Meeting concluded that there were insufficient data to estimate a maximum residue level and withdrew the previous recommendation for rice and rice, polished.

Tree nuts

It is common practice to harvest nuts from the ground, and this may result in residues of paraquat in the nuts.

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 nuts* (California) and *walnuts* (California).

Paraquat is registered for use on hazelnuts in Italy at a maximum rate of 1 kg ai/ha with a 40-day PHI and on walnuts at the same maximum rate but with no PHI specified. In the USA, paraquat is registered for use on pistachio nuts at a maximum rate of 1.14 kg ai/ha with a 7-day PHI, with the proviso that no more than two applications should be made after the nuts have split. It is registered for use in the USA on other tree nuts at the same maximum rate with no specification of the number of applications or PHI.

Two trials were conducted in Italy in which hazelnuts were harvested from the ground 1–10 days after treatment around the base of the trees at rates of 0.54–1.8 kg ai/ha. Although the PHI was shorter than 40 days, the residue levels in shelled nuts were below the LOQ of 0.05 mg/kg in one trial. At almost twice the maximum application rate and with a shorter PHI of 10 days, the levels were still below the LOQ.

In a trial in the USA, paraquat was applied at rates of 0.56–4.5 kg ai/ha one to eight times, to control weeds under mature nut trees. In some cases, applications were made over 2 years. Nuts were harvested, in some cases immature, 1–171 days after the last application. The residue levels in shelled nuts in trials following GAP were: < 0.01 (seven), 0.01, 0.02 and < 0.05 (three) mg/kg.

The combined results of all the trials, in ranked order, were: < 0.01 (seven), 0.01, 0.02 and < 0.05 (four) mg/kg. The Meeting estimated a maximum residue level for paraquat in tree nuts of 0.05 mg/kg, an STMR of 0.01 mg/kg and a highest residue level of 0.05 mg/kg.

Oil seeds

Cotton-seed

Paraquat is registered for use on cotton in the USA at a maximum rate of 1.14 kg ai/ha, with no specification of the number of applications of PHI, for pre-plant or pre-emergence treatment, and at a maximum rate of 0.55 kg ai/ha, with repeated application if necessary and a 3-day PHI as a harvest aid, with the proviso that a total of 1.5 l should not be exceeded in this use.

Residue trials were conducted in the USA over several years and locations, involving pre-emergence applications at 1.12 kg/ha and harvesting 4–176 days after application. The residue levels in fuzzy seed in trials at the maximum GAP were < 0.01 (four) and 0.04 mg/kg.

In numerous trials with pre-emergence application followed by harvest aid desiccation application or a single application as harvest aid desiccant, the residue levels of paraquat in fuzzy seed in trials following maximum GAP were: 0.07, 0.09, 0.15, 0.16 (two), 0.18, 0.21, 0.23, 0.30, 0.34, 0.35, 0.38, 0.44, 0.46, 0.49, 0.50, 0.58 and 2.0 mg/kg. On the basis of residue levels arising from harvest aid uses, the Meeting estimated a maximum residue level for cotton-seed of 2 mg/kg, to replace the previous recommendation, an STMR of 0.34 mg/kg and a highest residue level of 2 mg/kg.

Sunflower seed

In the USA, paraquat is registered for use on sunflower at a maximum rate of 1.14 kg ai/ha with no PHI specified for pre-plant or pre-emergence broadcast or banded over-row application and at a maximum rate of 0.55 kg ai/ha with a 7-day PHI for dessication use.

Trials were conducted with pre-emergence application to sunflowers at 1.12 or 5.6 kg/ha and sampling 41–131 days after application. The residue levels in seeds in four trials conducted in compliance with maximum GAP were < 0.05 mg/kg. When paraquat was applied at five times the maximum recommended rate, the levels were still below the LOQ of 0.05 mg/kg.

