Scand J Work Environ Health 2011;37(3):227-236

<https://doi.org/10.5271/sjweh.3133>

Published online: 19 Nov 2010, Issue date: May 2011

Spontaneous miscarriages and infant deaths among female farmers in rural South Africa

by [Naidoo S](#), [London L](#), [Burdorf A](#), [Naidoo R](#), [Kromhout H](#)

Affiliation: Department of Occupational and Environmental Health, Nelson R Mandela School of Medicine, University of KwaZulu-Natal, Private Bag 7 Congella, 4013, South Africa. naidoos71@ukzn.ac.za

The following article refers to this text: [2013;39\(4\):325-334](#)

Key terms: [agriculture](#); [female farmer](#); [infant death](#); [miscarriage](#); [pesticide](#); [South Africa](#); [spontaneous miscarriage](#); [women](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/21088808

This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Spontaneous miscarriages and infant deaths among female farmers in rural South Africa

by Saloshni Naidoo, MBChB,¹ Leslie London, MD,² Alex Burdorf, PhD,³ Rajen Naidoo, PhD,¹ Hans Kromhout, PhD⁴

Naidoo S, London L, Burdorf A, Naidoo R, Kromhout H. Spontaneous miscarriages and infant deaths among female farmers in rural South Africa. *Scand J Work Environ Health*. 2011;37(3):227–236. doi:10.5271/sjweh.3133

Objectives This study examined associations of demographics and occupational factors with spontaneous miscarriages and infant deaths among women working in agriculture in KwaZulu-Natal, South Africa.

Method This cross-sectional study in 2006 described and compared reproductive outcomes among 911 women working in agriculture in two distinct areas (ie, the irrigation scheme and drylands) of the Makhathini Flats, KwaZulu-Natal, South Africa. Associations between demographics, agricultural activities, physical load, pesticide spraying and self-reported “spontaneous miscarriage” and “infant death” (death in the first year) were explored using univariate and multivariate analyses.

Results Women (N=887) reported 4796 pregnancies, 322 spontaneous miscarriages, 137 infant deaths. Adjusting for age, education, and length of recall of pregnancy, spraying pesticides during the first three months of a pregnancy was associated with spontaneous miscarriage [irrigation scheme odds ratio (OR) 2.8, (95% CI) 1.1–7.2; drylands OR 2.5, 95% CI 1.2–5.6]. Irrigation scheme women aged ≥40 years were more likely to report spontaneous miscarriage (OR 3.1, 95% CI 1.2–8.2). Owning one’s farm or working a family farm among irrigation scheme women (OR: 2.3; 95 % CI 1.2–4.4) and working for ≥10 years among drylands women (OR 2.1, 95 % CI 1.1–4.3) were associated with infant death. Weeding was inversely associated with infant death among irrigation scheme women (OR 0.4, 95 % CI 0.2–0.7).

Conclusion This study found that women reporting spontaneous miscarriage were more likely to have sprayed pesticides during pregnancy, and those reporting infant death were more likely to have owned their farms and worked longer in agriculture.

Key terms agriculture; pesticide; women.

Occupational exposures and activities are increasingly linked to adverse reproductive outcomes in working populations (1–8). Occupational exposures associated with adverse reproductive outcomes include increased risks for spontaneous miscarriages among (i) healthcare workers exposed to chemicals including disinfectants, antineoplastic, and anesthetic drugs and (ii) women in industry exposed to heavy metals and solvents (9). Ergonomic exposures (including standing three hours a day, lifting, and heavy physical workload) associated with preterm and low birth weight babies have been reported (10).

In agriculture, chemical and ergonomic exposures represent important hazards for reproductive health, with associations between exposure and delayed fertility among pesticide-applying fruit growers and female greenhouse workers (11, 12). Pesticide exposure among men has been associated with increased sperm abnormalities (13), while studies have reported spontaneous miscarriages among pesticide-exposed women (6, 14). Birth defects have been reported in cases where either men or women were exposed to pesticides (15, 16). Of concern is the estrogen-disruptor effect that pesticides, such as dichlorodiphenyltrichloroethane (DDT), appear

¹ Department of Occupational and Environmental Health, School of Family and Public Health Medicine, Nelson R Mandela, School of Medicine, University of KwaZulu-Natal, Congella, South Africa.

² Centre for Occupational and Environmental Health Research, Department of Public Health, University of Cape Town, Cape Town, South Africa.

³ Department of Public Health, Erasmus MC, University Medical Centre, Rotterdam, the Netherlands.

⁴ Institute for Risk Assessment Sciences, Environmental Epidemiology Division, Utrecht Utrecht University, Utrecht, the Netherlands.

Correspondence to: Dr Saloshni Naidoo, Department of Occupational and Environmental Health, Nelson R Mandela School of Medicine, University of KwaZulu-Natal, Private Bag 7 Congella, 4013, South Africa. [Email: naidoo71@ukzn.ac.za].

to have on humans including sperm, urogenital, and neurodevelopmental effects in the offspring of exposed parents (17–19). Research in South Africa has identified both pesticide and ergonomic exposures as common amongst women workers (20, 21).

Limited data exists about reproductive outcomes due to occupational and environmental exposures among rural working women in developing countries. Studies in these communities focused largely on occupational exposure to pesticides and related neurological effects (22–25). However a study of Eastern Cape women found that women exposed to pesticides (by working in gardens and fields or using pesticide containers for carrying domestic water) were six times more likely to have a baby born with a birth defect than unexposed women (26).

As part of a larger study examining the occupational health of agricultural working women (20, 21), this study examined the association of demographics and occupational factors with spontaneous miscarriages and infant deaths among women working in small-scale agriculture in KwaZulu-Natal (KZN) South Africa.

Methods

In 2006, we conducted an interview survey of women involved in small-scale farming on the Makhatini Flats, northern KZN, South Africa.

