# Knapsack Shield for Herbicide Weed Control in Field Crops

Patterson Osei Bonsu[1], Michael Akuamoah Boateng
[1]Corresponding Author: CSIR –Crops Research Institute, Kumasi, Ghana

## Abstract

Over dependence on inefficient tools such as hoes for critical field operations limits crop production in developing countries. One such operation is weed control. A knapsack shield that suits the spray pattern of a drift reduction off centre nozzle (AirMix. ®. Nozzle) was developed and tested for herbicide weed control in cassava. The shield was developed locally using a thin aluminum sheet and it was tested at two locations in the forest and forest savanna transition ecological zones in Ghana. Paraquat was applied through the shield at a rate of 3l /ha to control mainly Euphorbia (*Euphorbia heterophylla*). The treatments were: i) spraying half row width with each pass with paraquat through the shield, ii) spraying entire row width with each pass with paraquat through the shield, iii) timely hand hoeing and iv) delayed hand hoeing. Weed control with the shield was effective and it resulted in similar cassava yields as timely hand hoeing. Economic analysis showed that the highest cost was incurred in the timely hand hoeing plots whilst the least cost was incurred in the delayed hand hoeing plots. Timely hand hoeing gave higher net benefit than shielded weed control but the reverse was true for marginal rate of return.



**Key words:** Knapsack, shield, herbicide, weed control, field crops, paraquat.

## Introduction

A major constraint limiting crop production in developing countries is the over dependence on primitive and inefficient implements such as hoes for critical field operations. One such operation is weed control after crop emergence. In Ghana, many farmers delay weed control due to scarcity of labour during the peak periods of demand. Crops are sensitive to weed infestation at the initial stages of growth (Onochie, 1975, Talatala *et al* 1980). Studies done in Nigeria show that herbicide weed control is more profitable than manual weed control (Usoroh, 1983, Adigun *et al*., 1993, Ishaya *et al.*, 2008). There has been increased use of herbicides by small scale farmers in Ghana in recent times (Ekboir *et al* 2002). For crops like maize and rice, farmers can use broad-spectrum herbicides such as glyphosate to control pre-plant weeds and selective herbicides to control in-crop weeds. However, cassava and many crops have no selective herbicide on the Ghanaian market therefore farmers have no option than to use manual labour to control in-crop weeds. Furthermore, many farmers practice intercropping system in which selective herbicide for one crop may not be suitable for the component crop(s). Tests conducted by Awadhwal *et al* (1991) show that attachment of a shied to a knapsack sprayer decreased off target drift by as much as 63% compared with unshielded spray. The shield used in the study consists of a conical wire frame covered with polythene material and it uses a hollow cone nozzle. Most knapsack shields are in the form of a fan and they use flat fan nozzles. One feature of a shield that uses a hollow cone or flat fan nozzle is that the swath of the nozzle increases towards both ends of the shield. If this type of shield is lifted up during spraying, the swath extends beyond the width of the shield, and directly drifts herbicide onto the adjacent crops. This shield is therefore not suitable for herbicide application on farms where the shield must be frequently lifted to avoid obstacles such as stumps. This paper describes a knapsack shield which we developed locally. Results of test on its efficiency for paraquat application in cassava are also presented.

## Materials and Methods

### Description of the shield

The shield was developed locally using a thin aluminum sheet. It is closed at 4 sides and open at the bottom. When it is placed on a flat surface, the back of the shield is directly perpendicular to the surface, and the two lateral sides are generally in a form of a right angle triangle as shown in figure 1 (left). The shield was designed to suit the spray pattern of a drift reduction off centre nozzle (AirMix. ®. Nozzle ) developed by Agrotop, Germany. The swath of the nozzle is in the form of a right angle triangle and it increases towards one direction only as shown in figure 1(right).



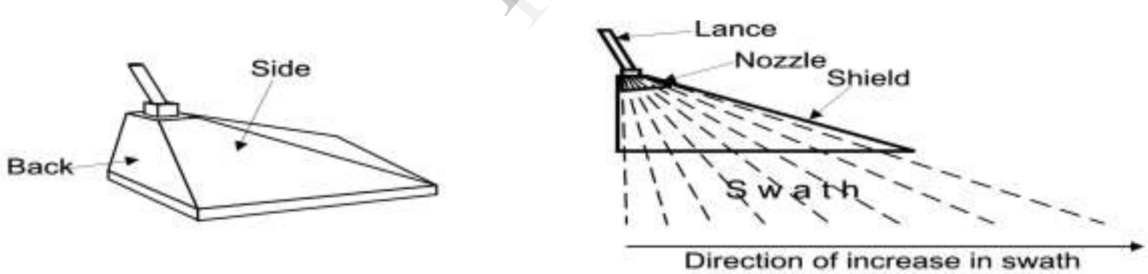


Fig 1. The shield (left) swath of nozzle (right)

The nozzle is fixed on the shield such that during spraying, the swath extends away from the back of the shield (figure 1 right).