In further trials, paraquat was applied as a harvest aid desiccator at 0.28–1.12 kg/ha, and sunflower seeds were harvested 7–21 days after application. The residue levels of paraquat in seeds in trials conducted at maximum GAP were: 0.09, 0.14, 0.15, 0.16 (three), 0.19, 0.22, 0.24, 0.32, 0.35, 0.51, 0.60, 0.74, 0.81 (two) and 0.93 mg/kg. The Meeting used the residue levels arising from harvest aid uses to estimate a maximum residue level for sunflower seed of 2 mg/kg, an STMR of 0.22 mg/kg and a highest residue level of 0.81 mg/kg.

Hops

Residue trials were conducted in Canada and the USA. Paraquat was registered in the USA for use as a directed spray or for suckering and stripping on hops at a maximum rate of 0.55 kg ai/ha in three applications with a 14-day PHI; no more than two applications or applications at no more than 1.5 l/ha were recommended.

In a trial in Canada, a single post-emergence directed application of 1.12 kg ai/ha, which is double the maximum recommended dose, resulted in residue levels of < 0.01 mg/kg in green hops harvested 53 days after application.

In the USA, trials were conducted in the states of Idaho, Oregon and Washington with three post-emergence directed applications of paraquat at 2.8 kg ai/ha. The residue levels of paraquat in dried hops prepared from hops harvested 14 days after the last of three directed application at the maximum GAP rate were 0.05 mg/kg in two trials. At double this rate, the levels in dried hops prepared from green hops harvested 13 or 14 days after the last treatment were below the LOQ of 0.1 mg/kg (0.01 and 0.07 mg/kg). Two applications at higher rates than that of maximum GAP resulted in 0.02 and 0.03 mg/kg in dried hops.

The residue levels in dried hops were 0.05 mg/kg (two). In view of the low levels of residues in the other trials, the Meeting estimated a maximum residue level of 0.1 mg/kg, to replace the previous recommendation, and STMR and highest residue values of 0.05 mg/kg for hops, dry.

Tea, green, black

Residue trials on tea were conducted in India, where paraquat is registered for use for pre-emergence or post-emergence directed application between rows at a maximum rate of 0.75 kg ai/ha in one application, with no PHI specified.

Six trials were conducted at a total application rate of 0.57–2.0 kg ai/ha over 5–6 months. Green tea leaves were harvested 7 or 21 days after blanket application (after the first or last spot application) and processed into black tea, which was analysed. The residue levels of paraquat in black tea from tea plants treated in accordance with GAP in India or at higher rates were almost always below the LOQ of 0.05 mg/kg. In trials conducted in accordance with GAP, the levels in black tea were: < 0.05 (three), 0.07, 0.09 and 0.12 mg/kg.

In other trials in India, with application rates of 0.05–0.06 kg ai/ha, black tea samples from green tea leaves harvested 5 or 7 days after application contained 0.05 mg/kg (one) or < 0.05 mg/kg. As the application rate was much lower than the maximum, these results were not considered in estimating the maximum residue level.

The Meeting estimated a maximum residue level for teas, green, black of 0.2 mg/kg and an STMR of 0.06 mg/kg.

Animal feedstuffs

Soya forage and hay or fodder

Paraquat is registered for use in Australia, Brazil and the USA for weed control andas a harvest aid on soya beans. In the USA, it is registered for use at a maximum rate of 1.14 kg ai/ha for pre-plant or pre-emergence treatment, not to exceed 1.9 l per season, at a maximum rate of 0.14 kg ai/ha as a post-emergence directed spray with a second and final application 7–14 days later; it can also be used at a maximum rate of 0.28 kg ai/ha with a 15-day PHI as a harvest aid.

The residue levels in forage in trials conducted in the USA in accordance with US GAP were: < 0.025 (12), < 0.05 (13), 0.05, 0.06 (four), 0.07, 0.08, 0.15, 0.28 and 1.8 mg/kg, expressed on a dry weight basis.

The Meeting estimated a maximum residue level for soya bean forage (green) of 2 mg/kg, an STMR of 0.05 mg/kg and a highest residue level of 1.8 mg/kg.