Study participants

Details of the study area, population, recruitment of study participants, and the data collection procedure have been reported previously (20, 21). The Makhatini Flats is a small-scale agriculturally intensive area that consists of farms on an artificial irrigation scheme (N=276; 1–10 hectares) and a drylands area (N=1200; 1–5 hectares) with all farmers involved in mixed cropping. Farmers on the irrigation scheme have enjoyed considerably more government support and resources than those on the drylands (27, 28). An estimated 2–3 women work per farm, with approximately 4400 women working in agriculture on the Makhatini Flats.

Prior to the survey, farmer unions and the community were informed about the study via workshops. Meeting points regularly used by the farmers were identified and 13 were randomly chosen as sites at which the survey would be held on different days over a 3-month period; sites were visited more than once. Women ≥ 18 years were directly invited and, through farmer unions, voluntarily participated in the interviews. A total of 913 women volunteered to participate in the study, representing approximately 20% of the estimated number of women working in agriculture on the Makhatini Flats (20).

Data collection

Researchers developed a questionnaire of open- and closed-ended questions covering demographics, crop production, agricultural activities, pesticide use and safety, and health outcomes (20). Exposure and health outcome information were collected during a single contact session, with exposure information being collected prior to information on pregnancy outcomes. Women reported on their agricultural activities and experience of physical load. There were questions on physical work load (carrying loads >5 kg), standing for long periods of time, walking long distances, squatting/kneeling, working in awkward postures, and slipping or falling during transport of loads. Workers rated their frequency of performing the activities above on a 4-point scale (1=seldom or never, 4=always) (29). Responses to questions on physical load provided a total score for each participant, which was dichotomized across the median identifying a summary measure of “low” exposure to physical risk as less than the median, while a score equivalent to or more than the median was categorized as having experienced “high” exposure to the physical load.

Women rated their perceived level of physical exertion at work on a scale (ranging from 1=no exertion at all to 9=maximal exertion). Scoring ≥ 6 was categorized as perceived “high exertion”.

Health status was rated on a scale of 1–5 (1=excellent and 5=poor) (30, 31). Ratings of 1–3 were categorized as “being in good health” while ratings of 4–5 were categorized as “being in poor health”.

Women responsible for spraying pesticides (women who sprayed at least ≥ 1 in the past year were categorized as “sprayers”), reported the frequency of reading pesticide label information, sources of pesticide information, and safety practices during pesticide mixing, spraying, and storage.

Women answering “yes” to spraying pesticides during the first three months of their pregnancy were questioned about spraying frequency during the reported pregnancy. Questions on pesticide spraying were asked after women responded to questions on pregnancy outcome. The data on spraying frequency was poorly reported and therefore not used in the analysis.

Women reported on gravidity, pregnancy histories with respect to year of pregnancy, pregnancy outcome, and gender of living and deceased offspring. Spontaneous miscarriages were defined as pregnancy loss at <28 weeks of gestation; deaths in the first year after birth were classified as infant deaths.

The questionnaire was translated into isiZulu, back-translated to ensure correctness of translation, and administered by trained field workers. All women present on the day of data collection were given information

on the study and signed or thumb-printed their informed consent. The University of KZN's Biomedical Research Ethics Committee approved the study (ethics number: E035/05).

Statistical analysis

The data were coded and captured in EpiData (EpiData Association, Odense, Denmark) and analyzed using STATA version 10 (StataCorp LP, College Station, TX, USA). Owing to poor recollection among women, we could not easily categorize perinatal deaths and had to consider all reported deaths. Means and ranges were calculated for continuous data; frequencies were established for categorical data. The independent samples Student's t-test and chi square were used to test for significant differences of outcomes for continuous and categorical variables. Exposure variables, collected for each study subject, included: (i) farm ownership; (ii) length of employment in agriculture; (iii) physical factors (level of exposure to physical load and perceived physical effort); (iv) reported agricultural activities; (v) pesticide spraying history (ever having sprayed pesticides, being the primary pesticide applicator, sprayed pesticides during the first three months of the pregnancy); and (vi) perceived health status.

Acknowledging the correlated nature of the multiple events reported by a single study subject, we used generalized linear mixed models with two dependent variables, comparing mothers who had a spontaneous miscarriage to those without and mothers with a dead child in the first year to mothers with infant death. We used the general linear latent and mixed models (GLLAMM) command in STATA for this analysis including independent variables which were significant in the univariate analyses. Age at the time of the pregnancy (<40 years versus ≥ 40 years) and education (<4 years versus ≥ 4 years of education) were controlled for in the models. The variable "sprayed pesticides during this pregnancy" was included even if no statistically significant effect was seen on univariate analysis to see the effect of this exposure variable in the GLLAMM models. A variable "length of recall" was created, describing the decade of each pregnancy, and included in the models.

Using principal component analysis of the sprayers' responses to questions on the frequency of reading labels, nature of their sources of pesticide information, and safety practices during pesticide mixing, spraying, and storage, three principal components described safety behavior (ie, frequency of reading pesticide labels, frequency of using personal protective equipment, and multiple sources of pesticide safety information). Of the 913 women who participated, two interviews were unusable. The level of statistical significance was set at 0.05 ($\alpha=0.05$).

Results

Demographics

A total of 911 women reported on their reproductive outcomes, 887 of whom were parous. Parous women from the irrigation scheme travelled a longer distance to their farms compared to their drylands counterparts, while the latter had lived and worked in agriculture for a longer period on the Makhatini Flats compared to their irrigation scheme counterparts (table 1).

Reported reproductive outcomes

Parous women reported a total of 4796 pregnancies. Twenty seven women reported multiple pregnancies, of which two had triplets. There were 3839 currently living children, 226 women reported 322 spontaneous miscarriages, 23 women reported 26 stillbirths and 356 reported 638 deaths. Of these 638 deaths, 137 (21.5%) were infant deaths and 20 (14.6%) women reported a previous infant death (figure 1). Among the women for whom the age of first pregnancy was available ($N=657$), the mean age was 19.3 years (range 10–41 years) with no significant differences between irrigation scheme and drylands women. The majority of women ($N=381$, 58.0%) had their first pregnancy aged ≤ 19 years, while only 2.7% of women ($N=18$) reported having their first pregnancy at >30 years. The proportion of spontaneous miscarriages was 6.7% among women from both areas, while the proportion of infant deaths was 3.9% and 2.5% among women from the irrigation scheme and drylands, respectively. No statistically significant differences between women from the two study areas with respect to the mean number of spontaneous miscarriages and infant deaths were reported.

