Journal of
Agricultural, Food, and Environmental Sciences ISSN 1934-7235
Volume 2, Issue 1 2008

Characterization of Foliar-Applied Potash Solution as a Non-selective Herbicide in Malian Agriculture

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Abstract

Studies were conducted to evaluate the potential of potash solution as a foliar herbicide with application to Malian agriculture. Potash samples were collected in Mali and analyzed for phytotoxicity and elemental composition. Aqueous potash solutions were applied as foliar sprays to seedlings of six plant species. All species were injured by the treatments, with 90% visual injury to common chickweed at 84.4 kg/ha potash. Broadleaf species showed greater injury in the absence of a surfactant, but addition of methylated soybean oil increased injury to most grass species. In all cases, injury was evident within three hours of treatment and approached maximum levels by 24 hrs. Elemental analysis of the potash showed the major component to be potassium (ranging from 454,300 to 493,310 ppm). Potash is a concentration of salts extracted from ash, and is readily available to Malian farmers as a byproduct of burning wood and crop residues. In light of the increasing interest in natural products, potash has potential to be an inexpensive, naturally-occurring herbicide that can fill needs for nonselective weed control in Malian agriculture.

Introduction

Weeds present a major constraint in agriculture in Mali and the rest of the world. The challenge of controlling weeds is greater in countries such as Mali, where most farmers have limited options because of a scarcity of available herbicides, few financial resources to purchase herbicides, and little opportunity for training in the safe use of pesticides. Most vegetable crops and traditional field crops such as sorghum (*Sorghum bicolor* (L.) Moench) and pearl millet (*Pennisetum glaucum* L.) are weeded manually. Hand weeding is laborious and the disturbance of the soil surface often leads to new flushes of weeds, necessitating additional weeding.

The current research was initiated in response to the need for weed control alternatives after Malian farmers observed that vegetation did not grow in areas where potash was discarded. This suggested that potash has potential utility as a herbicide, and its phytotoxicity was confirmed by application as a soil drench (N'Diaye et al., 2001). However, potash applied to the soil had residual activity, with the significant disadvantage that toxicity persisted in the soil and inhibited the growth of subsequent crops for months after application. It was noted that potash solutions were also phytotoxic when applied as a foliar spray, which requires lower application rates than soil drenches.

Although the term potash is commonly used to mean potassium, it originally referred to potassium carbonate (K_2CO_3) or potassium hydroxide (KOH) extracted from wood ash (Anonymous, 2000). This alkaline substance had several uses, including the manufacture of glass and soap, and potash production was an important industry in the 17th and 18th centuries, with a process for its production being the subject of the first U.S. patent assigned July 31, 1790 (Keesler, 2002; Paynter, 2004). The value of potash as a mineral nutrient in agricultural was recognized much later, and potassium fertilizers are currently produced from deposits of mineral salts such as KCl (Simpson, 1986). However, in Mali, some of the traditional uses of potash continue and it is used in soap making and added to food as a flavoring and preservative agent. Potash is produced throughout rural Mali from the waste ash of cooking fires and the burned residues of crops. It can be purchased inexpensively in most Malian markets, usually around $1-2 for a 5-Kg cake.

Potassium salts such as KCl and potassium cyanide were used at high rates for weed control in the era before selective herbicides (Helgeson, 1957; Robbins et al., 1952). During that time many inorganic compounds (e.g., sodium arsenite, sodium chlorate, ammonium thiocyanate, iron sulfate, copper sulfate, copper nitrate, sodium metaborate, sodium chloride, ammonium sulfate, and potassium chloride) and acids (e.g., trichloroacetic, sulfuric) were promoted as herbicides. However, despite a general acknowledgement of the phytotoxicity of ashes and concentrated salts, there is no scientific treatment of the herbicidal properties of potash in the available literature. Thus, the objective of this research was to apply a modern perspective to evaluating the composition and efficacy of potash as an herbicide.

Materials and methods

Sample Collection and Processing

Five potash samples (as potash cakes) were purchased from farmers or local markets near Bamako and Mopti, Mali. Sources of the ash included sorghum, millet, Wolo tree (*Terminalia macroptera*) wood, and wood from two unidentified tree species. The potash cakes were partially pulverized and transported in Nalgene bottles to Virginia Tech where they were stored at room temperature prior to chemical analyses and use in phytotoxicity tests. The samples were further pulverized using a mortar and pestle into particles that would pass through a 16 mesh screen, and oven-dried for 48 h at 120 ºC to obtain dry weights.

