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Exposure Measurements of Applicators Who Mix and Spray Paraquat in Grape Vineyards[1]

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Abstract. **Several Arkansas commercial grape growers operating tractor-mounted, low-boom vineyard spray rigs were monitored for potential dermal, respiratory, and internal exposure to paraquat (1-1′-dimethyl-4,4′-bipyridinium ion) during the 1980 and 1981 growing seasons. Workers followed their usual mixing and spraying routines with as little influence as possible from the test. Analyses by colorimetric methods revealed very low levels of paraquat exposure. Greatest dermal exposure levels averaging 0.015 mg paraquat/kg body weight were detected on persons operating the spray rigs. Respiratory exposure was minimal and there was no paraquat detected in any of the urine samples collected from each worker. Those persons receiving the highest levels of paraquat exposure had measurements which were well below those found to be toxic to laboratory animals. Hazards from using this material by this method of application should be low when used in accordance to label directions and precautions.**

Paraquat is a highly versatile general-use postemergence herbicide used extensively by farmers for control of certain grasses and weeds. Examples of frequent horticultural paraquat use include postemergence applications in vineyards and orchards and on cane fruits and bush fruits. Commercial grape growers prefer using herbicides such as paraquat over mechanical tillage (grape hoeing) since herbicides are less expensive to use and produce better weed control. However, in the last few years, there has been increasing concern regarding the possible health hazards occurring from exposure of workers to paraquat during mixing and spraying. Although the hazard from ingestion of paraquat is well-known, the possible hazards from normal agricultural use have not been fully investigated. Since poisoning by ingestion mainly affects the lungs (2, 5, 6, 9, 12), applicators and regulatory agencies are expressing concern that the respiratory and dermal routes of entry via spray droplets might be posing a problem.

Our objectives were to measure potential exposure (dermal, respiratory, and internal) to persons mixing and spraying paraquat in several Arkansas commercial grape vineyards for 2 consecutive growing seasons.

Field exposure tests were conducted in the early spring of 1980 and 1981 involving 7 commercial grape growers operating their own tractor-mounted, low-boom spray rigs. Worker cooperation was strictly voluntary, and they were instructed to work and dress in a manner no different from their usual mixing or spraying procedures. None of the workers used respirators, goggles, aprons, or special protective clothing during the study. The typical attire for the applicators in both years of testing included a shirt (long or short sleeves), long trousers, a baseball type cap, and leather work boots. None of the spray applicators had cabs or any other type of covering on their tractors. The spray rate of paraquat used was 0.6 kg/ha (0.5 lb/acre) and the spray pressure averaged 3.5 kg/cm^2 (50 psi). All workers during both years indicated that they had not worked with paraquat for at least 2 weeks prior to the study. In addition, the testing materials, sampling procedures and exposure calculations were similar to those used in previous human exposure studies performed by Lavy et al. (7, 8) on the herbicide 2,4,5-T.

During the 1980 field test, 6 different paraquat applications were monitored with exposure times ranging from 1.5 to 10 hr beginning with mixing and ending when the worker terminated spraying. In 1981, the mixing and spraying procedures were monitored separately in order to evaluate exposure levels in relation to worker duty. Five mixing and 6 spraying procedures, with mixing exposure times ranging from 15 to 45 min and spraying exposure times ranging from 1.5 to 10.5 hr, were evaluated.

Potential dermal exposure was measured by attaching preextracted gauze (cheesecloth) patches (10 × 10 cm) to the outer garments of the worker on the chest, upper back, biceps, and thighs just before each spray or mix operation began and removing them immediately after mixing or spraying was complete. In addition, a postmix and postspray hand-rinse procedure was added to the 1981 field test allowing for specific calculations of dermal exposure to the hands. Immediately after the mixing or spraying procedure, the workers' bare hands were immersed and shaken for 30 sec in 100 ml of distilled water contained in a polyethylene bag. For calculation of dermal exposure, each worker was photographed in his work clothes, his body weight was recorded, and the amount of his exposed skin area was calculated using the photograph and values derived by Durham and Wolfe (4). The amount of paraquat detected on the known patch area was used, in turn, to calculate the amount of exposure to bare skin areas. In the 1981 study, total dermal exposure was obtained by adding the amount of paraquat exposure as determined by patches to the amount of paraquat detected in the hand-rinse procedure. This total, divided by body weight, provides an estimation of total dermal exposure in mg paraquat/kg body weight.

The level of paraquat in the breathing zone was measured through a portable air pump worn by each worker. The pump drew a known volume of air through a cellulose filter pad trapping the paraquat present. To minimize contamination, only the project supervisors removed the patches and filters and conducted the hand-rinses. Since urine analysis is the best indicator of pesticide absorption, a total 24-hr urine sample was collected from each worker prior to paraquat mixing or application to serve as a control, and another total 24-hr sample was collected starting 4 hr after paraquat mixing or application began.

All paraquat samples were analyzed colorimetrically on a Perkin Elmer-Hitachi 200 Spectrophotometer using a modification of an analytical procedure developed by the Chevron Chemical Company (3). In the urine analysis, the paraquat was separated (cleaned up) from interferences with ion exchange chromatography.