Agricultural activities, physical risks, safety factors

Drylands women were significantly more involved in agricultural activities compared to their irrigation scheme counterparts; irrigation scheme women experienced significantly higher physical load compared to drylands women. Prevalence of safety factors among sprayers was 49.9% ($N=203$, frequency of reading pesticide labels), 50.0% ($N=204$, use of personal protective equipment) and 60.8% ($N=248$, multiple sources of pesticide information). Irrigation scheme sprayers reported a significantly higher frequency of reading pesticide labels compared to drylands sprayers (table 2).

Spontaneous miscarriages and infant deaths

Several associations identified on bivariate analysis (table 3) remained significant in GLLAMM models after adjusting for confounders (table 4). There was

Table 1. Demographic profile of parous agricultural workers on the Makhatini Flats by location (N=887).

	Irrigation scheme			Drylands		
	N	Mean	Range	N	Mean	Range
Age (years)	357	41.2	18–82	504	42.9	18–80
Education (years)	221	7.1	1–12	270	6.5	1–12
Number of years resident on the Makhatini Flats	346	18.9	1–76	482	28.0	1–80
Distance residing away from plot (kilometers)	334	13.5	0.2–60	442	9.5	0.2–40
Length of employment in agriculture (years)	284	7.1	1–50	281	8.2	1–40

Figure 1. Reproductive outcomes among women agricultural workers on the Makhatini flats, N = 911

no association between physical load and spontaneous miscarriages and infant deaths on univariate analysis (table 3). Using multiple categories for physical load and perceived health status did not result in different findings (results not shown).

Adjusting for age, education, and length of recall of pregnancy, spraying pesticides during the first three months of a pregnancy was associated with a history of a spontaneous miscarriage among all women from both areas and sprayers from the drylands area [odds ratio (OR) 2.6, 95% confidence interval (95% CI) 1.1–6.4]. Women on the irrigation scheme who had children when aged ≥ 40 were more likely to report a spontaneous miscarriage (OR 3.1, 95% CI 1.2–8.2). Owning one's farm or working on a family farm was associated with reporting an infant death among irrigation scheme women (OR 2.3, 95% CI 1.2–4.4). Working for ≥ 10 years was associated with reporting an infant death among drylands women (OR 2.1, 95% CI 1.1–4.3). Weeding was inversely associated with reporting an infant death among irrigation scheme women (OR 0.4, 95% CI 0.2–0.7). There was no clear association between safety factors and pregnancy outcome. The length of recall of a pregnancy did not influence the associations identified between pesticide exposure and a history of a spontaneous miscarriage.

Discussion

In comparison to other studies, our study investigated the association of pesticide exposure and spontaneous miscarriages and infant deaths among women working in small-scale agriculture thus contributing valuable information to the existing literature (7, 32–35). The data in this study was dependent on self-reported reproductive histories thus potentially subject to information bias. Women reported on exposures and health outcomes during a single contact session that could have resulted in an over-reporting of exposures and health outcomes. The prevalence of infant deaths in this study (3.2%) is similar to that reported for KZN in 2003 (36). However, the prevalence of spontaneous miscarriages (6.7%) is higher than that (0.6%) reported by Rollins et al (37) studying women attending KZN antenatal clinics but lower than that of European studies (8, 34), which would suggest underreporting of miscarriages among our study population. The finding of this study nevertheless provides valuable insights into spontaneous miscarriages and infant deaths in a neglected population.

An important finding was that spraying pesticides during the first three months of a pregnancy was significantly associated with having a spontaneous miscarriage

Table 2. Prevalence of self-reported agricultural activities, physical risk factors, perceived health status, safety factors among parous agricultural workers on the Makhatini Flats, by location (N=887).

Agricultural workers		Irrigation scheme		Drylands		P-value ^a
		N	%	N	%	
All women		363		524		
Agricultural activities (ever involved)	Ploughing	150	41.3	428	81.7	0.000
	Planting	291	80.2	499	95.2	0.000
	Manual Irrigation	68	18.7	178	34.0	0.000
	Weeding	334	92.0	503	96.0	0.017
	Harvesting	287	79.1	475	90.6	0.000
Physical risk factors	High level of exposure to physical load	226	62.3	265	50.6	0.001
	Perceived high exertion during work	249	68.6	385	73.5	0.130
Health status	Perceived to be in good health	68	18.7	92	17.6	0.658
Pesticide exposure	Ever sprayed pesticides	195	53.7	366	69.8	0.000
	Being the primary pesticide applicator	133	36.6	275	52.5	0.000
Sprayers		133		275		
Agricultural activities (ever involved)	Ploughing	68	51.1	235	85.5	0.000
	Planting	126	94.7	271	98.5	0.045
	Manual Irrigation	30	22.6	95	34.5	0.016
	Weeding	127	95.5	268	97.5	0.367
	Harvesting	117	88.0	263	95.6	0.006
Physical risk factors	High level of exposure to physical load	88	66.2	152	55.3	0.041
	Perceived high exertion during work	95	71.4	203	73.8	0.635
Health status	Perceived to be in good health	18	13.4	51	18.5	0.260
Safety factors	High frequency of reading pesticide labels	79	59.4	124	45.1	0.008
	Frequent use of personal protective equipment	72	54.1	132	48.0	0.291
	Use multiple sources of pesticide information	87	65.4	161	58.5	0.110

^a Chi square (2-sided)

among women from both areas. In a sub-group analysis of women primarily responsible for spraying pesticides, this association remained among drylands women. The estimate was also increased, 3.8 (95% CI 0.9–16.0) among irrigation scheme women although not statistically significant. Our finding is supported by findings of the Ontario farm family health study (32) that showed an increase in spontaneous miscarriages with post-conception exposure to glyphosate and thiocarbamates. The association seen among drylands sprayers may be due to the overall increased exposure of this subgroup since significantly more women on the drylands sprayed than on the irrigation scheme.

