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USE OF HERBICIDES FOR CONTROL OF BANANA BACTERIAL WILT IN UGANDA

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ABSTRACT

The potential of herbicides for destroying banana plants infected with bacterial wilt has been evaluated. Experiments were conducted on station at Kawanda Agricultural Research Institute (KARI) and on-farm at Nekoyedde and Kimenyedde, in Mukono district. Two systemic herbicides, Glyphosate and 2, 4-D were evaluated for their effectiveness in destroying infected banana plants. Selected plants were injected with 20 ml of herbicide in water at the rate of 1:20 administered in a perforated hole at the collar base of the pseudostem close to the corm using a sharp pencil-size metallic rod. All plants injected with 2,4-D herbicide snapped and died within 30-60 days while plants injected with glyphosate wilted and dried up within 90-120 days. Both herbicides were able to kill at least 85% of the plants. Plant destruction depended on herbicide dose, mat size and nature of suckering. Re-suckering rates between the two herbicides did not significantly differ. The mean re-suckering on farmer's fields was 1.5% for glyphosate and 7.2 % for 2,4-D compared to 15.2% and 11.3% on the station. Herbicides were able to destroy plants within radius of 16.8 ± 1.76 cm from the injected plant per mat. Higher doses killed faster and better but it was not clear why very high doses caused high re-suckering. It was therefore concluded that although 2,4-D herbicide destroyed banana mats faster than Glyphosate, in the long run however, the efficiencies of kill between the two herbicides do not differ significantly. Both herbicides showed great potential for use as an option for removal or destruction of diseased plants. However, considering environmental safety issues, Glyphosate is recommended for farmer use in Uganda.

Key Words: Banana mats, Glyphosate, 2-4D

RÉSUMÉ

La potentialité des herbicides à détruire les plantes de bananes infectées par le flétrissement d'origine bactérienne a été évaluée. Les expériences étaient conduites sur station à l'Institut de Recherche Agricole de Kawanda (KARI) ainsi que sur ferme à Nekoyedde et Kimenyedde dans le district de Mukono. Deux herbicides systémiques, Glyphosate et 2,4-D étaient évalués en vue de leur efficacité à détruire les plantes de banane infectées. Des plantes sélectionnées recevaient une injection de 20 ml d'herbicide dans l'eau au taux de 1:20 administrés au niveau d'un trou perforé à la base du col du pseudostème près du corn en utilisant une tige métallique fine aux dimensions d'un crayon. Toutes les plantes injectées au 2,4-D cassaient et mouraient dans une période de 30-60 jours pendant que les plantes injectées au Glyphosate flétrissaient et séchaient endéans une période de 90-120 jours. Tous les deux herbicides étaient capables de tuer au moins 80% de plantes. La destruction des plantes dépendait de la dose d'herbicide, de la dimension de la natte et la nature de la ventouse. Les taux de re-adhérence par ventouse entre les deux herbicides ne différaient pas de manière significative. La re-adhérence moyenne sur champ d'agriculteur était de 1.5% pour le Glyphosate et de 7.2% pour 2,4-D comparés a 15.2% et 11.3% sur station. Les herbicides étaient en mesure de détruire les plantes dans un rayon de 16.8 ± 1.76 cm à partir de la plante injectée par natte. Des doses plus élevées tuaient nieux et plus rapidement mais il n'était pas clair pourquoi des doses très élevées causaient une re-adhérence plus grande. Il était donc conclu que bien que l'herbicide 2,4-D provoque une destruction de plantes de banane plus rapide que celle de Glyphosate, à long terme cependant, l'efficacité de tuer des deux herbicides ne différait pas significativement. Tous les deux herbicides montraient un grand potentiel dans un usage destiné à se débarrasser des plantes malades ou à les détruire. Néanmoins eu égard aux questions de sécurité environnementales, le Glyphosate reste l'herbicide recommandé pour utilisation par l'agriculteur en Ouganda.