Figure 2 and figure 3 shows how the shield is used to apply herbicide in two crop rows R1 and R2. One method is to spray half the row width with a pass (at a go). In this method, the back of the shield is placed adjacent to crop row R1 and half the row width A-B is sprayed to the end. Thereafter, the back of the shield is placed adjacent to crop row R2 and the other half of the row width (C-B) is sprayed. When the shield is lifted to avoid an obstacle, the swath extends towards

ISSN: 2278-0181
Vol. 2 Issue 2, February - 2013

the middle of the row (and not towards the adjacent crop row, R1.); therefore direct drift of

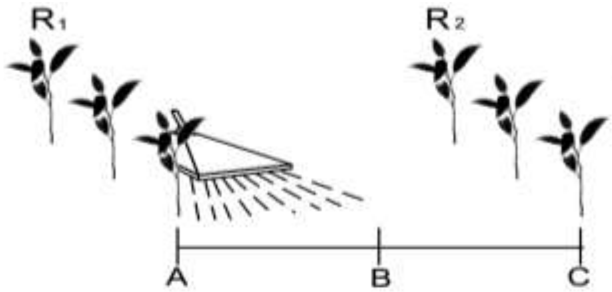


Fig 2. Spraying half row width

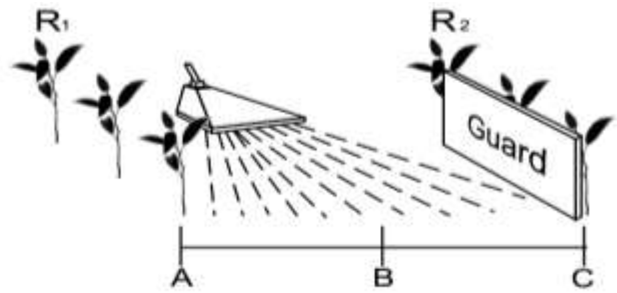


Fig 3. Spraying entire row width

herbicide onto the crops is minimized.

The other method involves spraying the entire row width (A-C) at a go. In this method, the knapsack operator places the back of the shield adjacent crop row R1 and increases the swath to reach the base of crop row R2. The swath is increased by lifting the shield up or tilting the back towards crop row R1. In order to prevent the herbicide from directly drifting onto crop row R2, another person uses a light rectangular board (1 m x 1 m) as guard to shield that row.



**Testing of the shield**

On farm experiments were conducted at Ejisu and Ejura in the forest and forest savanna transition zones of Ghana respectively in 2011 to evaluate the efficiency of the shield for herbicide weed control in cassava. The experimental design was a randomized complete block with 3 replications per site. The treatments studied were i) Half row width sprayed with each pass with paraquat through the shield ii) Entire row width sprayed with each pass with paraquat through the shield iii) Timely hand hoeing and iv) Delayed hand hoeing. The predominant weed at both locations was Euphorbia (*Euphorbia heterophylla*). Land preparation was by slashing and burning the existing vegetation at Ejisu and ploughing once with a tractor at Ejura as generally practised by farmers there. A local cassava variety (Dente) was used for the study. Cassava stems were cut into 25 cm sets and planted by burying at inter-row spacing of 1m x 1 m. Thus the target population was 10,000 plants/ha. Plot size was 6 rows of cassava, 10 m long and the two central rows were used for data collection.

