Crop Protection 109 (2018) 51–61

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Blanket application rates for synthetic grain protectants across agro-climatic zones: Do they work? Evidence from field efficacy trials using sorghum grain

Macdonald Mubayiwa[a], Brighton M. Mvumi[a,*], Tanya E. Stathers[b], Shaw Mlambo[a], Tinashe Nyabako[a]

[a] *Department of Soil Science and Agricultural Engineering, University of Zimbabwe, P. O. Box MP 167 Mt Pleasant, Harare, Zimbabwe*
[b] *Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Kent, ME4 4TB, United Kingdom*

ARTICLE INFO

Keywords:
Synthetic pesticides
Pesticide degradation
Pesticide tolerance
Sorghum grain storage
Climate change and variability
Storage pest dynamics

ABSTRACT

Many smallholder farmers in sub-Saharan Africa rely on synthetic pesticides for protecting stored-grain. Recommendations on use of these grain protectants are typically based on “blanket” application rates which are fixed rates that are not varied according to grain type, pest range or agro-climatic regions. There are numerous anecdotal reports of storage pesticide failure or reduced efficacy from farmers. Might rising global temperatures be a contributory factor? Smallholder farmers are responding by over-applying pesticides, increasing the application frequency or switching to non-recommended pesticides; leading to a pesticide treadmill. Trials to determine the efficacy and persistence of five commercially-available synthetic pesticides applied at manufacturer's recommended rates on stored sorghum grain under contrasting climatic conditions were conducted in Mbire (mean temperatures of 32–42 °C and 30–50% rh) and Harare (18–32 °C; 42–75% rh) districts in Zimbabwe. Grain samples were collected at 8-week intervals throughout a 10 month period in the 2014/15 and 2015/16 storage seasons. The samples were analyzed for insect grain damage, weight loss, total number of storage insects by species and grain moisture content. Results showed significant differences in the performance of treatments ($p < 0.001$). Grain damage was consistently higher in Harare than in Mbire. *Tribolium castaneum* was the dominant pest in Mbire, while *Sitotroga cerealella* and *Sitophilus oryzae* were dominant in Harare. *Tribolium castaneum* populations were high in the Shumba Super dust® (fenitrothion 1% + deltamethrin 0.13%) treatment in Mbire, while *S. cerealella* was dominant in Super guard® (pirimiphos-methyl 1.6% + permethrin 0.4%) and Actellic Gold dust® (pirimiphos-methyl 1.6% + thiamethoxam 0.36%) treated grain in Harare. Grain moisture content varied with ambient conditions, and was high in treatments with high insect pest levels. The results show that differences in climatic conditions influence insect pest species dynamics and response to pesticide treatments. Storage pesticides are not equally effective across different climatic conditions; thus more context-specific application recommendations are required.

1. Introduction

Improvements in the food and nutrition security status of many sub-Saharan African (SSA) countries through enhanced crop production are being hampered by a rapidly growing human population and the effects of climate change and variability (Kaminski and Christiaensen, 2014). Rising temperatures and less predictable rainfall patterns and amounts are already occurring in SSA (Niang et al., 2014). Temperatures are projected to increase by up to 4 °C by the end of the century, depending on the development pathway chosen (IPCC, 2014; Serdeczny et al., 2016). Due to this and inadequate and more intermittent rains during the growing season, the success of dryland crop production is getting more unpredictable. The importance of efficient postharvest grain management to protect whatever is harvested against loss due to storage insect pest damage is becoming ever more important (Stathers et al., 2013; Vassilakos et al., 2015). To guard against damage by storage insect pests, many smallholder farmers in SSA rely on applying synthetic pesticides composed of organophosphates and synthetic pyrethroids (Arthur, 1996; Stathers et al., 2002, Vassilakos et al., 2015). However, rising temperatures may promote increased degradation of these synthetic pesticides (Ismail et al., 2012) and may also favour development of many grain storage insect pests (Gornall et al., 2010) and affect their distribution and biology (Palikhe, 2007) such as shortening of life cycles. Shortened life cycles can increase the chances of insects developing resistance to pesticides as the insects more quickly adapt to treatments (Musolin and Saulich, 2012; Velázquez-Fernández et al., 2012).

---

* Corresponding author.
E-mail addresses: mvumibm@agric.uz.ac.zw, mvumibm@hotmail.com (B.M. Mvumi).

https://doi.org/10.1016/j.cropro.2018.01.016
Received 8 October 2017; Received in revised form 21 January 2018; Accepted 25 January 2018
0261-2194/

In many areas characterized by inadequate rainfall and high temperatures in SSA, small grains such as sorghum are staples and therefore widely grown as a coping and resilience strategy to these climatic conditions. However, the postharvest losses that occur reduce the amount of grain available for human consumption. Informed estimates suggest annual sorghum postharvest weight losses of 12.1% for SSA (APHLIS, 2014). Most of these farm-level postharvest losses are due to poor postharvest handling and insect pest attack (World Bank, 2011) and the latter necessitates use of effective control strategies, such as synthetic pesticides.

However, over-reliance on a narrow range of synthetic pesticides makes the development of pest resistance inevitable (Hagstrum and Subramanyam, 2006). Although most of the evidence is anecdotal, farmers across SSA frequently report storage pesticide failure or reduced efficacy (De Groote et al., 2013; Mlambo et al., 2017), and tend to respond by increasing the pesticide application rates, using non-recommended pesticides and/or increasing application frequencies to effect kill, which increases safety risks for users, consumers and the environment, and can trigger a pesticide treadmill effect.