Mots Clés: Nattes de bananes, Glyphosate, herbicide 2,4-D

INTRODUCTION

Banana production in Uganda is severely threatened by the arrival of the new and highly devastating disease, banana bacterial wilt caused by *Xanthomonas campestris pv. Musacearum*. All banana cultivars appear to be susceptible. Bunches, prematurely ripen, rot and the whole plants die (Tushemereirwe *et al.*, 2003). Transmission of this disease is said to be through insects frequently associating with the inflorescence, infected tools and movement of infected plants or plant parts (Thwaites *et al.*, 2000). The current prescribed preventive and control measures involve quarantine, breaking off male buds and roguing affected mats in order to limit or stop further disease spread (Ploetz, 2004). Roguing has proved virtually impractical as cut down plants re-sucker, while the large sizes of mats and pseudostems are difficult to destroy (Eden-Green, 2004; Addis *et al.*, 2004). Since infected parts serve as a source of inoculum, total destruction of infected plants is recommended (Yirgou *et al.*, 1974). Traditional destruction of banana plants by cutting them down gives chance for re suckering.

There was need for cheaper and faster methods of eliminating affected plants. Elsewhere, kerosene poured on to plants at growing points, has effectively been used to kill banana plants infected with Banana Bunchy Top Virus in Hawaii (Concepcion *et al.*, 1994). Glyphosate has been used to kill banana plants in Taiwan and Hawaii (Nelson, 1998), While 2, 4-D also a systemic herbicide has been used to defoliate trees bananas inclusive (Massey, 2000).

Studies intended to establish the potential of these two systemic herbicides – Glyphosate (Round up, 360 g/l Glyphosate) and 2,4-D Amine 72% SL, applied as injections to destroy infected banana plants were initiated in June, 2004 with following objectives: (i) to determine the optimum herbicide dose that can be used to kill banana plants, (ii) to compare the kill efficiencies of Glyphosate and 2,4-D herbicides, and (iii) to evaluate the performance of Glyphosate and 2,4-D herbicides in farmers fields.

MATERIALS AND METHODS

The experiments to determine the optimum herbicide dose and compare herbicide kill efficiencies were conducted on-station at Kawanda Agricultural Research Institute (KARI) (0.42N, 32.5E; 1220 masl), 13 km North of Kampala and 1195 m above sea level.

A total of four uniform size plants of each of the cultivars FHIA 03 and Williams, at flowering stage were randomly selected each from a separate mat, in 0.5 ha field of mixed cultivars. The selected plants were injected with either Glyphosate (360 g L^{-1}) or 2,4-D (720 g L^{-1}) herbicide in 5 concentration levels. There were two treatments (Glyphosate and 2.-4D) applied in 4 replicates and 5 concentration levels of treatments replicated 4 times (1:0, 1:10, 1:20, 1:50, 1:100).

Using a syringe, 20 ml of herbicide solution was injected into the banana plants through a hole perforated at the base of the pseudostem close to the collar, using a sharp pencil size metallic rod. Plants were observed for a period of 120 days and data were recorded on days to wilt/dry, days to die, number of dead plants, total number of surviving suckers on each mat and number of re-suckers from each treated mat.

For on-farm trials, two farms from Kawuku and Nekoyedde villages Mukono district were randomly picked in areas that had high bacterial wilt incidence. Mukono (0^0 1.4" N, 32^0 55"E) is located 30 km east of Kampala, lies 1200 m.a.s.l and area receives bimodal (march-June, September-December) averaging 1100mm annually. Average annual minimal and maximum temperatures were 16°C and 28°C respectively. The area soils have been classified as feralsol with sandy clay loam texture. On each farm 600 banana plants were randomly selected from Pisang awark (Kayinja) fields for injection with 2, 4-D and Glyphosate. The villages were 5 km apart. Twenty milliters of solution obtained from diluting 20ml herbicide in 1:20 herbicide: water rate was used. Each individual plant was injected with the herbicide. Plants were observed for a period of 120 days and data were recorded as already stated.

Data analyses. Responses on the proportion of plants that survived were analysed using the general linear model procedures of SAS (SAS, 1989) and mean separation were carried out using pair-wise t- test of least square means for number of plants killed and days taken to kill or die were analyzed using t-test.