In the herbicide treatment plots, paraquat was applied through the shield at 3 weeks and 6 weeks after planting at a rate of 3 l/ha. The herbicide was applied using a Jacto knapsack sprayer. Half row width spray was done using a low volume nozzle calibrated to deliver a spray volume of 150 l product per hectare. Entire row width spray was done using a medium volume nozzle calibrated to deliver 300 l/ha. Herbicide application was done in the morning, when wind was not blowing (wind was not moving leaves of surrounding trees). Timely hand hoeing involved hoeing at 3 and 6 weeks after planting and delayed hand hoeing was hoeing at 6 weeks after planting. A week after herbicide application, 5 plants were randomly uprooted from each plot and assessed for herbicide injury on a scale of 1-10; were 1 is no plant injury and 10 is total scorching of plant. Weed biomass was estimated at 6 weeks after planting (before weed control) within quadrates randomly taken from 5 points/plot. Time used in weed control was recorded at Ejisu using a stop watch. Economic analysis was performed using the partial budget analysis (CIMMYT, 1988) based on the following costs (Ghana Cedis/ha): paraquat, GH¢ 21; weeding, GH¢ 80; hiring knapsack sprayer and a shield, GH¢4/day; spraying, GH¢14; hauling water GH¢ 12; cassava GH¢ 300/t.

The marginal rate of return (MRR) which is the increased benefit of an option as a percentage of the increased cost, was used to determine the benefits to farmers (CIMMYT, 1988)

## Results

The effects of the different weed control options on cassava and weeds are shown in Tables 1 and 2. At Ejisu, there was no significant difference in plant stand of cassava due to the treatments. The entire row width spray resulted in higher scorching of plants than the half row width spray. Weed dry weight ranged from 10.1 $g/m^2$ for the half row width spray to 114.0 $g/m^2$ for delayed hand hoeing. There was no significant difference in weed biomass between the shielded weed control and the timely hand hoeing plots. Thus weed biomass on the delayed hand hoeing plots was about 5-10 times higher than the other weed control options. The least number of cassava tubers (32667 tubers/ha) was obtained from the delayed hand hoeing plots, and the highest (39556 tubers/ha) was from the timely hand hoeing plots. Similarly tuber yield was highest (21.9 t/ha) on the timely hand hoeing plots and lowest (14.1 t/ha) on the delayed hand hoeing plots. Yield from the shielded weed control plots did not differ significantly from the timely hand hoeing plots.

At Ejura, plant stand of cassava ranged from 7921 plants/ha to 9565 plants /ha, with no significant different among the treatments. Weed weight was highest (287$g/m^2$) on the delayed weed control plots and lowest (29.7 $g/m^2$) on the entire row width spray plots. However there was no difference in weed weight among the shielded weed control plots, and these were also not different from the timely hand hoeing plots (Table 2). The highest yield of cassava was obtained from the timely hand hoeing plot (19.2t/ha) followed by the half row width spray plots (17.9t/ha), then the entire row width spray plot (15.8 t/ha) and the least on the delayed hand hoeing plots (6.3 t/ha).

The economic analysis of the various weed control options are presented in Tables 3 and 4. At both locations delayed hand hoeing lead to the least costs that vary, whilst timely hand hoeing resulted in highest costs. The situation was the same with regards to net benefits. And the entire row width spray was less expensive than half row width spray. Marginal rate of return was highest for the entire row width spray (11,018% and14,900% at Ejisu and Ejura respectively) followed by the half row width spray (8,218% and 14,081% ) and least for the timely hand hoeing plots (2,525% and (4,250%).

**Discussion**

Time used for weed control was highest on the delayed weed control plots because weeds were over grown, which made hand hoeing difficult and time consuming.

Weed control was fastest for the entire row width spray because only one pass was done per crop row. Although weed control was fastest, this method was cumbersome and labour intensive since two people were involved. It also required extreme care in that the knapsack operator and the person holding the guard must move at the same pace to prevent herbicide from drifting onto the crops in row R2 (Figure 3).

The half row width spray resulted in significantly lower scorching of plants than the entire row width spray, possibly because the shield was operated at a lower level above the ground for the half row width spray. This observation is in agreement with findings of Jong *et al* (2000) that lowering the height of a boom sprayer from 70 cm to 30 cm reduced drift by 80%.



At both sites, weed biomass on the delayed hand hoeing plots was about 5-10 times more than the other weed control options. This agrees with Olorunmaiye *et al* who reported significantly higher (3 times) weed biomass on un-weeded plots compared with timely hand weeding and herbicide weed control. Harper (1974) reported that paraquat applied as a directed inter-row spray gave economical control of weeds in cassava for a period of three months or more. Generally weed pressure was higher at Ejura where land preparation was by ploughing than at Ejisu where residues were burnt. Reduced weed infestation due to stubble burning is well documented (Moss, S. R., 1980, Cussans et al 1987, Asefa et al 2004, Joseph at al 2007)

Delayed weed control resulted in 32-35% and 60-67% reduction in yield at Ejisu and Ejura respectively. This agrees with findings of Akobundu (1980) who reported that uncontrolled weed growth caused 40% reduction in root yield of short profusely branching cassava cultivar, while a 68% reduction in root yield was observed in a tall non-branching cultivar.

