THE EFFECTS OF VOLCANIC ASH FROM PUYEHUE-CAULLE RANGE ERUPTION ON THE SURVIVAL OF *DICHROPLUS VITTIGERUM* (ORTHOPTERA: ACRIDIDAE)

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The eruption of the volcanic complex Puyehue-Caulle Range (PC) in Chile on 4 Jun 2011 dispersed about 100 million metric tons of ash on 7.5 million hectares, mainly in northern Patagonia [Argentina] (Gaitán et al. 2011). The general consequences of this type of event to flora and fauna in the areas affected by volcanic ash is the loss of habitat (Arendt et al. 1999) and population decrease of susceptible insect species due to its insecticidal effect (Shanks & Chase 1981; Akre et al. 1981; Buteler et al. 2011). The chemical analysis of the volcanic ash from PC eruption showed that it is extremely abrasive (Informe UNCO-Neuquén 2011) and predominantly composed of glass shards (SiO_2) and alumina (Al_2O_3) (Buteler et al. 2011; Mogni et al. 2011), two substances with well known insecticidal properties.

Inert dusts such as diatomaceous earth, kaolin, sodium carbonate, calcium carbonate, and volcanic ash are well known for their insecticidal properties (Allen 1972; Shanks & Chase 1981; Golob 1997; Subramanyan & Roesli 2000). The mechanism of action of these insecticides is thought to be related to abrasion and adsorption phenomena of the epicuticular waxes, leading to desiccation of the insects (Kalmus 1944; Wigglesworth 1944; Stadler et al. 2010). The aim of this work was to evaluate the toxicity of volcanic ash from the PC and diatomaceous earth on the grasshopper, *Dichroplus vittigerum* (Blanchard 1851, Orthoptera: Acrididae) an occasional insect pest in northern Patagonia.

A first experiment consisted of exposing adults of *D. vittigerum* (0.25 ± 0.008 g) to fine-grained volcanic ash (collected by Ing. Jacobacci, Río Negro, particle size < 500 µ) or diatomaceous earth (Celite® 503, World Minerals, Celite Corporation), at either a high humidity of 75% RH ± 2 (using a saturated solution of sodium chloride; Winston & Bates 1960), or ambient humidity of 39.57 ± 0.09% RH. Each adult was placed in a plastic dish (7 × 5.5 × 8.5 cm) with 100 mm^2 of fresh leaves of dandelion (*Taraxacum officinale* F. H. Wigg; Asterales: Asteraceae). Treatments consisted of 0.5 g of volcanic ash or diatomaceous earth per container. The treatment dust spread over the surface of the dish, so the grasshoppers had to always contact it, at any point in the dish. Control insects were placed in clean containers. Three insects were used for each treatment and the experiment was replicated 3 times at each humidity level. After 24 h mortality as well as amount of plant material consumed was recorded. Categories established were: 1 for insects that consumed 50% or less of the leaf area, and 2 for insects that consumed more than 50% of the leaf area. Mortality data were analyzed with ANOVA with treatment and humidity as fixed effects and replicate and number of experiment as random effects. Significantly different least square means ($P < 0.05$) were separated by the Tukey adjusted option in SAS (SAS Institute 1998).

A second dry dust application toxicity test was carried out to study the survival time (in days) of adult insects exposed to diatomaceous earth and volcanic ash (both 15 g/m^2). We used a total of 62 adults of *D. vittigerum* (0.26 ± 0.01 g), and in each experiment 5 or 6 individuals were introduced in a 15 × 30 × 8 cm plastic container (Colombraro®) containing either the inert dust treatment plus food or only food (control). A fan (1.65 m.seg^{-1}) was set on the top of the plastic containers to simulate the wind gusts that occur in the region affected by the PC (7 km/h). This fan was turned on 4 times a day for one h. The dust spread over the entire container and the fan simply recirculated the dust within the container. The insects were fed ad libitum on dandelion plants, which were renewed daily. Temperature and humidity were controlled (20.43 °C ± 0.01, 39.57 ± 0.09% RH). Mortality was recorded daily. Data analyses were carried out with Log-Rank, Survival Analysis. Significantly different least square means ($P < 0.05$) were separated by the Tukey test (Sigma Stat).