Older women on the irrigation scheme were more likely to report spontaneous miscarriages, a finding in keeping with the literature (38). Educated women on the irrigation scheme were less likely to report having had an infant death; research has shown that educated women are more likely to access maternal health services (39), which may be the case with the better-educated irrigation scheme women.

In our study, owning one's farm or working on a family-owned farm on the irrigation scheme was associated with reporting an infant death. This association can be interpreted in two ways. Firstly, rural female-headed households operate under tremendous financial constraints (40) and women who own their farms on the irrigation scheme may be pressurized to return to

work early as compared to their drylands counterparts to supervise and participate in activities. Further, a woman's activity on family farms has traditionally been seen as assisting the family, and she may inadvertently return to activities early. In other working populations, the early return of mothers to work was associated with adverse health outcomes among their offspring (41). For example, the early return of a mother to work may result in early weaning of infants and introduction to formula feeds. In a rural community, such as those on the Makhatini Flats where there have been cholera outbreaks (42), limited access to clean potable water increases the risk for diarrhoeal diseases and infant deaths. It is not uncommon practice for rural women in agriculture to take their infants into the fields while working (43). This potentially exposes the infant to several hazards including pesticides increasing the risk of death. Secondly, with irrigation scheme farmers receiving more government financial aid (27, 28), women on the irrigation scheme who own their farms may be financially better off and thus have better access to healthcare and, as a result, be more likely to report infant deaths.

Chronic poverty exists among individuals involved in agriculture (44). In KZN, the majority of rural households are poor (45). Thus employment in small-scale agriculture may be seen as a proxy measure of poverty. Our study found that working in small-scale agriculture for >10 years was associated with a history of infant

Table 3. Crude odds ratios (OR) of demographics, agricultural activities, physical risk factors and perceived health status with reproductive health outcomes among parous agricultural workers on the Makhatini Flats, by location. [95% CI=95% confidence interval]

	Spontaneous miscarriage								Infant death							
	Irrigation scheme				Drylands				Irrigation scheme				Drylands			
	N	%	OR	95% CI	N	%	OR	95% CI	N	%	OR	95% CI	N	%	OR	95% CI
All women ^a	127	39.4			195	60.6			68	49.6			69	50.4		
Demographic factors																
Age (≥ 40 years)	9	7.1	2.9	1.4–6.0	4	2.1	0.9	0.3–2.4	2	2.9	0.7	0.2–2.6	4	5.8	1.5	0.6–4.2
Education (>4 years of school attendance)	44	34.7	0.8	0.6–1.1	67	34.4	1.0	0.8–1.4	25	37.0	0.9	0.5–1.4	38	55.1	2.5	1.6–4.0
Farm ownership	85	67.0	1.1	0.8–1.6	182	93.3	1.0	0.5–1.7	55	81.0	2.3	1.3–4.3	65	94.2	1.1	0.4–2.9
Length of employment in agriculture (>10 years)	33	26.0	1.2	0.8–1.9	40	20.5	1.4	0.9–2.0	19	27.9	1.2	0.7–2.2	20	28.9	2.2	1.2–4.1
Number of years resident on the Makhatini Flats (>10 years)	91	71.7	1.1	0.7–1.8	157	80.5	1.7	1.0–2.8	43	63.2	0.6	0.4–1.0	60	86.9	2.4	0.9–6.4
Distance residing away from plot (>10 kilometers)	81	63.8	1.3	0.9–1.9	86	44.1	1.0	0.8–1.4	34	50.0	0.6	0.4–1.0	29	42	1.1	0.6–1.9
Physical factors																
Level of exposure to physical load (high)	66	52.0	0.9	0.7–1.3	90	46.2	0.9	0.7–1.2	35	51.0	0.9	0.6–1.5	34	49.3	1.0	0.6–1.6
Perceived high exertion during work	99	78.0	1.5	1.0–2.2	153	78.5	1.1	0.8–1.6	62	91.2	1.9	0.8–4.4	62	89.9	1.1	0.5–2.4
Agricultural activities (ever involved: yes)																
Ploughing	66	52.0	1.3	0.9–1.9	150	76.9	0.8	0.5–1.1	30	44.1	1.0	0.6–1.6	59	85.5	1.3	0.7–2.6
Planting	106	83.5	1.1	0.7–1.8	188	96.4	1.3	0.6–2.7	55	80.9	0.9	0.5–1.7	64	92.8	0.6	0.2–1.4
Weeding	115	90.6	0.8	0.4–1.4	188	96.4	0.9	0.5–2.1	54	79.4	0.3	0.2–0.5	65	94.2	0.6	0.2–1.6
Harvesting	103	81.1	1.0	0.7–1.6	177	90.8	1.1	0.6–1.7	57	83.8	1.2	0.7–2.4	67	97.1	3.6	0.9–14.6
Manual irrigation	25	19.7	1.1	0.7–1.7	59	30.3	0.9	0.6–1.2	12	17.6	0.9	0.5–1.8	22	31.9	0.9	0.6–1.5
Ever having sprayed pesticides	81	63.8	1.4	1.0–2.0	139	71.3	1.1	0.8–1.5	42	61.8	1.3	0.8–2.1	51	73.9	1.3	0.7–2.2
Being the primary pesticide applicator	53	41.7	1.1	0.8–1.6	95	48.7	0.9	0.7–1.2	35	51.0	1.7	1.0–2.7	42	60.9	1.5	0.9–2.4
Sprayed pesticides in 1st 3 months of this pregnancy	12	9.5	2.0	1.1–3.7	17	8.7	1.4	0.8–2.3	2	2.9	0.6	0.1–2.3	4	5.8	0.9	0.3–2.4
Health																
Perceived to be in good health	10	7.9	0.5	0.3–1.0	12	6.2	0.4	0.2–0.7	13	19.1	1.4	0.8–2.7	8	11.6	0.8	0.4–1.6
Sprayers ^b	53	35.8			95	64.2			35	45.5			42	54.5		
Demographic factors																
Age (≥ 40 years)	3	5.7	2.4	0.7–8.2	2	2.1	1.1	0.3–4.3	2	5.7	1.9	0.7–7.3	2	4.8	1.6	0.4–6.3
Education (>4 years of school attendance)	22	42.0	0.8	0.5–1.5	34	35.8	1.0	0.6–1.5	11	31.4	0.5	0.3–1.1	24	57.1	2.4	1.3–4.5
Farm ownership (yes)	40	75.5	0.6	0.3–1.2	92	96.8	0.7	0.2–2.3	31	88.6	1.6	0.6–4.4	42	100.0	.	.
Length of employment in agriculture (>10 years)	20	37.7	1.5	0.8–2.7	21	22.1	1.2	0.7–2.1	16	45.7	2.3	1.1–4.8	15	35.7	2.5	1.2–5.1
Number of years resident on the Makhatini Flats (>10 years)	44	83.0	1.6	0.7–3.4	83	87.4	2.7	1.0–7.3	24	68.6	0.7	0.3–1.4	38	90.5	1.7	0.5–5.2
Distance residing away from plot (>10 kilometers)	36	67.9	1.4	0.7–2.6	44	46.3	1.1	0.7–1.7	15	42.9	0.5	0.2–1.0	18	42.9	1.1	0.6–2.2
Physical factors																
Level of exposure to physical load (high)	30	56.6	1.0	0.5–1.7	48	50.5	0.8	0.5–1.1	21	60.0	1.1	0.6–2.2	26	61.9	1.1	0.7–2.3
Perceived high exertion during work	40	75.5	1.2	0.6–2.3	79	83.2	1.6	0.9–2.7	31	88.6	1.4	0.5–3.8	38	90.5	1.1	0.4–3.0
Agricultural activities (ever involved: yes)																
Ploughing	31	58.5	1.2	0.7–2.2	81	85.3	0.9	0.5–1.6	20	57.1	1.2	0.6–2.3	35	83.3	0.8	0.3–1.7
Planting	47	88.7	0.5	0.2–1.2	94	98.9	1.6	0.2–11.0	33	94.3	1.0	0.3–4.2	41	97.6	0.7	0.1–5.0

