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Annex III: Cytogenetic changes in workers following pesticide exposure in EU

Table arranged according to occupation

Subjects (exposed/controls)	End-point	Duration of exposure	Protective clothing	Results	Comments	Author
Czech production workers (44/30)	CA and SCE	< 2 years	Not stated	<b>Positive CA</b> Both males and females had a significantly higher percentage of CA <b>Positive SCE</b> Only male workers had a significantly higher SCE frequency.	Workers were exposed to Mancozeb.	Jablonicka, <i>et al.</i> , 1989
Yugoslavian pesticide sprayer (27/15/20)	CA, SCE and MN	12.1 ± 6.02	Not stated	<b>Positive CA</b> Significant higher CA in workers compared to controls and references in prespraying period. CA in exposed workers increased at 3 <sup>rd</sup> sampling time. <b>Negative MN</b> No significant difference in MN frequency between workers, controls and references. Significant increase in MN in exposed workers at 2 <sup>nd</sup> and 3 <sup>rd</sup> sampling time. <b>Negative SCE</b> No significant variation in SCE frequency in exposed workers.	Three groups used; exposed workers; controls and references. All subjects were non-smokers. Air samples taken showed the presence of diazinon. Blood was collected during the pre-spraying period, a month after spraying and at the end of the spraying season.	Joksic, <i>et al.</i> , 1997
Danish pesticide sprayer (134/157)	SCE	17 (range 1-50)	Groups assigned according to protection worn.	<b>Negative.</b> No significant increase in SCE frequency in exposed workers. Significant increase related to age and smoking. SCE frequency increased in workers with medium or high exposure.	Blood samples were collected at the end of the spraying season.	Lander and Ronne, 1995

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Hungarian pesticide sprayer (80/24)	CA	1- >15	Not stated.	<b>Positive.</b> Significant increase in CA in exposed workers. Age not associated with CA induction.	Blood samples collected before and after pesticide application.	Paldy, <i>et al.</i> , 1987
Greek pesticide sprayer (29/27/30)	CA and SCE	6	None of the workers used protective clothing.	<b>Positive CA.</b> Increase in CA in exposed workers. Higher CA in workers in greenhouses compared to those in open fields. CA frequency not affected by smoking. <b>Negative SCE</b> No significant difference between exposed and control groups.	Subjects divided into 3 groups; pesticide sprayers in greenhouses; in open fields and controls.	Kourakis, <i>et al.</i> , 1996
Greek pesticide sprayer (29/14)	CA	4	None of the workers used protective clothing.	<b>Positive</b> Increase in CA in exposed workers. No correlation between CA and duration of exposure.	Blood samples during autumn, after spraying from September to November.	Kourakis, <i>et al.</i> , 1992
Turkish pesticide sprayer (33/33)	Comet assay	10 ± 6 (range 1-23)	64% wore only overalls and masks without filters. 27% used no protection. No worker wore gloves or glasses.	<b>Positive.</b> Significant increase in DNA damage in exposed workers. DNA damage not affected by smoking. Significantly lower DNA damage when protective clothing used.	Comet assay was scored visually.	Undeger and Basaran, 2002
Italian floriculturist (51/24)	MN	26.35 ± 14.46 (range 2-10)	Most (86%) wore protection	<b>Negative</b> Non-significant increase in MN in subjects exposed to pesticides, in those not using protective clothing, in females. Non-significant relationship with age and duration of exposure. Non-significant decrease in MN frequency in smoking workers.	Subjects (80%) worked mainly in greenhouses.	Bolognesi, <i>et al.</i> , 2004