The residue levels in hay or fodder in trials conducted in accordance with US GAP were: < 0.025 (five), 0.04, < 0.05 (four), 0.05, 0.1, 0.2 and 0.3 mg/kg, on a dry weight basis. The Meeting estimated a maximum residue level for soya bean fodder of 0.5 mg/kg, an STMR of 0.05 mg/kg and a highest residue level of 0.3 mg/kg.

Sugar-beet tops

Trials were conducted on beet and sugar-beet in the United Kingdom and the USA. The residue levels in sugar-beet tops in six trials conducted in accordance with US GAP were < 0.025 mg/kg, on a fresh weight basis. The Meeting estimated a maximum residue level of 0.2 mg/kg and an STMR of 0.11 mg/kg. On the basis of 23% dry matter and a highest residue level on a fresh weight basis of 0.025

mg/kg, the Meeting calculated the highest residue level on a dry weight basis to be 0.11 mg/kg. As there is no code for sugar-beet tops, the maximum residue level was recommended for fodder beet leaves and tops.

Maize forage and fodder

Trials were conducted in Italy and the USA. The residue levels in maize forage in trials in the USA conducted in accordance with US GAP were < 0.025 (eight), 0.09, 0.6, 2 (two) and 3 (two) mg/kg on a dry weight basis. The Meeting estimated a maximum residue level for maize forage of 5 mg/kg, an STMR of 0.025 mg/kg and a highest residue level of 3 mg/kg.

The levels of residues in silage were mostly below the LOQ of 0.025 or 0.05 mg/kg, except in one trial in which levels up to 0.04 mg/kg were found.

The residue levels in maize fodder in trials in the USA conducted in accordance with US GAP were: < 0.025 (eight), 0.03, 0.05, 0.06, 0.2, 1, 2 and 6 mg/kg on a dry weight basis. The Meeting estimated a maximum residue level for maize fodder of 10 mg/kg, an STMR of 0.025 mg/kg and a highest residue level of 6 mg/kg.

Sorghum forage (green) and straw and fodder, dry

In trials conducted in the USA in accordance with GAP, the residue levels in sorghum forage were: < 0.025 (six), 0.025 (three), 0.04, 0.06 and 0.2 mg/kg. The Meeting estimated a maximum residue level for sorghum forage (green) of 0.3 mg/kg, an STMR of 0.025 mg/kg and a highest residue level of 0.2 mg/kg.

The residue levels in sorghum fodder or hay (whichever gave higher levels) in trials conducted in accordance with GAP were: < 0.025 (four), 0.03, 0.04, 0.05, 0.06 (two), 0.09, 0.1 and 0.2 mg/kg. The Meeting estimated a maximum residue level for sorghum straw and fodder, dry, of 0.3 mg/kg, an STMR of 0.035 mg/kg and a highest residue level of 0.2 mg/kg.

Rice straw and fodder, dry

The Meeting concluded that there were insufficient data for estimating a maximum residue level for rice straw and fodder, dry.

Almond hulls

In three trials conducted in the USA in accordance with GAP, the residue levels in almond hulls were < 0.01 mg/kg. The Meeting estimated maximum residue, STMR and highest residue values of 0.01 mg/kg.

Cotton fodder

The Meeting concluded that there were insufficient data for estimating a maximum residue level for cotton fodder.

Fate of residues during processing

Numerous studies of residue levels after processing conducted in conjunction with supervised trials were submitted. Residue levels found after processing of raw agricultural commodities into animal feedstuffs are described in the section above. Some processed commodities for which maximum residue levels and STMR-Ps were estimated are also described in that section.

In this section, processing factors from raw commodities to processed food products and by-products are discussed. Information on processing was provided for orange, plum, grape, olive, tomato, sugar-beet, maize, sorghum, cotton-seed, sunflower seed and hop. Processing factors could not be reliably calculated for the processing of orange, plum, grape, tomato and sugar-beet because the paraquat residue levels in both raw commodities and processed products were all below the respective LOQs.

Processing factors were calculated for olive (oil), potato (crisps and granules), maize (milling fractions and oil), sorghum (milling fractions), cotton-seed (trash, gin products and oil), sunflower seed (oil) and hop (dried hop and beer) and are shown below.