(continued)

Table 3. (continued)

	Spontaneous miscarriage								Infant death							
	Irrigation scheme				Drylands				Irrigation scheme				Drylands			
	N	%	OR	95% CI	N	%	OR	95% CI	N	%	OR	95% CI	N	%	OR	95% CI
Agricultural activities (ever involved: yes)																
Manual irrigation	10	18.9	0.8	0.4–1.5	31	32.6	0.9	0.6–1.4	7	20.0	0.8	0.4–1.8	14	33.3	0.9	0.5–1.8
Sprayed pesticides in 1 st 3 months of this pregnancy	5	9.4	1.5	0.6–3.7	14	14.7	1.6	0.9–2.9	1	2.9	0.4	0.1–2.9	4	9.5	1.3	0.4–2.7
Health																
Perceived to be in good health	1	1.9	0.2	0.02–1.2	8	8.4	0.5	0.2–0.9	4	11.4	1.0	0.4–2.8	5	11.9	0.7	0.3–1.7
Safety factors																
High frequency of reading pesticide labels	25	47.2	0.7	0.4–1.3	42	44.2	1.1	0.7–1.6	18	51.4	0.9	0.4–1.7	27	64.3	2.3	1.2–4.7
Frequent use of personal protective equipment	31	58.5	1.2	0.7–2.0	48	50.5	1.1	0.7–1.7	22	62.9	1.4	0.7–2.8	20	47.6	1.0	0.5–1.8
Uses multiple sources of pesticide information	35	66.0	1.0	0.5–1.7	59	62.1	1.1	0.7–1.6	25	71.4	1.2	0.6–2.6	26	61.9	1.1	0.6–2.0

^a All women: spontaneous miscarriage (N=322); infant deaths (N=137).

^b Sprayers spontaneous miscarriage (N=148); infant deaths (N=77).

death among drylands women. As previously indicated, drylands farmers have received less government financial support (27, 28) as compared to irrigation scheme farmers and, in the presence of poverty, drylands families may have been unable to provide sufficient nutrition for young infants, resulting in increased deaths.

Although participating in most agriculture activities can lead to pesticide exposure, in our study, being involved in crop weeding was inversely associated with infant deaths among irrigation scheme women. Fewer women on the irrigation scheme reported pesticide spraying, and manually weeding the fields may have required less herbicide use. In addition, irrigation scheme women may have actively avoided spraying postnatally and were more involved in weeding, or women involved in weeding may have spent shorter periods at work and did not bring their newborns to the farm, reducing the infant's risk of pesticide exposure and potential death.

No significant associations between high exertion during work and spontaneous miscarriages and infant deaths were found, although generally the estimates were in the expected direction. In addition, there was no association between physical load and spontaneous miscarriages. These findings may be a result of women reporting on current physical load. However the majority of women have only worked in agriculture and agricultural production methods in small-scale agriculture have hardly changed over time. Thus current responses on physical load probably resemble that at the time of their pregnancy.

Estimates for safety factors <1 were expected since safety factors reflected positive behavior in the women towards measures to reduce potential exposure to pes-

ticides. However, no clear association was found and this may reflect a misclassification of exposure as well as inadequate use of protective equipment.

Most women were recalling events that had occurred approximately two decades ago. This long interval between the interview and the event may have reduced the accuracy of information on pesticide exposure during the pregnancy and reproductive outcome. We attempted to control for this bias by including a variable on length of recall for each pregnancy in the GLLAMM models. Women reporting spontaneous miscarriage may have overemphasized pesticide spraying activities in the first three months of their pregnancies as compared to women not reporting spontaneous miscarriages, possibly inflating the measures of association. Unfortunately, in small-scale agriculture, where records of spray schedules are non-existent, one is unable to verify externally the information provided by the study participants. In asking about pesticide application after a woman's response to the question on pregnancy outcome, the extent of the reporting bias may have been reduced.