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Italian floriculturist (107/61)	MN	27.8 ± 15.5 (range 2-70)	Most (84%) wore protection	<b>Positive</b> Significant increase in MN in floriculturists compared to controls. Significant increase in MN frequency in female workers compared to male workers and female controls. Age and duration of exposure significant related to MN frequency.	Most subjects worked in open fields (56%).	Bolognesi, <i>et al.</i> , 2002
Italian floriculturist (71/75)	MN	25.3 years ± 1.57 (range 2-55)	Not stated	<b>Positive.</b> MN frequency increased in females and workers exposed to pesticides. Age and duration of exposure significant related to MN frequency. Smoking did not affect MN induction.	Subjects worked in open fields (39.4%) both in fields and greenhouses (55%) or greenhouses (5.6%).	Bolognesi, <i>et al.</i> , 1993a
Italian floriculturist (71/75)	MN	1 - >30	Not stated	<b>Positive.</b> Significantly higher MN in exposed subjects and in females. MN frequency increased with age and duration of employment and with smoking. Significantly higher MN frequency in greenhouse workers or those working both inside and outside.	Subjects worked in open fields (39.4%) both in fields and greenhouses (55%) or greenhouses (5.6%).	Bolognesi, <i>et al.</i> , 1993b
Italian floriculturist (71/75)	MN	1 - >30	Not stated	<b>Positive.</b> MN frequency significantly increased in exposed workers and is significantly associated with duration of exposure. MN frequency higher in greenhouse workers, or in those working inside and outside.	Subjects worked in open fields (39.4%) both in fields and greenhouses (55%) or greenhouses (5.6%).	Bolognesi, <i>et al.</i> , 1993c

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Italian floriculturist (32/32)	CA and SCE	Not stated	Not stated	<p><b>Positive CA</b> Significantly increased total CA in exposed workers, but non-significant increase in chromatid-type aberrations.</p> <p><b>Positive SCE</b> SCE frequency significantly increased in exposed workers. Smoking significantly increased SCE frequency</p>	Little demographic data on the groups. Three groups were studied; healthy workers and bladder cancer patients, both exposed to pesticides and the control group. The groups were different in terms of age, sex and smoking.	De Ferrari, <i>et al.</i> , 1991
Italian greenhouse floriculturist (43/42)	CA, SCE and MN	Not stated	Not stated	<p><b>Negative MN</b> MN frequency not increased by pesticide exposure.</p> <p><b>Negative SCE</b> In exposed workers, significant difference due to smoking. SCE frequency significantly increased in heavy smokers.</p> <p><b>Negative CA</b> No significant difference in CA frequency due to pesticide exposure. CA frequency higher in heavy smokers.</p>	Exposure category dependent on the area sprayed. Samples collected after spraying period.	Scarpato, <i>et al.</i> , 1996
Italian greenhouse worker (34/33)	MN	7-41	1 group wore full protection and 1 group wore only gloves and boots.	<p><b>Negative</b> No significant increase in MN frequency in exposed workers. Frequency of MN associated with age but not sex. Slightly higher frequency of MN in greenhouse workers, due to smoking, although smoking controls had lower MN frequency.</p>	Blood collected during pesticide application. Study investigated if polymorphism of GSTT1, GSTM1 and NAT2 affected MN frequency after pesticide exposure.	Falck, <i>et al.</i> , 1999
Finnish greenhouse worker (116/29)	CA	Not stated	Gloves worn by some workers.	<p><b>Positive.</b> CA significantly higher in workers after spraying compared to before spraying. Non-significant increase in CA in non-smoking workers, pre-seasonally and a significant increase post-seasonally, compared to controls. Increased RR</p>	Blood samples collected before and after the spraying season.	Lander, <i>et al.</i> , 2000