Exposure to volcanic ash and diatomaceous earth for 24 h (experiment 1) induced mortality in adult grasshoppers ($F = 5.92$; df = 2, 46; $P = 0.005$). There was no significant effect of humidity on mortality ($F = 0$; df = 1, 46; $P = 1$). There was a significant insecticidal effect of the treatments on the amount of food consumed ($F = 5.11$; df = 2, 46; $P = 0.01$). Treated insects maintained at a higher ambient humidity consumed a lower amount of food than control insects and treated insects exposed to lower ambient humidity (experiment 1) (Fig. 1).

Under doses simulating typical conditions after the eruption (15 g/m^2 with simulated wind at 7 km/h), and where food was provided ad libitum, survival was also significantly reduced (experiment 2) (Fig. 2) (Log-Rank test; Statistic 42.04; df = 2; $P < 0.001$; Holm Sidak Test: control vs. diatomaceous earth $P = 0.017$; control vs. volcanic ash $P = 0.025$). Our study demonstrated the toxicity of volcanic ash emitted by the PC to grasshopper adults, as well as a reduction in food consumption in the diatomaceous earth treatment that could suggest deterrence, analogous to other inert powders and nano-insecticides (Stefanazzi et al. 2012). In general, inert dusts are more effective in low humidity environments (Ebeling 1961; Fields & Korunic 2000; Stadler et al. 2011). In this study, mortality under low ambient humidity was similar to that of a higher humidity of 75% RH (experiment 1). It is possible that the grasshoppers were able to obtain enough humidity from the food (fresh leaves) to mask this effect. This is supported by the observation that insects maintained at low humidity environment consumed more food than insects exposed to high humidity environment. These results suggest the onset of the volcanic eruption may have had a negative impact on individual mortality as the pyroclastic material (ashes) was suspended in the air and the fine particles were dispersed by local winds. Further studies are needed to understand the effect of the volcanic ash on the grasshopper populations given that mortality of adults in the field would be affected by a combination of factors like climatic conditions during the initial ash fall, dispersal of the ash by wind, suspended volcanic ash and particle size among others. Moreover, the ash accumulated on the ground may also challenge the first nymphal instar throughout its emergence process from the soil. Further studies should address its insecticidal effect on eggs and nymphs of *D. vittigerum* as well as their effects on behavior.

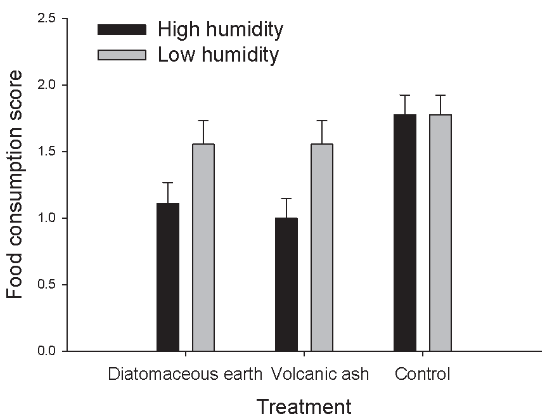

Fig. 1. Food (fresh dandelion leaves) consumption scores of *Dichroplus vittigerum* 220 adults during a 24 h dry dust toxicity bioassay in which each grasshopper was placed in a plastic dish with of 0.5 g of volcanic ash or diatomaceous earth and with 100 mm^2 of fresh leaves of dandelion (*Taraxacum officinale*). Control insects were placed in clean container with food. Each insects that consumed 50% or less of the leaf area received a score of 1, and each insect that consumed more than 50% of the leaf area received a score of 2. Bars topped with different lower case letters are significantly different.