We have reported on the failure to practice appropriate safe re-entry times following pesticide spraying in this study population (46). Women who reported never having actively sprayed pesticides will have been exposed during re-entry work. In addition, women may have been exposed because some of them applied pesticides despite not being the primary sprayer. Alternatively, women who reported being the primary sprayer may not have been the primary sprayer at the time of their pregnancies resulting in a misclassification of their exposure. These may be reasons for the absence of sig-

Table 4a. Adjusted odds ratios (OR) of demographics, agricultural activities, physical risk factors and perceived health status with reproductive health outcomes among parous agricultural female workers on the Makhatini Flats, by location. [95% CI=95% confidence interval]

All women	Reproductive outcomes ^a							
	Spontaneous miscarriages (N=322)				Infant death (N=137)			
	Irrigation scheme ^b (N=127)		Drylands ^b (N=195)		Irrigation scheme ^c (N=68)		Drylands ^d (N=69)	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Demographics								
Age (≥40 years)	3.1	1.2–8.2	1.0	0.3–3.0	0.4	0.1–2.0	1.3	0.3–5.9
Education (>4 years of school attendance)	1.2	0.6–2.4	1.4	0.8–2.2	0.5	0.3–0.8	1.6	0.8–3.1
Length of recall of pregnancy (≥10 years)	1.2	0.6–2.2	1.2	0.7–2.0	0.8	0.5–1.5	1.4	0.6–3.0
Farm ownership	.	..	.	..	2.3	1.2–4.4	.	..
Length of employment in agriculture (>10 years)	.	..	.	..	.	..	2.1	1.1–4.3
Agricultural activities (ever involved: yes)								
Weeding	.	..	.	..	0.4	0.2–0.7	.	..
Sprayed pesticides in 1 st 3 months of this pregnancy	2.8	1.1–7.2	2.5	1.2–5.6	0.4	0.1–1.8	1.1	0.4–3.4
Health								
Perceived to be in good health	0.5	0.2–1.4	0.5	0.2–1.0	.	..	.	..

^a All models included variables: age at pregnancy (≥40 years), being educated or not, and length of recall of pregnancy (≥10 years), sprayed pesticides in the 1st three months of this spontaneous miscarriage / infant death.

^b Model included: perceived to be in good health.

^c Model included: owned ones own farm, involved in weeding.

^d Model included: employed in agriculture for >10 years.

Table 4b. Adjusted odds ratios (OR) of demographics, agricultural activities, physical risk factors and perceived health status with reproductive health outcomes among parous agricultural sprayers on the Makhatini Flats, by location. [95% CI=95% confidence interval.]

Sprayers	Reproductive outcomes ^a							
	Spontaneous miscarriage (N= 148)				Infant death (N= 77)			
	Irrigation scheme ^b (N=53)		Drylands ^c (N=95)		Irrigation scheme ^d (N=35)		Drylands ^e (N=42)	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Demographics								
Age (≥40 years)	3.5	0.7–18.0	1.3	0.3–6.0	2.3	0.4–12.7	0.9	0.1–7.4
Education (>4 years of school attendance)	1.2	0.4–3.4	1.2	0.6–2.3	0.4	0.2–1.0	1.9	0.8–4.6
Length of recall of pregnancy (10 years +)	1.1	0.5–2.8	1.3	0.6–2.5	1.3	0.5–3.6	1.4	0.5–3.7
Length of Employment in Agriculture (>10 years)					1.3	0.5–3.0	2.4	1.0–6.0
Agricultural Activities (ever involved: yes)								
Weeding	0.2	0.04–1.2	.	..	0.4	0.1–1.1	.	..
Sprayed pesticides in 1 st 3 months of this pregnancy	3.8	0.9–16.0	2.6	1.1–6.4	0.9	0.1–6.9	1.0	0.3–3.3
Health								
Perceived to be in good health	.	..	0.6	0.3–1.5	.	..	.	..
Safety Factors								
High frequency of reading pesticide labels	0.6	0.2–1.7	1.1	0.5–2.1	0.7	0.3–1.5	1.4	0.6–3.4
Frequent use of personal protective Equipment	1.8	0.6–5.5	1.3	0.6–2.5	1.6	0.7–3.9	1.2	0.5–2.9
Uses multiple sources of pesticide information	1.0	0.3–3.3	1.0	0.5–1.9	1.4	0.5–3.8	1.1	0.4–2.6

^a All models included variables: age at pregnancy (≥40 years), being educated or not, and length of recall of pregnancy (≥10 years), sprayed pesticides in the 1st three months of this spontaneous miscarriage / infant death, high frequency of reading pesticide labels, frequent use of personal protective equipment, uses of multiple sources of pesticide safety information.

^b Model included: involved in weeding.

^c Model included: perceived to be in good health.

^d Model included: employed in agriculture for >10 years, involved in weeding.

^e Model included: employed in agriculture for >10 years.

nificant differences between the groups of women with respect to reproductive outcomes.

Owing to poor recollection of the types of pesticides used by our participants (20), we were unable to test for associations between types of pesticides and having a spontaneous miscarriage as reported in the literature in other study populations (32). This is a matter requiring further investigation since such information can be used

as a basis for protective interventions. Poor recollection of pesticides' names prevented differentiation between the different classes of hazardous pesticides used by the majority of women.

Dependent on participant's historical recall, we had difficulty separating perinatal from other infant deaths. A death several months after a delivery may be totally unrelated to agricultural activities. In using infant as

opposed to perinatal deaths as an adverse reproductive health outcome, we may have attenuated the associations that we found.

Despite the limitations mentioned above, key findings of this study, supported by similar findings in the literature, provide added evidence that women in rural agriculture are at increased risk for adverse spontaneous miscarriages and infant deaths. Associations between spraying in the first three months of pregnancy and a history of spontaneous miscarriages, employment duration, farm ownership, and reporting an infant death are important findings that may inform reproductive and occupational health interventions in similar populations in South Africa and other developing countries.