The application of synthetic pesticides on stored grain is based on “blanket” or generalised application rates (Pretty, 2012). These are fixed rates that are not varied according to grain type, pest range or agro-climatic regions (temperature, relative humidity), despite the often wide variability in these factors under field conditions. This is also irrespective of possible implications on pesticide stability and dominant insect pest species in the different physical environments. These synthetic grain protectants are supposed to be applied just once at the start of a 6–12-month storage period. The use of “blanket” application rates, makes manufacturers’ recommendations easier for agricultural extension agents to extend, and are simpler to implement for farmers. However, this practice could eventually render the pesticides ineffective; a potential drawback not always understood by stakeholders. The objective of the current study was to determine the suitability of “blanket” application rates across different agro-climatic regions, a topic which has not previously been well-investigated under field conditions.

Much of the research undertaken to investigate insect response to synthetic pesticides has focussed on acute effects on adult mortality under rigidly controlled experimental conditions in the laboratory. There is, therefore, limited information on the effect on insect fecundity, pesticide persistence, or the effects on mixed populations of insects *in vivo*. The current studies were on sorghum, a small-grain grown in some of the more marginal agro-climatic zones; areas which are likely to get even warmer in the future. Therefore, information generated in this study is important in terms of deepening understanding of crop postharvest protection and food security in already highly vulnerable situations. The study, therefore, also sought to determine the diversity of storage insect species found on sorghum under the prevailing ambient conditions in two contrasting agro-climatic zones.

2. Materials and methods

2.1. Description of trial sites

On-station researcher-managed trials to determine the persistence and effectiveness of synthetic grain protectants under contrasting agro-climatic conditions were set up at Mahuwe Rural Service Centre in Mbire district (20° 43′ S; 30° 34′ E), Zimbabwe, and at the Department of Crop Science, University of Zimbabwe in Harare (17° 47′ S; 31° 03’ E), Zimbabwe, during the 2014/15 and 2015/16 storage seasons. Mbire district is located in the Zambezi valley, in northern Zimbabwe, about 283 km from the capital city, Harare (Fig. 1). The district is characterized by high annual temperature ranges of 32–42 °C, low rainfall of less than 450 mm per annum, and low mean annual relative humidity of 30–50%. Harare, is located in central Zimbabwe, and experiences warm to high temperatures ranging between 18 and 30 °C, a high mean annual rainfall range of 900–1000 mm, and has a mean annual relative humidity of 42–75%.

2.2. Experimental layout

Five commercially available synthetic grain protectant pesticides commonly used in Zimbabwe and an untreated control treatment were evaluated in this study (Table 1). In response to numerous anecdotal reports from farmers that locally-purchased grain protectants had lower efficacy than those bought at agro-dealers in urban centres, two Shumba Super dust® pesticide products were evaluated in the first season; one was purchased from a registered agro-dealer in Harare and the other bought from a local agro-dealer in Mbire. The Mbire local Shumba Super dust was not applied in Harare. However, as no significant differences were found between the locally-bought and Harare-bought pesticides in the first season trials, the Mbire locally purchased Shumba Super treatment was replaced by a newly introduced synthetic pesticide dust, Actellic Gold dust® during the second season.

Sorghum grain weighing 450 kg was thoroughly mixed to ensure it was as homogenous as possible before dividing it into lots of 75 kg of threshed grain per treatment. The 75 kg of the threshed grain was subdivided into three 25 kg lots before being separately admixed with pesticides at the application rates recommended on their labels (Table 1). During the 2014/15 season, SC Sila variety of sorghum was used, while in the 2015/16 storage season, a 1:1 mixture of SC Sila and Macia varieties of sorghum grain was used. These smallholder farmers commonly change and mix the crop varieties they store as grain for food. Therefore grain protectants need to be effective on a range of varieties and mixtures.

After admixing, each treatment replicate was loaded into new polypropylene bags, which were then labelled and placed on brick dunnage to avoid direct contact with the floor and therefore reduce the chances of moisture accumulation in the stored grain. The trials were conducted over a 40-week period (~10 months) during each storage season. The treatments were laid out in a completely randomized design with three replicates of each treatment per site. Temperature and relative humidity data were collected using Easylog data loggers (Model EL-USB-1, Whiteparish, Wiltshire, SP5 2SJ, United Kingdom) installed 1.5 m above the ground in the storage rooms. The trials were housed in brick-walled rooms, with ceilings, and iron sheet roofs at both sites.

2.3. Sampling, sample analysis and measurements

Composite samples of 500 g were collected from each treatment at each sampling timepoint using a Seedburo Bag Trier spear (No. 76 13″, Nickel Plated steel, 1½” outside diameter at the large end, 7 3/8″ long with top slot of 1¼” tapering down to ¼”). The 500 g (approximately 18 000 grains) sample was used for analysis of grain moisture content, grain damage, storage insect numbers present by species, and grain weight loss. The grain samples were collected by probing from at least five equidistant points around the bag, ensuring that grain was collected from the top, middle and bottom sections of each bag. Sampling was done every eight weeks until trial termination at 40 weeks. Insect counts per species were expressed per kilogram of grain; % grain damage was calculated as a proportion of the total number of grains in the sub-sample; and grain weight loss was determined using the count-and-weigh method (Boxall, 1986). Grain moisture content was measured using a pre-calibrated Dickey-John digital moisture meter (M3G™ model; Dickey-John Corporation, Minneapolis, USA).

2.4. Data analysis and data presentation

The percentage number of damaged grains, and the percentage weight loss data were analyzed in Genstat version 14, using a repeated measures analysis of variance (rANOVA) as the samples were collected