Yield of cassava was not affected by paraquat despite the injuries caused by the herbicide. This may be due to the fact that cassava recovered from the minor injuries very quickly (about 2 weeks) after herbicide application.

The economic analysis showed that although timely hand hoeing and shielded herbicide weeding resulted in similar net benefits; the marginal rate of return was much higher for shielded herbicide weeding. This is due to the fact that the cost of hand hoeing is about 60% higher than shielded weeding. These findings agree with Akobundu (1980) who drew a conclusion from a study in Nigeria that, it is cheaper to practice chemical weed control in cassava than to rely on hand weeding even if labour is readily available and the weeding can be carried out on time. Usoroh, (1983), Adigun *et al*., (1993), Ishaya *et al*., (2008) also concluded that herbicide weed control is more profitable than manual weeding in Nigeria.

## Conclusion

The knapsack shield that uses off centre nozzle was effective in controlling euphorbia (*Euphorbia heterophylla*) in cassava and resulted in similar yields as timely hand hoeing. Although the economic analysis showed that entire row width spray is more attractive, this method is cumbersome and risky. This is because the shield is operated at a higher level above the ground, which could increase off target drift especially on windy conditions. Consequently the half row width spray is recommended. Further studies are required to determine the efficiency of the shield for application of other broad spectrum herbicides such as glyphosate in other crops. Optimum rates of the herbicides and times of application should also be determined. There is the need to develop a mould for industrial production of the shield using durable plastic.



Table 1: Plant stand and tuber yield of cassava as affected by shield spray (Ejisu)

| Treatment | Plants per ha | Weeding time/plot (minutes) | Plants Scorched | Weed dry weight (g/m$^2$) | No. of tubers/ha | Tuber wt. (t/ha) |
|---|---|---|---|---|---|---|
| Half row width spray | 8542 | 8.4 | 2.0 | 10.1 | 38879 | 20.9 |
| Entire row width spray | 8542 | 5.8 | 3.5 | 12.7 | 33423 | 21.1 |
| Timely hoeing | 8958 | 24.4 | 1.0 | 23.3 | 39556 | 21.9 |
| Delayed hoeing | 7708 | 32.1 | 1.0 | 114.0 | 32667 | 14.1 |
| CV % | 10.7 | 14.3 | 13.8 | 24.2 | 22.7 | 14.2 |
| LSD (0.05) | Ns | 6.2 | 1.5 | 34.4 | 1653 | 5.5 |

Table 2: Plant stand, plants scorched, weed dry weight and tuber yield of cassava (Ejura)

| Treatment | Plt. stand/ha | Plants scorched | Weed dry wt ($g/m^2$) | Tuber wt. t/ha |
|---|---|---|---|---|
| Half row width spray | 9,051 | 2.0 | 32.2 | 17.9 |
| Entire row width spray | 9,565 | 3.0 | 29.7 | 15.8 |
| Timely Hoeing | 8,923 | 1.0 | 42.1 | 19.2 |
| Delayed hoeing | 7,921 | 1.0 | 287.0 | 6.3 |
| CV % | 15.0 | 12.2 | 18.1 | 19.3 |
| LSD (0.05) | ns | 1.0 | 13.2 | 4.2 |

Table 3: Economic analysis of shield spray of paraquat in cassava (Ejisu)

| | Weed management | | | |
|---|---|---|---|---|
| | Delayed hoeing | Half row width spray | Entire row width spray | Timely hoeing |
| Average yield (t/ha) | 14.1 | 20.9 | 21.1 | 21.9 |
| Adjusted yield (t/ha) | 12.7 | 18.8 | 19.0 | 19.7 |
| Gross benefit | 3810 | 5640 | 5700 | 5910 |
| Costs that vary | | | | |
| Paraquat (2X) | - | 42 | 42 | - |
| Renting knapsack sprayer and shield (2X) | - | 8 | 8 | - |
| Hauling of water | - | 24 | 12 | - |
| Spraying herbicide | - | 28 | 21 | - |
| Hand hoeing | 80 | - | - | 160 |
| Labour for holding guard | - | - | 14 | - |
| Total cost that vary | 80 | 102 | 97 | 160 |
| Net benefit | 3730 | 5538 | 5603 | 5750 |
| Marginal rate of return (%) | - | 8,218 | 11,018 | 2,525 |