Sample analyses

Potash solutions were prepared for analysis by dissolving 10 g of potash sample in 1 L distilled water. The solution was vacuum-filtered using a Buchner funnel containing a pre-weighed circle of Whatman #1 paper that had been dried at 120 ºC for 24 h. After filtration, the filter was dried again (120 ºC for 24 h) and weighed to determine the quantity of insoluble material in the potash samples.

The filtered potash solutions were subjected to elemental analysis using inductively-coupled plasma spectrometry (SpectraFlame Modula TableTop ICP, Model number FTMOA85D) for specific elements: K, Fe, Mg, S, Ca, P, Mn, Cu, B, Na, Ba, and Si. The pH of each solution was also determined.

Phytotoxicity Experiments

Plant species evaluated were common chickweed, prickly sida, field bindweed, yellow foxtail, shattercane, and Kentucky bluegrass. Each species was seeded into one row in 41 x 84 cm flats containing Pro Mix BX soil-less media (Premier Horticulture, Dorval, Quebec**)**. The flats were maintained in a greenhouse with a 16L/8D photoperiod supplemented with sodium halide lighting at 500 $\mu E/m^2/sec$. Temperatures averaged 27/15 ºC (day/night) and the plants were watered as needed. Fourteen day-old plants were sprayed twice in immediate succession with potash solutions using an automated spray table system (Model Number 517-8351287, Allen Machine Works, Midland, Michigan) calibrated to provide a 211 L/ha spray volume at 3.38 km/h with a 8002E nozzle (Spraying Systems Co., Wheaton IL) at 33 cm above the foliage. Solutions applied consisted of 0, 10, 50, and 100 g/L of millet potash, resulting in field application rates of 0, 21.1, 42.2, and 84.4 kg/ha, respectively. All rates were applied either with or without 1% methylated soybean oil (MSO) surfactant. Visual injury ratings were taken 3, 6, 12, and 48 h after treatment, with 0 representing no injury and 100 being complete foliar necrosis. The experiment was arranged as a completely randomized design with three replications per treatment and the entire experiment was repeated.

Statistical analyses

Data were subjected to analysis of variance (ANOVA) using SAS PROC GLM (The SAS System V. 8.2. SAS Institute Inc., Cary, NC). Although the two repetitions of the experiment showed consistent trends with respect to plant injury responses, analysis of the combined data indicated significant differences between the repetitions. Thus, ANOVA was conducted individually for each experiment and results are shown in Table 2. Because overall trends were similar between the experimental repetitions, data are presented from just experiment 2. For graphing, data were subjected to regression analysis using Microsoft Excel and TableCurve 2-D software (Jandel Scientific, San Rafael, CA.). Dose response data were fitted with a second order polynomial equation: $y = ax^2 + bx$. Equations describing the time course of symptomology were best fit with the polynomial equation, $y = a + bx + cx^{0.5}$.

Results and Discussion

Elemental analysis confirmed that the major component in all potash samples was potassium (Table 1). The potash samples contained K levels between 4,543 ppm from unidentified wood and 4,931 ppm from wolo tree wood. These values were over 10-fold higher than the next most abundant element, S, which ranged from 199 to 363 ppm. Si, P, Na, Ca, and Mg were the next most abundant elements, while Fe, Mn, Cu, B and Ba were present at levels less than 1 ppm. These proportions are consistent with those of water-soluble cations from wood ash (Ulery et al., 1993; Voundi Nkana et al., 1998). The process of extracting ash with water during the process of making potash enriches the proportion of K by leaving behind less water-soluble elements such as Ca and P. The potash samples studied were highly soluble in water and ranged from 0.3 to 1.5% insoluble material.

The samples were also similar in having a pH of about 11. Such an alkaline pH is a characteristic of ash and potash, as the oxidation process and subsequent reactions in the ash favor the formation of KOH and K_2CO_3 (Demeyer et al., 2001). This pH value is in the range of those reported for wood ashes (Demeyer et al., 2001; Voundi Nkana et al., 1998) and consistent with one of the main effects of wood ash on soil being the elevation of pH (Ulery et al., 1993). Because of the general similarity in physical composition of the potash samples, only the millet potash was used in assays of herbicidal activity.