Acknowledgements

Our sincere thanks to Dr Lutzen Portengen (Institute for Risk Assessment Sciences, Environmental Epidemiology Division, Utrecht University, Utrecht, Netherlands), for his statistical advice during the data analysis for this paper. This work was supported by the South African Netherlands Research Program on Alternatives in Development (SANPAD) and the South African Medical Research Council (SA MRC) – grant number 04/15. The authors have no direct interests in the funding organizations and, to the best of their knowledge, the study is unlikely to benefit any organization financially.

References

- Ahmed P and Jaakola JJ. Maternal occupational and adverse pregnancy outcomes: a Finnish population-based study. *Occup Med.* 2007;57(6):417–423. doi:10.1093/occmed/kqm038
- Croteau A, Marcoux S, Brisson C. Work activity in pregnancy, preventive measures, and the risk of preterm delivery. *Am J Epidemiol.* 2007;166(8):951–965. doi:10.1093/aje/kwm171.
- Figa-Talamanca I. Reproductive problems among women health care workers: epidemiologic evidence and preventive strategies. *Epidemiologic Rev.* 2000;22(2):249–260.
- Fransman W, Roeleveld N, Peelen S, de Kort W, Kromhout H, Heederik D. Nurses with dermal exposure to antineoplastic drugs: reproductive outcomes. *Epidemiology.* 2007;18(1):112–119. doi:10.1097/01.ede.0000246827.44093.c1.
- Garlanteczec R, Monfort C, Rouget F, Cordier S. Maternal occupational exposure to solvents and congenital malformations: a prospective study in the general population. *Occup Environ Med.* 2009;66(7):456–463. doi:10.1136/oem.2008.041772
- Garry VF, Harkins M, Lyubimov A, Erickson L, Long L. Reproductive outcomes in the women of the Red River Valley of the north. I. The spouses of pesticide applicators: pregnancy loss, age at menarche, and exposures to pesticides. *J Toxicol Environ Health A.* 2002 Jun 14;65(11):769–786. doi:10.1080/00984100290071333.
- Hooiveld M, Haveman W, Roskes K, Bretveld R, Burstyn I, Roeleveld N. Adverse reproductive outcomes among male painters with occupational exposure to organic solvents. *Occup Environ Med.* 2006;63(8):538–544. doi:10.1136/oem.2005.026013.
- Lauria L, Ballard TJ, Caldora M, Mazzanti C, Verdecchia A. Reproductive disorders and pregnancy outcomes among female flight attendants. *Aviat Space Environ Med.* 2006 May; 77(5):533–539.
- Figa-Talamanca I. Occupational risk factors and reproductive health of women. *Occup Med.* 2006;56(8):521–531. doi:10.1093/occmed/kql114.
- Bonzini M, Coggon D, Palmer KT. Risk of prematurity, low birthweight and pre-eclampsia in relation to working hours and physical activities: a systematic review. *Occup Environ Med.* 2007;64(4):228–243.
- de Cock J, Westveer K, Heederik D, te Velde E, van Kooij R. Time to pregnancy and occupational exposure to pesticides in fruit growers in The Netherlands. *Occup Environ Med.* 1994;51(10):693–699. doi:10.1136/oem.51.10.693.
- Lauria L, Settimi L, Spinelli A, Figa-Talamanca I. Exposure to pesticides and time to pregnancy among female greenhouse workers. *Reproductive Toxicol.* 2006 Oct;22(3):425–430. doi:10.1016/j.reprotox.2005.12.011.
- Meeker JD, Barr DB, Hauser R. Human semen quality and sperm DNA damage in relation to urinary metabolites of pyrethroid insecticides. *Hum Reprod.* 2008;23(8):1932–1940. doi:10.1093/humrep/den242.
- Idrovo AJ, Sanin LH. Adverse reproductive outcomes among women working in Colombian floriculture: a summary of the evidence through metaanalysis. *Biomedica.* 2007;27(4):490–497.
- Garry VF, Harkins ME, Erickson LL, Long-Simpson LK, Holland SE, Burroughs BL. Birth defects, season of conception, and sex of children born to pesticide applicators living in the Red River Valley of Minnesota, USA. *Environ Health Perspect.* 2002 Jun;110 Suppl 3:441–449.
- Thulstrup AM, Bonde JP. Maternal occupational exposure and risk of specific birth defects. *Occup Med.* 2006;56(8):532–543. doi:10.1093/occmed/kql115.
- Aneck-Hahn NH, Schulenburg GW, Bornman MS, Farias P, de Jager C. Impaired semen quality associated with environmental DDT exposure in young men living in a malaria area in the Limpopo Province, South Africa. *J Androl.* 2007;28(3):423–434.
- Bornman R, de Jager C, Worku Z, Farias P, Reif S. DDT and urogenital malformations in newborn boys in a malarial area. *BJU Int.* 2010 Aug, 106(3):405–11. doi:10.1111/j.1464-410X.2009.09003.x.
- Eskenazi B, Marks AR, Bradman A, Fenster L, Johnson C, Barr DB, et al. In utero exposure to dichlorodiphenyltrichloroethane (DDT) and dichlorodiphenyldichloroethylene (DDE) and neurodevelopment among young Mexican American children. *Pediatrics.* 2006;118(1):233–241. doi:10.1542/peds.2005-3117.
- Naidoo S, London L, Burdorf A, Naidoo RN, Kromhout H.