Commodity	Processing factor	STMR-P (mg/kg)
Olive		0.05
Unwashed olives before processing	0.57	
Washed olives before processing	< 0.43	
Virgin oil	< 0.35	0.018
Refined oil	< 0.35	0.018
Potato		0.02
Wet peel	> 1.9	0.04
Dry peel	> 11	0.22
Peeled potato	0.27[a]	0.01
Crisps	> 0.95	0.02
Granules	> 2.7	0.05
Maize		0.025
Wet milling		
Coarse starch	< 0.25[a]	0.006
Starch	< 0.25[a]	0.006
Crude oil	< 0.25[a]	0.006
Refined oil	< 0.25[a]	0.006
Dry milling		
Germ	0.3[a]	0.0075
Grits	0.25–0.5[a]	0.0006–0.013
Coarse meal	1[a]	0.025
Meal	0.5[a]	0.013
Flour	1.5[a]	0.038
Crude oil	< 0.25[a]	0.006
Refined oil	< 0.05[a]	0.001
Sorghum		0.025
Hulled grain	0.07[a]	0.002
Dry milled bran	3.9	0.097
Coarse grits	0.17	0.004
Flour	0.14	0.004
Wet milled bran	2.3	0.058
Starch	0.07	0.002
Shorts	2.6	0.065
Germ	0.52[a]	0.013
Cotton (from cotton including trash and bolls)		
Fuzzy seed	0.08	0.34
Crude oil	< 0.006	0.01[b]
Meal	< 0.009	0.04
Sunflower seed		0.3
Hulls	2.8[a]	0.64
Meal	0.05[a]	0.01
Oil	< 0.05[a]	0 [b]
Hop		

Commodity	Processing factor	STMR-P (mg/kg)
Dry cones	1.2	0.05 [b]
Beer	< 0.28	0.0001[c]

[a] Based on only one trial.
[b] Estimated from supervised trials
[c] Calculated from a factor of 0.0001

The STMR values for processed products from raw commodities with no residues or for which the results of many supervised trials were available were estimated on the basis of supervised trials.

In four trials in the USA, orange fruit was processed into juice, and the paraquat residues were measured; in all cases, the levels were below the LOQ of 0.01 mg/kg. The residue levels in *orange juice*, including those in trials conducted at rates higher than the maximum application rate, were all below the LOQ of 0.01 mg/kg. The Meeting estimated an STMR-P for orange juice of 0 mg/kg.

No residues of paraquat were found at levels above the LOQ of 0.05 mg/kg in *dried prunes* prepared from plums in two trials. The STMR-P for dried prunes was estimated to be 0 mg/kg.

In a number of trials, olives were processed into oil for analysis of residues. *Olive oil* prepared from olive fruits harvested directly from trees did not contain levels above the LOQ of 0.05 mg/kg. Most samples of olive oil prepared from olive fruits picked up from ground or sprayed directly did not contain paraquat residues at levels above the LOQ; however, in some samples, paraquat residues were found at levels up to 0.06 mg/kg, and fruit harvested at the same time contained 6.8 mg/kg of paraquat residues. As paraquat is unlikely to be transferred into oil owing to its chemical and physical characteristics, its STMR-P is calculated from the processing factor to be 0.018 mg/kg.

Tomato juice and *ketchup* prepared from tomato in trials conducted at an exaggerated rate did not contain paraquat residues at levels above the respective LOQ (0.005 mg/kg for juice and 0.025 mg/kg for ketchup). The STMR values for these products were estimated to be 0 mg/kg.

The residue levels in oil prepared from soya bean treated with paraquat as a harvest aid desiccant in accordance with GAP were below the LOQ of 0.01 mg/kg in five trials. The Meeting estimated an STMR-P for *soya bean oil* of 0.01 mg/kg.

The residue levels in cotton-seed oil, crude, were below the LOQ of 0.01 mg/kg in two trials. The Meeting estimated an STMR-P for *cotton-seed oil* of 0.01 mg/kg and decided to withdraw the previous recommendation for cotton-seed oil, edible.