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				for workers not wearing gloves.		
Italian greenhouse floriculturist (26/22)	<sup>32</sup> P DNA post-labelling	22 ± 12	Not stated	<b>Positive.</b> DNA adduct rate higher in exposed workers and females. No significant associations with age or gender.	All subjects were non-smokers. Little demographic data presented	Peluso, <i>et al.</i> , 1996
Italian greenhouse workers (57/33)	<sup>32</sup> P DNA post-labelling	Not stated	Not stated	<b>Positive.</b> Six DNA adducts observed in some workers. Significant increased levels of DNA adducts in workers.	All subjects were non-smokers. Little demographic data presented.	Munnia, <i>et al.</i> , 1999
Greek greenhouse workers (50/66)	Comet assay	8.62 ± 1.13 (range 5-15)	Some workers wore protective clothing (62%).	<b>Negative.</b> No significant difference in basal levels of DNA damage in workers compared to controls or after H <sub>2</sub> O <sub>2</sub> treatment.	Blood collected during late winter/early spring. Lymphocytes were treated with H <sub>2</sub> O <sub>2</sub> to induce DNA damage.	Piperakis, <i>et al.</i> , 2003
Spanish, Hungarian, Polish, Greek agricultural workers (247/231)	MN	9-18	Most workers (~80%) wore protective clothing.	<b>Negative.</b> Frequency of MN not significantly affected in exposed workers. MN frequency significant associated with age. Polish workers had highest MN frequency whereas Hungarian workers had lowest MN frequency.	Subjects mainly worked in greenhouses, but some Polish and Hungarian farmers also worked in open fields.	Pastor, <i>et al.</i> , 2003
Hungarian agricultural worker (84/65)	MN	18.75 ± 0.89	Most workers (85%) wore protective clothing.	<b>Negative.</b> MN frequency not significant increased following pesticide exposure. Age and sex significant associated with MN frequency	Several differences between groups in terms of age, smoking, caffeine consumption. Exposed group worked in greenhouses and in open fields. Subjects were categorised according to symptoms of pesticide intoxication.	Pastor, <i>et al.</i> , 2002a
Spanish agricultural worker (39/22)	MN	8.31 ± 1.12	Most workers (93%) wore protective clothing.	<b>Negative.</b> No difference in MN frequency in workers and controls. Neither exposure or season had a significant effect on MN frequency	Several differences between groups in terms of age, smoking, caffeine consumption. Blood	Pastor, <i>et al.</i> , 2002b

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Polish agricultural worker (49/50)	MN	8.62 ± 1.13	Most workers (78%) wore protective clothing.	<b>Negative.</b> MN frequency not significant affected by pesticide exposure. Alcohol significant decreased MN frequency	collected during a period of high and low exposure. Exposed groups worked in greenhouses and open fields. Pesticide intoxication was reported by 10% of workers.	Pastor, <i>et al.</i> , 2001a
Greek agricultural worker (50/66)	MN	16.28 ± 1.10	Some workers (62%) wore protective clothing.	<b>Negative BNMN.</b> No significant effect of pesticide exposure on BNMN frequency. <b>Negative MNL.</b> MN frequency not significant affected by pesticide exposure. Non-significant increase in MN frequency in female controls compared t males. Age significantly affected frequency of MN.	All workers worked in greenhouses. All subjects were non-smokers. Controls consumed more wine than workers.	Pastor, <i>et al.</i> , 2001b
Spanish agricultural worker (64/50)	MN	9.82 ± 1.01	~80 % workers wore protective clothing.	<b>Negative.</b> No significant differences observed between exposed workers and controls.	Controls were younger than exposed workers.	Lucero, <i>et al.</i> , 2000
Spanish agricultural worker (29/53)	CA	> 10 years	3% wore protection. 59% wore masks incorrectly.	<b>Positive.</b> Significant increase in CA during high exposure period to pesticides. During low exposure period, CA not significantly different to controls.	Exposed subjects worked in open fields more than greenhouses. Blood was collected during a high and low exposure period.	Carbonell, <i>et al.</i> , 1995
Spanish agricultural worker (70/69)	CA and SCE	<5 - >29	Not stated.	<b>Negative SCE</b> No significant difference in SCE frequency in exposed workers and no dose-relationship. Significant increase in SCE in smokers, related to time smoked.  <b>Positive CA</b> Significant increase in CA frequency in total workers. Horticulturists, but not floriculturists had	Groups differed in terms of alcohol and coffee consumption and smoking. Subjects worked in open fields for more time than greenhouses. Blood samples were collected during a high exposure period.	Carbonell, <i>et al.</i> , 1993