Analyses of the gauze patches for both years and of the hand-rinses used in 1981 revealed very low levels of dermal exposure. In the 18 different exposure situations studied, the highest potential dermal exposure value was 0.044 mg paraquat/kg body weight which was found in 1981 on a worker who sprayed for 5 hours but was not involved in the mixing and loading procedures (Table 1). If the acute dermal LD_{50} value of 80 mg paraquat/kg body weight obtained for white 'Sherman' male rats (6) is used in comparison, this highest value of 0.044 mg/kg would only represent 0.06% of a toxic dose. Therefore, this worker (#9, 1981 test) could have received 1818 times as much exposure before he reached this acute dermal LD_{50} level.

The hand-rinse procedure conducted in 1981 proved worthwhile, because relatively large amounts of dermal paraquat contamination were found on the hands in relation to the total dermal exposure received (Table 1). For

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Table 1. Potential dermal exposure of spray applicators and mixers to paraquat.[z]

Year	Operation / Worker no.	Total on patches (mg)	Total on hands[y] (mg)	Total estimated dermal exposure (mg)	Estimated dermal exposure per body wt (mg/kg)
1980	*Mix & spray*				
	1	1.217	---	2.319	0.032
	2	0.052	---	0.173	0.002
	3	0.075	---	0.250	0.002
	4	0.060	---	0.200	0.003
	5	0.075	---	0.143	0.002
	6	0.106	---	0.202	0.002
	7	0.140	---	0.267	0.004
1981	*Spray only*				
	8	0.030	0.345	0.434	0.004
	9	1.769	1.324	3.420	0.044
	10[x]	1.895	0.121	2.370	0.031
	11	0.032	---	0.077	0.031
	12[x]	0.514	0.163	0.772	0.010
	13[x]	0.068	0.081	0.162	0.002
1981	*Mix only*				
	1M	0.015	0.049	0.067	0.001
	2M	nd[w]	0.231	0.231	0.003
	3M[x]	nd	nd	0	0
	4M[x]	nd	0.081	0.081	0.001
	5M[x]	0.015	0.202	0.220	0.003

[z]Calculated on the basis of the applicator wearing a short- or long-sleeved, open-necked shirt, hat and long trousers, with the clothing worn giving protection of the areas covered.
[y]Hand-rinse procedure conducted in 1981 only.
[x]Indicates applicator wore cotton gloves; the others wore rubber gloves during the field testing.
[w]nd = not detected or below lower limit of detection (0.002 mg) for the test.

example, the hand-rinse procedure accounted for 39% of the spray applicators' total dermal exposure and 91% of the mixers' total dermal exposure. These findings should stress the importance of following the manufacturer's label precaution to wear gloves, especially when handling paraquat in the concentrate form. All but one of the workers who wore gloves received significantly less dermal contamination on their bare hands as compared to the workers who did not wear gloves.

Values obtained for potential respiratory exposure in both years of testing were extremely low (Table 2). In fact, detectable traces (those above 0.5 μg) were found in only 5 of the 17 total air filter pad samples. The established "safe" or "threshold limit value" (TLV) for respirable paraquat particles has been set at 0.1 mg/m^3 for an 8-hr, time-weighted average (1). The highest level of potential respiratory exposure obtained in both years of our testing was 0.008 mg/m^3 on an 8-hr, time-weighted average (Table 2). Thus, by comparing these 2 values, the 2 workers could have received 12.5 times as much paraquat inhalation exposure and still have been safe according to the established safe TLV values. In addition, the air monitors used in our study measured "total" airborne paraquat particles and not respirable particles. Therefore, if respirable particles had been measured, the investigators anticipate that the respiratory exposure detected would have been significantly lower than what was initially reported. Nevertheless, there is still a considerable margin of safety when comparing the TLV to the total particles recovered in this study.

Table 2. Potential respiratory exposure of spray applicators and mixers to paraquat.

Year	Operation	Exposure situations studied	Total paraquat on filter		Potential exposure[z] (mg paraquat/m^3 air)		TWA potential exposure[y] (mg paraquat/m^3 air)	
			Range	Mean	Range	Mean	Range	Mean
1980	Mix and spray	7	nd-4.2	1.17	nd-0.014	0.003	nd-0.008	0.002
1981	Spray only	6	nd	nd	nd	nd	nd	nd
	Mix only	4	nd-10.2	4.55	nd-0.163	0.053	nd-0.008	0.003

[z]Concentration of paraquat in the air immediately around the worker = μg paraquat on filter × 1 mg/rate of air pulled through filter in m^3 per min × min exposure × 1000 μg.
[y]TWA = Time-weighted average based on 8-hr workday. nd = not detected or below lower limit of sensitivity (0.5 μg) of the test. Values falling between limit of detection (0.5 μg) and limit of quantitation (4.0 μg) were averaged as 4.0 μg.

No paraquat was detected in any of the urine samples (limit of detection = 60 ppb) collected from the workers; thus, if any significant absorption occurred, it was not excreted in the urine.

Results of these studies, which were conducted without any modification to the workers' normal routines, indicate that hazards to field applicators who mix and apply paraquat by the previously described method are minimal when the paraquat is applied in accordance to the manufacturer's label directions and precautions. These data support earlier studies and conclusions by Staiff et al. (10), who monitored worker exposure while spraying paraquat through similar spray rigs in orchards in the northwestern United States and by Swan (11), who studied paraquat exposure to workers using knapsack sprayers on Malaysian rubber plantations.

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