RESULTS

The time taken for plants treated with different rates of 2,4-D to dry up or die varied only slightly. In the case of glyphosate the variation was significant for the 1:50 (chemical: water) and lower concentrations when compared with higher concentrations (Tables 1 and 2). The observation was that higher doses of 2,4-D dried and killed plants faster than lower doses. Overall time taken for plants treated with 2,4-D to die was shorter than for those treated with glyphosate.

Higher doses gave higher kill percentages than lower doses (Table 3). All concentrations ratios of 2,4-D killed at least 61% of the banana plants in less than 54 days. The general observation was that for both 2,4-D and Glyphosate, the percent kill for concentration rates 1:0 to 1:20 did not significantly differ, making 1:20 most cost effective.

There was significant difference (P=0.0001) between Glyphosate and 2,4D in the number of days it took to cause drying and death but no cultivar difference was registered with respect to treatments with either herbicide (Table 4). There were no significant differences in percent kill for both herbicide on-station (Table 5) and on-farm (Table 6). Sucker resurgence and survival was higher in 2,4-D treated mats than Glyphosate but not significant (P>0.05). It is on the basis of cost effectiveness that the dilution rate 1:20 was selected for subsequent use in other on-station and on-farm evaluation. Using this dilution rate, 1000ml of herbicide can be used to kill 1050 plants. This is equivalent to approximately 1ml (0.36g a.i) of chemical injected per plant. Preliminary test results already suggest that injecting 1ml of undiluted herbicide produces similar results with any other dilution not

TABLE 1. Comparison of 2,4-D and wilt and die Glyphosate in terms of days taken for banana plants dry at KARI, June – October, 2004

Chemical to H_2O(a.i)	2,4-D(±2.01)	Glyphosate (±2.01)
1:0 (7.2g)	28.8a	58.2a
1:10 (0.72g)	29.4a	50.3a
1:20 (0.36g)	27.6a	53.3a
1:50 (0.14g)	31.1b	66.3b
1:100(0.072g)	30.5b	71.3b

Same letters within columns indicates not significantly different (P >0.05) by pair-wise t- test of least square means
a.i = amount of active ingredient applied

TABLE 2. Comparison of 2,4-D and Glyphosate in terms of number of days taken for banana plants to die at KARI, June – October, 2004

Chemical to H_2O(a.i)	2,4-D (±3.26)	Glyphosate (±3.26)
1:0 (7.2g)	43.5a	98.8a
1:10 (0.72g)	44.8a	106.8a
1:20 (0.36g)	47.1a	102.5a
1:50 (0.14g)	52.0b	115.0b
1:100(0.0 72g)	53.5b	120.0b

Same letters within columns indicates not significantly different (P >0.05) by pair-wise t- test of least square means
a.i = amount of active ingredient applied

TABLE 3. Comparison of 2,4-D and Glyphosate in terms of number of banana plants dead from each mat at 120 days at KARI, June – October, 2004

Chemical to H_2O(a.i)	2,4-D (±7.72)	Glyphosate (±9.28)
1:0 (7.2g)	81.4 a	88.7 a
1:10 (0.72g)	77.7 a	77.4 a
1:20 (0.36g)	73.9 a	70.6 a
1:50 (0.14g)	70.2 a	38.2 b
1:100(0.072g)	61.7 a	8.3 b

Same letters within columns indicates not significantly different (P >0.05) by pair-wise t- test of least square means.
a.i = amount of active ingredient applied

exceeding 1:20. The added cost therefore due to use of water could then be escaped in future by just applying undiluted glyphosate.

DISCUSSION

The use of herbicides, especially non selective systemic types like Glyphosate and 2,4-D is not new and has always been turned to for total destruction and elimination of illicit and unwanted plants including bananas (Massey, 2000). In this study the potential of herbicide use to destroy diseased banana plants was evaluated.

In these studies herbicides were injected into plants through holes punctured around the base of the pseudo stem just above the corm. Injecting directly on corm is hard, while on the other hand, injecting high above on the pseudo stem causes the chemical to gush out with water. Nelson *et al* (1998) indicated that injecting herbicide solution at any convenient height above the ground (20-30cm) gave good results.