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				significant higher CA. Frequency of CA related to duration of exposure but not age.		
Spanish agricultural worker (27/28)	SCE	> 10	Not stated.	<b>Negative</b> No difference in SCE frequency following pesticide exposure. SCE frequency not affected by age or duration of exposure. Smoking increased SCE frequency in workers and controls.	Little demographic data provided.	Carbonell, <i>et al.</i> , 1990
Hungarian agricultural worker (55/60)	CA	<1 - >15	All subjects wore protective clothing.	<b>Positive.</b> Significant increase in CA in exposed workers. 1-2 months after spraying, frequency of cells with CA was lower than controls. Higher percentage of workers had CA compared to the percentage in controls.	Most subjects worked in greenhouses or plastic tents. Blood was collected from different workers at different times points.	Nehez, <i>et al.</i> , 1988
French farmer (29/1)	Comet assay	Not stated	Not stated	<b>Positive.</b> Significant increase in DNA damage in workers in spraying period. Smoking significantly increased DNA damage. Significant negative correlation between time without spraying and DNA damage.	Four groups used; workers in summer, January, April and June.	Lebailly, <i>et al.</i> , 1998a
Italian farmer (48/50)	SCE and MN	18.35 ± 12.42 (range 3-50)	Few workers (29%) wore protective clothing.	<b>Negative SCE</b> No difference in SCE frequency following pesticide exposure. SCE frequency not affected by age or duration of exposure. Smoking significantly increased SCE frequency in workers and controls. <b>Positive MN</b> Significant increase in MN frequency in workers. MN frequency increased in smokers in both groups. MN not affected by age, but significant associated with duration of exposure.	Blood was collected during pesticide application periods during two seasons (1992 and 1995).	Pasquini, <i>et al.</i> , 1996

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French farmer (29)	Comet assay	Not stated	34% wore gloves. 15% wore gloves + masks.	<p><b>Negative – triazoles/isoproteruron (Group 2-4)</b> Spraying with these pesticides did not induce DNA damage (group 3-4) or decreased DNA damage (group 2).</p> <p><b>Positive – chlorothalonil (Group 1)</b> Workers exposed to chlorothalonil had a slight increase in DNA damage.</p>	Four groups used: workers using chlorothalonil; workers using isoproteruron + herbicides; those using triazoles with or without herbicides; and those using chlorlthalonil + insecticides.	Lebailly, <i>et al.</i> , 1998b
French fruit farmer (19)	Comet assay	Not stated	14% wore no protection, 14% wore masks/protective clothes, 17% wore only gloves, 41% wore all protection.	<p><b>Negative.</b> Overall, no significant differences before and after spraying. Five out of twelve had a significantly increase in DNA damage.</p>	Mean predictive dose of Captan calculated as 14.8 mg and 14.0 mg for each season.	Lebailly, <i>et al.</i> , 2003
Finnish forestry workers (19/15)	CA	6-28 days	Not stated	<p><b>Negative.</b> No significant increase in CA in exposed workers.</p>	Blood collected after spraying season. Low 2,4-D and MCPA concentrations measured in breathing zone of workers	Mustonen, <i>et al.</i> , 1986
Finnish forestry workers (50/15)	SCE	Not stated	No stated	<p><b>Negative.</b> No significant differences in SCE in samples taken before, during and after pesticide exposure. No difference in SCE between workers and control. Smoking shifted distribution of cells towards higher no. of SCEs.</p>	Blood samples taken before, during and after spraying.	Linnainmaa, 1983

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### Abbreviations

2,4-D	2,4-dichlorophenoxyacetic acid
CA	Chromosome aberrations
GSTT1	Glutathione-S-transferase T1
GSTM1	Glutathione-S-transferase M1
H <sub>2</sub> O <sub>2</sub>	Hydrogen peroxide
MCPA	4-chloro-2-methylphenoxyacetic acid
MN	Micronuclei
NAT2	N-acetyltransferase 2
SCE	Sister chromatid exchange

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