Table 4: Economic analysis of shield spray of paraquat in cassava (Ejura)

| | Weed management | | | |
|---|---|---|---|---|
| | Delayed hoeing | Half row width spray | Entire row width spray | Timely hoeing |
| Average yield (t/ha) | 6.3 | 17.9 | 15.8 | 19.2 |
| Adjusted yield (t/ha) | 5.7 | 16.1 | 14.2 | 17.3 |
| Gross benefit | 1710 | 4830 | 4260 | 5190 |
| Costs that vary | | | | |
| Paraquat (2X) | - | 42 | 42 | - |
| Renting knapsack sprayer and shield (2X) | - | 8 | 8 | - |
| Hauling of water | - | 24 | 12 | - |
| Spraying herbicide | - | 28 | 21 | - |
| Hand hoeing | 80 | - | - | 160 |
| Labour for holding guard | - | - | 14 | - |
| Total cost that vary | 80 | 102 | 97 | 160 |
| Net benefit | 1630 | 4728 | 4163 | 5030 |
| Marginal rate of return (%) | - | 14,081 | 14,900 | 4,250 |



**References**

Adigun, J.A., Lagoke, S.T.O., Kumar, V. and Erinle, I.D. 1993. Weed management studies in transplanted tomato in the Nigerian savanna. Samaru journal of Agricultural Research 10:29-39

Akobundu I.O. 1980. Weed control in cassava cultivation in the Sub-humid Tropics. Tropical Pest management 26:420-426.

Asefa, T., Douglas T. and Alan T.P B. 2004. Effects of stubble management, tillage and cropping sequence on wheat production in the south eastern highlands of Ethiopia. Soil and Tillage Research 76 (1):69-82.

Awadhwal, N.K., Cabrido, E.F. and Quick, G.R. 1991. Minimizing drift and exposure of herbicides from knapsack sprayers. Journal of Environmental Science and Health 26: 589-600

Cussans, G.W., Moss, S.R., and Wilson B.J. 1987. Straw disposal techniques and their influence on weeds and weed control. Proceedings 1987 British Crop Protection Conference. Weeds. 1:97-106

Ekboir, J., Boa, K. and Dankyi, A.A. 2002. Impacts of No-Till Technologies in Ghana. Mexico D.F.: CIMMYT

Harper, R.S. 1974. Chemical weed control in cassava using paraquat. Tropical Pest Management. 20 (2): 185-189.

Harper, R.S. 1973. Cassava growing in Thailand. World Crops 25:94-97.

Ishaya, D.B., Tunku P. and Kuchinda, N.C. 2008. Evaluation of some weed control treatments for long season weed control in maize (Zea mays L) under zero and minimum tillage at Samaru, in Nigeria. Crop Protection 27 (7) 1047-1051

Jong, A de. Michielsen J.M.G.P., Stallinga, H, and Zande J.C. 2000. Effect of sprayer boom height on drift. Proceedings, 52nd International Symposium of Crop Protection. Gent, Belgium, 9 May 2000, Part II. 919-930

Joseph M. Ditomaso, Matthew L. B,, Edith B A, Ralph M. P. M., Rice, and Guy B. K. *2006.* Control of Invasive Weeds with Prescribed Burning. Weed Technology: 20, (2): 535-548

Olorunmaiye P.M., and Olorunmaiye K. S. 2009. Effect of integrated weed management on weed control and yield components of maize and cassava intercrop in a Southern Guinea Savanna ecology of Nigeria. Australian Journal of Crop Science: 3 (3):129-136.

Onochie, B.E. 1975. Critical periods for weed control in cassava in Nigeria. PANS 24:292-299.

Talatala, R.l., Bacusmo, J.L., Villanueva, M.R. 1980. Response of cassava to different durations of weed control and weed competition. Philippine Journal of Weed Science 7: 11-16

Usoroh, N.J. 1983. Field screening of herbicides for weed control in tomato (Lycoperesicon esculentum Mill). Paper presented at the 13th Annual conference of the Weed Science Society of Nigeria. National Cereal Research Institute, Ibadan 5 December 1983.

Moss, S. R. 1980. Some effects of burning cereal straw on seed viability, seedling establishment and control of *Alopecurus myosuroides* Huds. Weed Research, 20: 271–276.