Results from these studies suggested that, under the conditions in which these studies were conducted, 20ml of herbicide at a dilution rate of 1:20, herbicide: water, is optimum for destruction of banana plants. This result is supported by the findings of (Lindsay *et al.*, 2003) in which they suggested that a product of Glyphosate 360g/l as active ingredient can be mixed as 100ml per liter of water with 5-15ml of solution injected per adult plant, 2 lots of 10ml (20ml) is required to kill adult banana plants with huge pseudo stems. While 1 or 2 lots of 5ml (5-10ml) may be required to kill younger suckers depending on age and size. Eden-Green (2004) also suggested 10-30ml

TABLE 4. Days taken for banana cultivars FHIA 03 and Williams to dry and die at KARI when treated with 2,-4D and Glyphosate

Herbicide	Cultivar	Days dry (±1.27)	Pr>ltl	Days die (±2.06)	Pr>ltl
2,4-D	FHIA 03	29.0	0.0001	47.5	0.0001
2,4-D	Williams	29.9		48.9	
Glyphosate	FHIA 03	55.2		110.9	
Glyphosate	Williams	61.2		106.3	

TABLE 5. Comparison of overall percentage herbicide kill efficiency and days to kill banana for 2,4-D and Glyphosate (using 20ml, 1:20) on-station at KARI, June- October, 2004

Herbicide	Mean days to wilt/dry	Pr>ltl	Mean days to die/rot	Pr>ltl
2,4-D	42.5 ± 2.06	0.0001	59.6 ± 1.78	0.0001
Glyphosate	63.0 ± 2.25		112.3 ± 0.95	

TABLE 6. Comparison of overall percentage herbicide kill efficiency for 2,4-D and Glyphosate in terms of number of bananaplants dead from each mat (using 20ml, 1:20) on- station in KARI and on-farm in Mukono, June- October, 2004

Herbicide	On-station		On-farm	
	Mean ±SE (%) plant death	Pr>ltl	Mean ±SE (%) plant death	Pr>ltl
2,4-D	88.8 ± 3.89	0.44ns	92.8 ± 5.83	0.42ns
Glyphosate	84.9 ± 3.62		98.7 ± 0.33	

ns= not significantly different (P > 0.05) depending on size of the plant. From the above it is clear that 20ml herbicide in the ratio 1:20 (containing 0.36g a.i) is most cost effective.

According to these studies, there was resurgence of suckers from treated mats for both herbicides (2,4-D and Glyphosate) but differences between herbicides appeared insignificant. These studies showed that higher doses killed faster but also exhibited a higher rate of sucker resurgence (Table 1). Earlier results on-station, showed that efficiency of kill depended on nature of mat spread. Only suckers attached to the treated plant were killed. This probably explains why the rate of re-suckering was higher on- station than it was on-farm where all plants were individually injected. This appears to agree with findings from the 'BANANACIDE' experiments conducted in Hawaii using Round up ultra max herbicide in which Ferreira *et al.* (1997) indicated that, only a small proportion of plants within the treated plots are likely to re sucker. The implication is that the overall cost of eliminating such volunteer plants would be expected to be considerably low and therefore affordable by any farmer's standard.

In these studies 2,4-D herbicide, applied at the same rate of dosage with Glyphosate killed plants faster. The nature of kill was by snapping plants at the base of the pseudo stem close to point of herbicide solution introduction. Non snapped plants, were observed to continue wilting up, while corms of snapped plants died and rotted. On the other hand Glyphosate killed much slowly. Treated plants wilted gradually, dried up but remained standing until the pseudo stems became completely rotten and collapsed. The other observation was that in the short run 2,4-D killed plants fastest and the furthest suckers and the furthest suckers attached to the treated plant. This could offer an added advantage in that banana bacterial wilt disease infected plants are eliminated faster and therefore do not remain a standing source of inoculums. Much fewer cases of sucker resurgence were registered in the case of Glyphosate. The systemic nature of Glyphosate ensures gradual but total kill and whole corm decay, thereby providing the best opportunity for reduction of burrowing nematodes and banana weevil populations (Lindsay *et al.*, 2003). Plant residues form mulch, decay and add to organic matter. Herbicides therefore, provide the opportunity for successful fallowing.