- Agricultural activities, pesticide use and occupational hazards among women working in small-scale farming in Northern KwaZulu-Natal, South Africa. *Int J Occup Environ Health*. 2008;14(3):218–224.
21. Naidoo S, Kromhout H, London L, Naidoo RN, Burdorf A. Musculoskeletal pain in women working in small-scale agriculture in South Africa. *Am J Ind Med*. 2009;52(3):202–209. doi:10.1002/ajim.20662.
22. Ngowi AV, Maeda DN, Partanen TJ, Sanga MP, Mbise G. 2001. Acute health effects of organophosphorus pesticides on Tanzanian small-scale coffee growers. *J Expo Anal Environ Epidemiol*. 2001;11(4):335–339. doi:10.1038/sj.jea.7500172.
23. Ohayo-Mitoko GJA, Heederik DJJ, Kromhout H, Omondi BEO, Boleij JSM. Acetylcholinesterase Inhibition as an Indicator of Organophosphate and Carbamate Poisoning in Kenyan Agricultural Workers. *Int J Occup Environ Health*. 1997;3(3):210–220.
24. Wesseling C, Hogstedt C, Fernandez P, Ahlbom A. 2001. Time trends of occupational pesticide-related injuries in Costa Rica, 1982–1992. *Int J Occup Environ health*. 2001;7(1):1–6.
25. Wesseling C, Keifer M, Ahlbom A, McConnell R, Moon JD, Rosenstock L, et al. Long-term neurobehavioral effects of mild poisonings with organophosphate and n-methyl carbamate pesticides among banana workers. *Int J Occup Environ Health*. 2002;8(1):27–34.
26. Heeren GA, Tyler J, Mandeya A. Agricultural chemical exposures and birth defects in the Eastern Cape Province, South Africa: a case-control study. *Environ Health*. 2003;2(1):11. doi:10.1186/1476-069X-2-11.
27. Pschorn-Strauss E. Bt cotton in South Africa. The case of the Makhatini Farmers. *Seedling*. 2005;2:13–24.
28. Witt H, Patel R, Schnurr M. Can the Poor Help GM Crops? Technology, representation cotton in the Makhatini flats, South Africa. *Rev Afr Polit Econ*. 2006;33(109):497–513. doi:10.1080/03056240601000945.
29. Elders LA, Burdorf A. Prevalence, incidence, and recurrence of low back pain in scaffolders during a 3-year follow-up study. *Spine (Phila Pa 1976)*. 2004 Mar 15;29(6):E101–6.
30. Miilunpalo S, Vuori I, Oja P, Pasanen M, Urponen H. Self-rated health status as a health measure: the predictive value of self-reported health status on the use of physician services and on mortality in the working-age population. *J Clin Epidemiol*. 1997;50(5):517–528. doi:10.1016/S0895-4356(97)00045-0.
31. Statistics South Africa. [internet] Perceived health and other health indicators in South Africa. Pretoria: Statistics South Africa. 2004 [Available from: <http://www.statssa.gov.za/publications/HealthOHS/HealthOHS1999.pdf>. Accessed on 10 April 2010.]
32. Arbuckle TE, Lin Z, Mery LS. An exploratory analysis of the effect of pesticide exposure on the risk of spontaneous abortion in an Ontario farm population. *Environ Health Perspect*. 2001;109(8):851–857. doi:10.1289/ehp.01109851.
33. Greene LE, Riederer AM, Marcus M, Lkhasuren O. 2010. Associations of fertility and pregnancy outcomes with leather tannery work in Mongolia. *Int J Occup Environ Health*. 2010;16:60–68.
34. Ronda E, Moen BE, Garcia AM, Sanchez-Paya J, Baste V. Pregnancy outcomes in female hairdressers. *Int Arch Occup Environ Health*. Epub 2010 Feb 4. doi:10.1007/s00420-010-0517-3.
35. Bretveld RW, Hooiveld M, Zielhuis GA, Pellegrino A, van Rooij IALM, Roeleveld N. Reproductive disorders among male and female greenhouse workers. *Reproductive Toxicol*. 2008;25:107–114. doi:10.1016/j.reprotox.2007.08.005.
36. Day C, Gray A. Health and Related Indicators. In Barron P and Roma-Reardon J, editors. *South African Health Review*. Durban, South Africa: Health Systems Trust; 2008. p.369–506.
37. Rollins NC, Coovadia HM, Bland RM, Coutoudis A, Bennish ML, Patel D, et al. Pregnancy Outcomes in HIV-Infected and Uninfected Women in Rural and Urban South Africa. *J Acquir Immune Defic Syndr*. 2007;44:321–328. doi:10.1097/QAI.0b013e31802ea4b0.
38. de la Rochebrochard E, Thonneau P. Paternal age and maternal age are risk factors for miscarriage; results of a multicentre European study. *Hum Reprod*. 2002; 17(6):1649–56. doi:10.1093/humrep/17.6.1649.
39. Elo IT. Utilization of maternal health-care services in Peru: the role of women's education. *Health Transit Rev*. 1992;2:49–69.
40. Doss CR. Designing Agricultural Technology for African Women Farmers: Lessons from 25 Years of Experience. *World Development*. 2001; 29(12):2075–2092. doi:10.1016/S0305-750X(01)00088-2.
41. Berger LM, Hill J, Waldfogel J. Maternity Leave, Early Maternal Employment and Child Health and Development in the US. *Economic Journal*. 2005;115(501):F29–F47. doi:10.1111/j.0013-0133.2005.00971.x.
42. Hoque AKM, Worku Z. The cholera epidemic of 2000/2001 in KwaZulu-Natal: implications for health promotion and education. *Health SA Gesondheid*. 2005;10(4):66–74.
43. Vodouhe SD. Livelihoods and Women's Health. Pesticide Action Network. In: Jacobs M, Dinham B, editors. *Silent Invaders: Pesticides*. London, United Kingdom: Zed Books Ltd; 2003. p.69–77.
44. Okidi J and Kempaka G. An overview of chronic poverty and development policy in Uganda. Chronic Poverty Research Centre working paper no 11. University of Manchester: Institute for Development Policy and Management. 2002. [Available from: http://www.dfid.gov.uk/r4d/PDF/Outputs/ChronicPoverty_RC/11OkidiMugambe.pdf. Accessed 5 April 2010].
45. Aliber M. Chronic poverty in South Africa: incidence, causes and policies. *World Development*. 2003;31(3):473–490. doi:10.1016/S0305-750X(02)00219-X.
46. Naidoo S, London L, Rother HA, Burdorf A, Naidoo RN, Kromhout H. Pesticide safety training and practices in women working in small-scale agriculture in South Africa. *Occup Environ Med*. Epub 2010 Jun 24. doi:10.1136/oem.2010.055863.

Received for publication: 24 May 2010