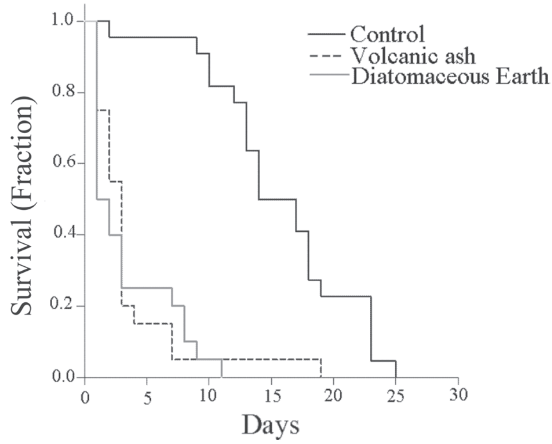

Fig. 2. Survival times (days) of grasshoppers placed in plastic cages with either diatomaceous earth (15 g/m^2) or volcanic ash or without either of these abrasive materials (control) and fed fresh leaves of dandelion (*Taraxacum officinale*) ad libitum. A fan was used to simulate wind gusts. Holm Sidak Test applied to the data indicated: control vs. diatomaceous earth ($P = 0.017$; control vs. volcanic ash $P = 0.025$).

SUMMARY

The aim of this work was to evaluate the toxicity of volcanic ash from the volcanic complex Puyehue-Caulle Range on the grasshopper, *Dichroplus vittigerum,* and compare the results with the effect of diatomaceous earth, an organic pesticide. To test this, we carried out 2 experiments: (i) an acute toxicity test, which consisted of exposing adults of *D. vittigerum* differentially to volcanic ash and diatomaceous earth, and (ii) a study to determine the survival time of the adult stage by separately exposing the insects to diatomaceous earth and volcanic ash, and by simulating with fans the wind gusts that occur naturally in the area of influence of the volcano. The laboratory data showed that constant exposure to volcanic ash and diatomaceous earth induces mortality in adult grasshoppers. Interestingly, the toxicities of the 2 products were very similar. These results suggest that the onset of the volcanic eruption with the consequent suspension of the pyroclastic material in the air may have had a negative impact on *D. vittigerum* populations through the mortality of individual adults. In summary, volcanic ash has an insecticidal effect similar to that of diatomaceous earth.

Key Words: grasshopper, diatomaceous earth, volcanic ash, insecticide, pyroclastic

Resumen

El objetivo de este trabajo fue evaluar la toxicidad de las cenizas volcánicas del complejo volcánico Puyehue-cordón Caulle en la tucura (langosta sudamericana), *Dichroplus vittigerum*, y comparar los resultados con un insecticida orgánico como la tierra de diatomeas. Para evaluar esto, se realizaron dos experimentos: ensayo de toxicidad aguda, que consistió en la exposición de adultos de *D. vittigerum* a la ceniza volcánica o a la tierra de diatomeas; y estudiar el tiempo de supervivencia de la etapa adulta exponiendo por separado a los insectos en tierra de diatomeas y en la ceniza volcánica, simulando ráfagas de viento que se producen naturalmente en el área de influencia del volcán. Los resultados demuestran que la exposición constante a la ceniza volcánica y la tierra de diatomeas inducen mortalidad en las tucuras en estado adulto. Curiosamente, la toxicidad de los dos productos resultó muy similar. Estos resultados sugieren que la aparición de la erupción volcánica con la suspensión consiguiente del material piroclástico en el aire, pudo haber tenido un impacto negativo en las poblaciones de *D. vittigerum* a través de la mortalidad de los adultos individuales. En resumen, la ceniza volcánica tiene un efecto insecticida como la tierra de diatomeas.

Palabras Clave: tucura, tierra de diatomeas, ceniza volcánica, insecticida, piroclástico

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