The herbicidal effect of potash was highly dose-dependent, with increasing rates generally causing greater injury (Table 2, Figure 1). Phytotoxicity was also enhanced by the presence of a surfactant that facilitated wetting of leaf surfaces, and this may explain some of the differences observed between plant species (Table 2). Without surfactant, the dicot species (common chickweed, prickly sida, and field bindweed) and yellow foxtail showed the greatest visual injury (Figure 1A). Shattercane and Kentucky bluegrass were only slightly injured, even at the highest rate, and this was likely due to low interception and retention of the spray. Addition of MSO increased the injury on yellow foxtail and shattercane, raising the control of these grass species to levels equaling that of the dicot weeds (Figure 1B). Only Kentucky bluegrass remained relatively uninjured by the addition of surfactant, and this is still attributable to the small leaf area

Table 1. Major elements and pH value of solutions of potash collected in Mali. Solutions were made by dissolving 10 g dry potash in 1 L water[1,2].

Plant Source	Collection site	Concentration (ppm)[3]					pH
		K	S	Si	P	Na	
Millet	Sanambele	4,828 ± 50	208.5 ± 9.1	154.5 ± 3.7	54.4 ± 0.7	12.2 ±1.4	10.9 ± 0.0
Sorghum	Bougoulla	4,857 ± 49	199.8± 0.5	89.4 ± 1.1	38.3 ± 0.2	15.5 ± 1.7	11.0 ± 0 0
Wolo tree	Bougoulla	4,931 ± 16	277.7± 1.2	71.9 ± 0.1	71.5 ± 0.1	16.8 ±1.9	11.0 ± 0.0
Unidentified wood no. 1	Diakoroba	4,848 ± 17	363.2± 2.3	4.5 ± 0.1	5.7 ± 0.2	40.7 ± 2.2	11.1 ± 0.0
Unidentified wood no. 2	Mopti	4,543 ± 87	246.7± 4.5	143.0 ± 1.0	357.0 ± 0.1	17.9 ± 1.5	10.8 ± 0.1

[1]Numbers are means of 4 replicates ± one standard error.
[2]Minor elements included Ca (1.4 - 9.8 ppm), Mg (0.36 - 2.3 ppm), B (0.3 - 1.1 ppm), Fe (0.02 - 0.21 ppm), Cu (0.03 - 0.1 ppm), Ba (0.02 – 0.07 ppm), and Mn (0.01 – 0.05 ppm).
[3]Concentrations are reported on analyses of 1% solutions; the concentrations of these elements in dry potash are 100 times these amounts.

Table 2. Analysis of variance for main effects and interactions of potash solutions applied with or without an adjuvant to six plant species.

Source	DF	Type I Sum of Squares	Mean Square	F Value	Pr > F
			Experiment 1		
Species	5	18995	3799	13.25	<.0001
Potash rate	3	89906	29968	104.50	<.0001
Adjuvant	1	3306	3306	11.53	0.0010
Species * rate	15	10333	688	2.40	0.0047
Rate * adjuvant	3	6236	2078	7.25	0.0002
Species * adjuvant	5	6083	1216	4.24	0.0014
			Experiment 2		
Species	5	22948	4589	23.75	<.0001
Potash rate	3	58894	19631	101.57	<.0001
Adjuvant	1	2062	2062	10.67	0.0014
Species * rate	15	11843	789	4.09	<.0001
Rate * adjuvant	3	2426	808	4.19	0.0076
Species * adjuvant	5	7352	1470	7.61	<.0001

and low retention by these plants. These observations support the action of potash solution as a contact herbicide because injury was highly correlated to solution coverage on the leaves. These data also suggest that the selectivity of the herbicide can be controlled by the spray formulation, with surfactant added to increase the spectrum of weeds controlled and omitted to selectively target broadleaf weeds.

Plant injury occurred rapidly following application of potash solutions, and reached a maximum by 24 h after treatment (Figure 2). Because only the surfaces contacted by the spray were injured, weeds were able to regrow from sheltered meristems, as appeared to be the case with common chickweed. The symptomology caused by potash application was consistent with desiccation due to plant cell membrane disruption. Affected plant tissues rapidly become necrotic, with injury ranging from flecks to complete collapse of the leaves (Figures 3 and 4), depending on thoroughness of coverage. Single drops applied to leaf surfaces create a necrotic spot that extends only a few mm in the direction of the transpiration stream (data not shown), indicating little translocation. The alkaline, high salt nature of the potash would be injurious to membranes and would seem to be similar to the burn that can occur with high concentrations of foliar K fertilizer (Oosterhuis, 1993). Considering that the activity assays were conducted under greenhouse conditions in Virginia, phytotoxicity may well be more pronounced in the warm, arid climate of Mali.