The residue levels in *sunflower seed oil* obtained from sunflower seed in eight trials conducted at the maximum GAP were < 0.01 mg/kg. Oil obtained from sunflower seed in a trial at double the rate did not contain residues at levels above the LOQ of 0.01 mg/kg. The Meeting estimated an STMR-P for sunflower seed oil of 0 mg/kg and decided to withdraw the previous recommendation for sunflower seed oil, crude and edible.

The residue levels of paraquat in *cotton gin by-product* in trials for harvest aid uses were (including results for cotton harvested 13–17 days after treatment): 5.2, 5.3, 5.9, 6.2, 7.3, 8.0, <u>9.4</u>, <u>11</u>, 12 (two), 18, 23, 32, 34 and 69 mg/kg. The Meeting estimated an STMR-P of 10.2 mg/kg for cotton gin by-products.

As *maize flour* contained a higher concentration of paraquat residues than maize grain in one trial, the Meeting estimated a maximum residue level of 0.05 mg/kg.

Residues in animal commodities

Dietary burden of farm animals

The Meeting estimated the dietary burden of paraquat residues for farm animals on the basis of the diets described in Appendix IX to the *FAO Manual* (FAO, 2002), by summing the contribution of each feed to the residue.

Estimated maximum dietary burden of farm animals

Crop	Residue (mg/kg)	Basis	Group	Dry matter (%)	Residue/ Dry matter (mg/kg)	Dietary content (mg/kg)			Residue contribution (mg/kg)		
						Beef cattle	Dairy cows	Poultry	Beef cattle	Dairy cows	Poultry
Sugar-beet tops	0.025	HR	AV	23	0.11						
Cotton-seed	2	HR	SO	88	2.27	25	25		0.57	0.57	
Cotton gin by-product	10.2	STMR-P		90	11.3	20	20		2.27	2.27	
Maize grain	0.025	HR	GC	88	0.03			80			0.023
Maize forage	3	HR	AF		3	40	50		1.2	1.5	–
Potato, wet peel	0.04	STMR-P	VR	15	0.27						
Sorghum grain	0.025	HR	GC	86	0.03				–		–
Sorgum forage	0.2	HR	AF	–	0.20				–		–
Soya bean	0.41	HR	VD	89	0.46			20			0.092
Soya bean, forage	1.8	HR	AL	–	1.8	15	5		0.27	0.09	–
Soya bean, hay	0.3	HR	AL	–	0.3				–		–
Sunflower meal	0.011	STMR-P	AL	92	0.01	–	–	–	–	–	–
Turnip tops	0.05	HR	VL	30	0.17						
Total									4.30	4.43	0.11

Estimated maximum dietary burden of farm animals

Crop	Residue (mg/kg)	Basis	Group	Dry matter (%)	Residue/ Dry matter (mg/kg)	Dietary content (mg/kg)			Residue contribution (mg/kg)		
						Beef cattle	Dairy cows	Poultry	Beef cattle	Dairy cows	Poultry
Sugar-beet tops	0.025	STMR	AV	23	0.11						–
Cotton-seed	0.34	STMR	SO	88	0.39	25	25		0.098	0.098	
Cotton gin by-product	10.2	STMR-P		90	11.3	20	20		2.27	2.27	
Maize grain	0.025	STMR	GC	88	0.028			80			0.02
Maize forage	0.025	STMR	AF		0.03	40	50		0.010	0.013	–
Potato wet peel	0.55	STMR-P	VR	15	0.27						
Sorghum grain	0.025	STMR	GC	86	0.03				–		–
Sorgum forage	0.025	STMR	AF		0.03				–		–
Soya bean	0.08	STMR	VD	89	0.09			20			0.02
Soya bean, forage	0.05	STMR	AL		0.05	15	5		0.008	0.003	–
Soya bean, hay	0.05	STMR	AL		0.05				–		–
Sunflower meal	0.011	STMR-P	AL	92	0.01	–	–	–	–		–
Turnip tops	0.025	STMR	VL	30	0.08						
Total									2.39	2.38	0.04

The dietary burdens of paraquat for estimation of MRL and STMR values for animal commodities are: beef cattle, 4.30 and 2.39 ppm; dairy cattle, 4.43 and 2.38 ppm; and poultry, 0.11 and 0.04 ppm.