These results suggest that in the short run, there were significant differences in the efficiency of kill between 2,4-D and Glyphosate when applied under the same conditions. Injected plants were snapped within two weeks, wilted within six weeks and died within eight weeks in the case of 2,4-D. In the case of plants injected with Glyphosate, wilting occurred within six weeks and plants died within sixteen weeks. However, in the long run, these differences in the efficiency of kill between 2,4-D and Glyphosate appeared un important as both herbicides finally killed plants. The implication being that the farmers could then be advised to choose the cheaper, healthier and environmentally safer option. On-farm, where the plantations used were always intercropped, 2,4-D was observed to have selectively killed one tree species related to *Eucalyptus*. Glyphosate did not act this way and therefore farmers felt much safer using it. There was less sucker resurgence observed within glyphosate treated mats.

According to (Shearer, 1994), although 2,4-D is a moderately toxic herbicide, the manufacturers are under obligation to label it as highly toxic because of its skin, eye irritation plus other effects to the environment. 2,4-D is unusual among herbicides in that it causes an array of adverse effects to the nervous system and its exposure causes cancer in humans (Russell, 2002)

During the Vietnam war the US defense forces used 'Agent Orange' a herbicide composed of 2,4-D and 2,4,5T to defoliate trees. Today, American war veterans who were exposed to 'Agent Orange' still suffer elevated rates of diabetes and certain cancers with their children suffering elevated birth defects (Massey, 2000). Currently its use is under restricted limits. For example, Nufarm Amicide (2,4-D) used in carvendish bananas and destruction of suckers is permitted for use only under emergency (Henriques *et al.*, 2003). These facts make use of 2,4-D less acceptable.

Glyphosate is the active ingredient in the well known herbicide called Round up. It is listed among the world's least toxic herbicides (Brent, 2003). It is systemic, non selective and environmentally safe herbicide used as a burn down spray. Glyphosate has very low toxicity and once applied breaks down into natural compounds such as Carbondioxide, nitrogen and water. It has no rooting activity (Breeze *et al.*, 1992). It is extensively metabolized in some plants while remaining intact in others.

Glyphosate is said to be comparatively less toxic than table salt and aspirin (Massey, 2000). It is less harmful to human beings and farm animals. It is absorbed through out the plant tissue and acts on various enzyme systems inhibiting amino acid metabolism through the shikimic acid pathway. This path way exists in higher plants and micro organisms but not in animals (Russell, 2002).

Glyphosate is also inactivated when it comes into contact with soil and gets adsorbed into soil particles where it binds into the soil the same way inorganic phosphates do. The unbound is rapidly degraded. Glyphosate is not easily leached and is therefore unlikely to cause contamination in the soil because of the low adsorption. Microbes are primarily responsible for the break down of the products and volatilization or photo degradation losses will be negligible. Glyphosate is moderately persistent in soil with estimated half life of 47 days. Reported field half lifes ranges from 1-147 days (Wauchope, 1992). Its half life in pond water ranges from 12 days to 10 weeks (USDA, 1989). The injection of Glyphosate to eradicate banana plants is allowed as a permited minor use by the Australian pesticides and Veterinary Medicines Authority (APVMA) (Lindsay *et al.*, 2003). In the US, 2,4-D is now mainly as a synthetic auxin, noxious weed and tree killer. In Hawaii, Vietnam, and Taiwan, herbicides have been used to destroy banana plants infected with banana bunchy top virus and Moko disease (Nelson, 1998)

In conclusion these results suggest that both 2,4-D and Glyphosate are an effective and cheaper option of killing unwanted banana plants. However, health and environmental safety considerations outweigh the usefulness of 2,4-D for the purpose. Consequently, glyphosate is recommended for use by the farmers.

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