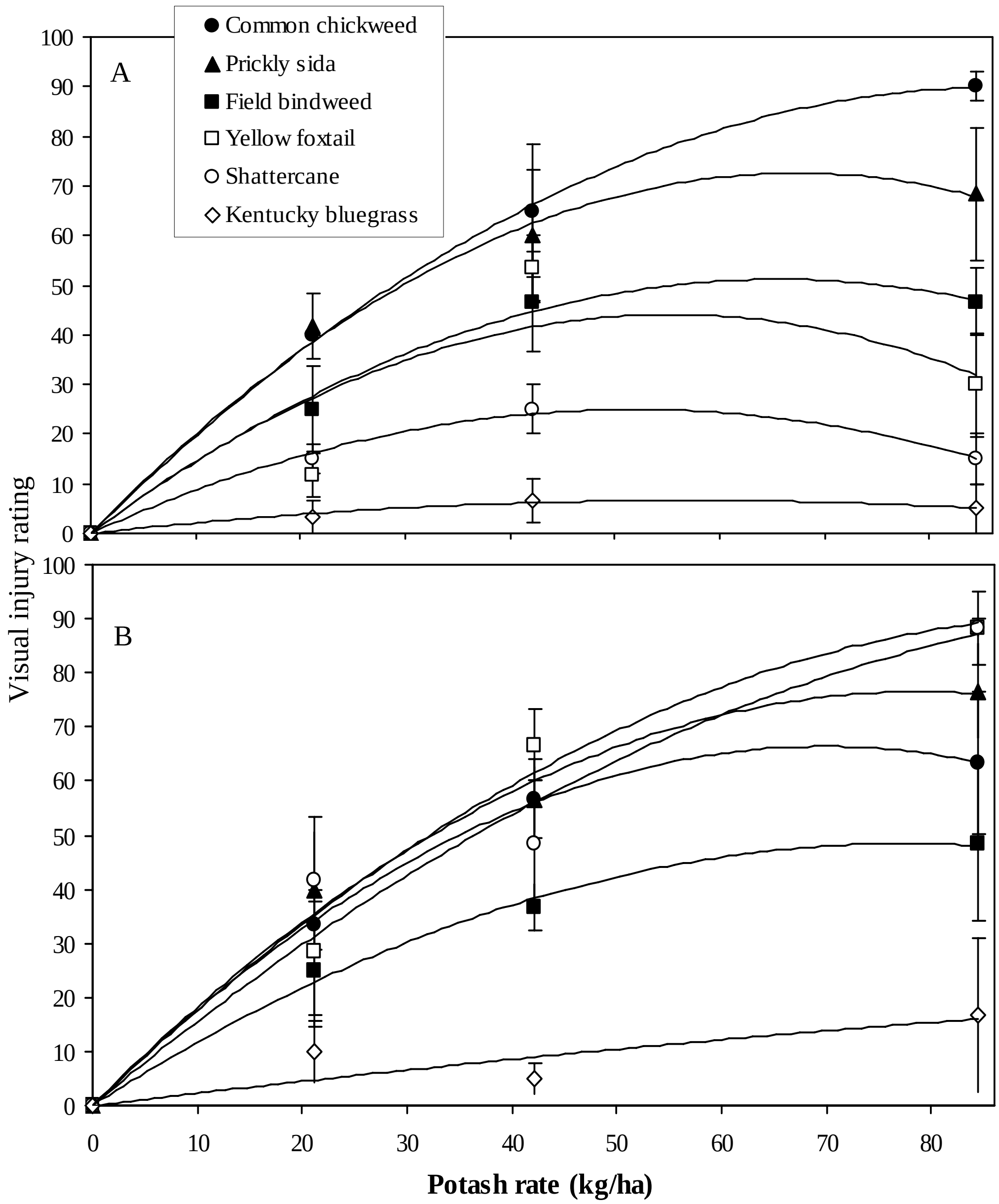

Figure 1. Effect of potash concentration on six plant species. Potash solutions were applied without (A) and with (B) methylated soybean oil surfactant, and visual injury was rated 24 h later. Data are means of three replicates with standard error indicated by vertical lines. Regression lines have the following equations: Panel A. common chickweed, $y = -0.012x^2 + 2.07x$, $r^2 = 0.99$; prickly sida, $y = -0.016x^2 + 2.16x$, $r^2 = 0.99$; field bindweed, $y = -0.012x^2 + 1.56x$, $r^2 = 0.99$; yellow foxtail, $y = -0.014x^2 +1.60x$, $r^2 = 0.76$; shattercane, $y = -0.009x^2 + 0.96x$, $r^2 = 0.99$; Kentucky bluegrass, $y = -0.002x^2 + 0.23x$, $r^2 = 0.97$. Panel B. common chickweed, $y = -0.014x^2 + 1.91x$, $r^2 = 0.99$; prickly sida, $y = -0.012x^2 + 1.94x$, $r^2 = 0.99$; field bindweed, $y = -0.008x^2 + 1.25x$, $r^2 = 0.99$; yellow foxtail, $y = -0.010x^2 + 1.86x$, $r^2 = 0.98$; shattercane, $y = -0.007x^2 + 1.63x$, $r^2 = 0.96$; Kentucky bluegrass, $y = -0.0005x^2 + 0.24x$, $r^2 = 0.71$.