Feeding studies

In a study of metabolism in goats (see above), one goat was dosed at a rate equivalent to 100 mg/kg of total diet. This is considerably higher than the estimated maximum dietary burden for cattle of 4.30 or 4.43 mg/kg. At 100 mg/kg of diet, the maximum TRRs, expressed in paraquat ion equivalents, found in milk and edible goat tissues were 0.009 mg/kg in milk, 0.12 mg/kg in meat, 0.03 mg/kg in fat, 0.56 mg/kg in liver and 0.74 mg/kg in kidney. In milk, 75.9% of the radiolabel was identified with paraquat.

At the estimated maximum animal burden of 4.30 or 4.43 mg/kg, the levels of paraquat residues were calculated to be < 0.005 mg/kg in milk, 0.005 mg/kg in meat, 0.025 mg/kg in liver and 0.033 mg/kg in kidney. The Meeting estimated maximum residue levels of 0.005* mg/kg for milks, 0.005 mg/kg for mammalian meat and 0.05 mg/kg for edible mammalian offal. These levels replace the previous recommendations for related animal commodities. The STMR values were estimated to be 0.0002 mg/kg for milk, 0.003 mg/kg for meat and 0.0018 mg/kg for edible offal; and the highest residue level values were estimated to be 0.005 mg/kg for meat and 0.033 mg/kg for edible offal.

In the study of metabolism in hens (see above), birds were dosed at a rate equivalent to 30 mg/kg of total diet, which is considerably higher than the estimated maximum dietary burden for poultry of 0.11 mg/kg. At 30 mg/kg diet, the maximum TRRs, expressed in paraquat ion equivalents, found in eggs and edible chicken tissues were 0.18 mg/kg in egg yolk, 0.001 mg/kg in egg albumen, 0.05 mg/kg in meat, 0.05 mg/kg in fat and 0.09 mg/kg in liver.

At the estimated maximum animal burden of 0.11 mg/kg, the maximum residue levels were calculated to be far below the LOQ of 0.005 mg/kg in eggs and other tissues. The Meeting estimated the maximum residue levels to be 0.005* mg/kg for eggs, poultry meat and edible poultry offal. The STMR and highest residue level values were estimated to be 0 for these commodities.

RECOMMENDATIONS

On the basis of the data from supervised trials the Meeting concluded that the residue levels listed below are suitable for establishing maximum residue limits and for IEDI and IESTI assessment.

Plant commodities and animal commodities

Definition of the residue for compliance with MRLs: paraquat cation

Definition of the residue for estimation of dietary intake: paraquat cation

Commodity		Recommended MRL mg/kg		STMR/ STMR-P[1)] mg/kg	HR/HR-P[1)] mg/kg
CCN	Name	New	Previous		
AM 0660	Almond hulls	0.01 (*)			
FI 0030	Assorted tropical fruits – inedible peel (except passion fruit)	0.01 (*)		0.01	0.01
FB 0018	Berries and other small fruits	0.01 (*)		0	0
MO 1280	Cattle kidney	W	0.5		
FC 0001	Citrus fruits	0.02	-	0.01	0.02
JF 0004	Orange juice			0	
SO 0691	Cotton seed	2	0.2	0.34	
OC 0691	Cotton seed oil, crude			0.01	
OR 0691	Cotton seed oil, Edible	W	0.05 (*)		
MO 0105	Edible offal (mammalian)	0.05		0.018	0.033
MO 0097	Edible offal of cattle, pigs & sheep	W	0.05 (*)		
PE 0112	Eggs	0.005 (*)	0.01 (*)	0	0
AV 1051	Fodder beet leaves or tops	0.2 (dry wt)			
VC 0045	Fruiting vegetables, cucurbits	0.02		0	0
VO 0050	Fruiting vegetables, other than cucurbits	0.05		0.01	0.04
JF 0448	Tomato juice			0	
	Ketchup			0	