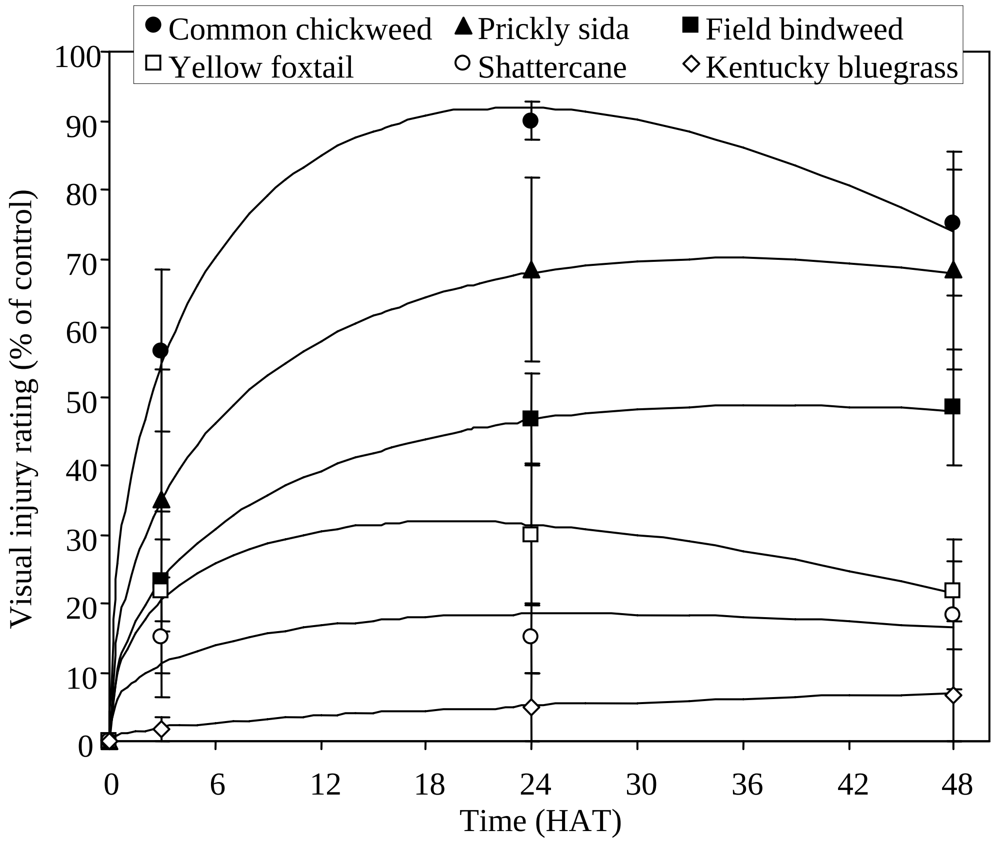

Figure 2. Evolution of injury following potash application to six plant species. Potash solution was applied at 200 g/L without a surfactant. Data are means of three replicates with standard error indicated by vertical lines. Regression lines have the following equations: common chickweed $y = 1.05 - 3.95x + 37.88x^{0.5}$, $r^2 = 0.99$; prickly sida $y = -0.01 - 2.00x + 23.69x^{0.5}$, $r^2 = 0.99$; field bindweed $y = -0.18 - 1.28x + 15.81x^{0.5}$, $r^2 = 0.99$; yellow foxtail $y = 0.75 - 1.62x + 14.17x^{0.5}$, $r^2 = 0.99$; shattercane $y = 1.86 - 0.63x + 6.45x^{0.5}$, $r^2 = 0.84$; Kentucky bluegrass $y = 0.04 - 0.015x + 1.10x^{0.5}$, $r^2 = 0.99$.

This research provides a starting point for reconsideration of the advantages and disadvantages of potash as an herbicide. Potash can be used as a contact herbicide with potential utility pre-plant or as a directed spray in established crops. It has already been used by Malian farmers to prevent seed production by emerged purple witchweed [*Striga hermonthica* (Del.) Benth] growing on sorghum (N'Diaye, unpublished observations). Aside from its herbicidal properties, potash is inexpensive, naturally-occurring, and locally available. Wood ash is generally considered to contain no noxious elements that would adversely affect plant growth, so the limiting factors in adding ash to soils come from increased pH and K levels (Demeyer et al., 2001). Indeed, wood ash has been proposed as an aid in neutralizing acid soils (Aronsson and Ekelund, 2004; Voundi Nkana et al., 1998). With respect to human safety, potash is already handled routinely in Mali and is consumed in small amounts. In other parts of Africa, wood ash is mixed with sorghum grains during processing to improve its nutritional quality (Mukuru et al., 1992).

Potential disadvantages of potash herbicide would include the risk of increased pH and salt concentrations in the soil such that crop growth would be inhibited. The foliar application of potash was studied specifically to avoid such residual soil toxicity, although it remains a matter of concern. The highest rate of potash used in the current study was 84.4 Kg/ha, which is well within the range of rates that may be recommended for potassium fertilizer application, for example, recommendations for sugar beets range up to 200 Kg/ha K_2O (Simpson, 1986). However, repeated applications of potash herbicide could cause problems, depending on soil conditions. Research is currently underway to reduce the amount of potash required for phytotoxicity and to evaluate the residual soil effect of potash sprays on growth of a subsequent crop

Figure 3. Symptomology of potash solutions on tall morningglory 0 and 24 h after application of 0 (control), 5 and 10 % (21.1 and 42.2 kg/ha, respectively) potash solution.

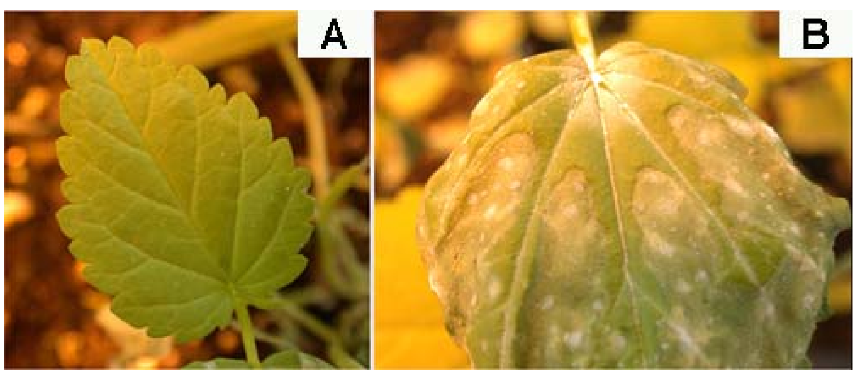

Figure 4. Detail of potash symptomology on prickly sida leaf 48 h after application of (A) water and (B) 84.4 kg/ha millet potash.

Acknowledgements

This project was supported by a USDA Collaborative Research Support Program Challenge Grant “Discovery-based undergraduate research program” (USDA CREES #2002-38411-12114) to D.M. and R.F. Additional support was provided by the Integrated Pest Management

Collaborative Research and Support Project (IPM CRSP) Grant No. LAG-G-00-93-00053-00 from USAID to D.M., J.H.W., M.N., B.D., and K.G. and Hatch Grant No. 135657 to J.H.W. Thanks to Sandra Gabbert for technical assistance during the project.

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