Commodity		Recommended MRL mg/kg		STMR/ STMR-P[1)] mg/kg	HR/HR-P[1)] mg/kg
CCN	Name	New	Previous		
DH 1100	Hops, Dry	0.1	0.2	0.05	0.05
	Beer			0.0001	
VL 0053	Leafy vegetables	0.07		0.025	0.05
GC 0645	Maize	0.03	0.1	0.025	
CF 1255	Maize flour	0.05		0.038	
	Maize germ			0.0075	
	Maize grits/meal			0.013	
OC 0645	Maize oil, crude			0.006	
	Corn starch			0.006	
AS 0645	Maize fodder	10 (dry wt.)			
AF 0645	Maize forage	5 (dry wt.)			
MM 0095	Meat (from mammalian other than marine mammals)	0.005		0.003	0.005
MM 0097	Meat of cattle, pigs & sheep	W	0.05 (*)		
ML 0106	Milks	0.005*	0.01 (*)	0.0002	
FT 0305	Olives	0.1	1	0.05	0.1
OC 0305	Olive oil, virgin			0.018	
FI 0351	Passion fruit	W	0.2		
MO 1284	Pig kidney	W	0.5		
FP 0009	Pome fruits	0.01 (*)	-	0	0
VR 0589	Potato	W	0.2		
	Potato crisps			0.02	
	Potato granules			0.05	
PO 0111	Poultry, Edible offal of	0.005 (*)		0	0
PM 0110	Poultry meat	0.005 (*)		0	0
VD 0070	Pulses	0.5		0.08	
GC 0649	Rice	W	10		
CM 1205	Rice, Polished	W	0.5		
VR 0075	Root and tuber vegetables	0.05		0.02	0.05
MO 1288	Sheep kidney	W	0.5		
GC 0651	Sorghum	0.03	0.5	0.025	
	Sorghum flour			0.004	
	Sorghum germ			0.013	
AF 0651	Sorghum forage (green)	0.3			
AS 0651	Sorghum straw and fodder	0.3			
VD 0541	Soya bean (dry)	W	0.1		
AL 0541	Soya bean fodder	0.5 (dry wt.)			
AL 1265	Soya bean forage (green)	2 (dry wt.)			
OC 0541	Soya bean oil, crude			0.01	
FS 0012	Stone fruits	0.01 (*)		0	0
DF 0014	Prune			0	
SO 0702	Sunflower seed	2	2	0.23	
OC 0702	Sunflower seed oil, Crude	W	0.05 (*)	0	
OR 0702	Sunflower seed oil, Edible	W	0.05 (*)		
DT 1114	Tea, green, black	0.2		0.06	
TN 0085	Tree nuts	0.05		0.01	0.05
AO1 0002	Vegetables (except as otherwise listed)	W	0.05 (*)		

DIETARY RISK ASSESSMENT

Long-term intake

The IEDIs were calculated for the five GEMS/Food regional diets from the STMR values for fruit, vegetables, maize, sorghum, cotton-seed, sunflower, hops, tea and animal commodities and the STMR-P values for their processed products, as estimated by the current Meeting (Annex 3 of the Report). The ADI is 0–0.005 mg/kg bw, and the calculated IEDIs were 2–5% of the ADI. The Meeting concluded that the intake of residues of paraquat resulting from uses considered by the current JMPR was unlikely to present a public health concern.

Short-term intake

The IESTIs of paraquat by the general population and by children were calculated for commodities for which STMR or STMR-P values had been estimated by the current Meeting when information on consumption was available (Annex 4 of the Report). The ARfD is 0.006 mg/kg; the calculated IESTIs for children up to 6 years range from 0 to 50% and those for the general population from 0 to 20% of the ARfD. The Meeting concluded that the short-term intake of residues of paraquat from uses considered by the current Meeting was unlikely to present a public health concern.

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