Solving Africa's Weed Problem: Increasing Crop Production & Improving the Lives of Women

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"Without weeding do not expect any harvest. The back has to ache to conquer the weeds!" ~ Women's group, Zimbabwe

"Oh, weeding is the most taxing job, both in energy and time, because you have to bend down and work carefully not to damage the crop, pull out the weeds and shake them. At the same time, you want to finish the operation before weeds outgrow the crops."
~ Women's group, Zimbabwe

"It is weeding that almost kills women!" ~ Men's discussion group, Uganda

"Hoes with short handles make weeding easier and faster, but they give us backache. There is nothing we can do about that, because if we just complain and don't work, we'll starve!" ~Women's group, Zambia

~ IFAD, Agricultural Implements used by Women Farmers in Africa, 1998.

Photo Credit: E.A. Heinrichs, IAAPS, "Weeding at Niena Village Women's Rice Project," Mali, 2009.

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Introduction

Food production in Africa needs to increase to keep up with the growing population. One key constraint to increasing crop production and improving farmer's lives is poor weed control. Current weed control methods in Africa are inadequate leading to low crop production and lives of drudgery for farmers. This Report provides an overview of the problem of weeds and the inadequacy of current methods of weed control in Africa. A summary is provided of research that has demonstrated the potential for herbicides to overcome the weed problem. Finally, the Report provides quantitative estimates of the potential increase in crop production and reduction in the drudgery of handweeding if herbicides became widely-used by smallholders.

Crop Production

There are 180 million farms in sub-Saharan Africa totaling 170 million crop hectares. About 70% of the food production in the region comes from small farms with the remainder produced on large commercial plantations and government-operated farms (Olofintoye, 1987). The typical smallholder farm consists of several mixed crops –some grown for food (maize, sorghum) and some for cash (groundnuts, cotton). The typical one hectare farm is divided into 8-9 individual fields which are planted sequentially (Tittonell *et al.*, 2007). There is approximately one farm worker per hectare in sub-Saharan Africa.

Most farms in Africa are engaged in both subsistence and market agriculture. Areas where production is used entirely for subsistence, and which are completely self-contained and cut off from the rest of the economy, are very rare, if indeed any remain at all (Cleave, 1992). Smallholder families often survive by means of off-farm employment, principally in other sectors outside the area. Nonfarm income is a significant factor in rural households and provides cash for productivity-enhancing inputs, thus easing credit constraints (Matshe & Young, 2004). A recent survey in

Zimbabwe determined that farm households have an average of two members residing off the farm, providing some monthly remittances from off-farm employment (Dalton *et al.*, 1997).

Current food production in sub-Saharan Africa is substantial including maize (43 million tons), rice (14 million tons), groundnuts (8 million tons), cassava (118 million tons), and sorghum (20 million tons).Total production of all crops is about 250 million tons per year.

Crop yields per hectare in sub-Saharan Africa are significantly lower than the global averages. For maize, rice, groundnuts, and sorghum, yields in sub-Saharan Africa are one-third to one-half of the global average. In fact, the global averages are considerably reduced as a result of the low African yields.

Average yields obtained by smallholder farmers are considerably less than yields demonstrated in African research plots utilizing best management practices. Smallholder maize yields are typically 1-2 tons per hectare in comparison to the 8 tons per hectare achieved in research plots in the region (Tittonell *et al.*, 2007; Bishop-Sambrook, 2003). Typical rice yields are 25% of the experimental plot yields (Devries & Toenniessen, 2001). Cassava yields on experimental sites are often four times greater than the average national yields for many countries (Ambe *et al.*, 1992). Average groundnut yields are one-fifth of the yields achieved on well-managed plots (Page *et al.*, 2002). Smallholder cowpea yields are about one-sixth of those achieved in experimental plots (Obuo *et al.*, 1999).

Optimal yields on small experimental plots are achieved by carrying out farming operations (such as planting, weeding, and fertilizing) at the optimal time and in the optimal amounts. Clearly, smallholder farmers are constrained in replicating the optimal practices conducted in experiments.

The key operation that needs improvement is the timely removal of weeds. Until weeding is improved, farmers in Africa will not obtain the optimum from their crops.

Weed-Crop Interactions

Weeds are the most universal of all crop pests, proliferating each year on every farm in Africa (Obuo *et al.*, 1997). African soils contain 100 to 300 million buried weed seeds per hectare of which a fraction germinate and emerge each year. The soil seed population in a Nigerian experiment was estimated at 20,130 seeds per square meter (200 million per hectare (Chikoye *et. al.*,1997). A review of crop pests in Sub-Saharan Africa indicated that weeds are the most important pest to control in all zones studied (Sibuga, 1997). Over 286 species of common weeds have been identified in crop fields in some West African countries (Njoku, 1996). A total of 263 weed species belonging to 38 families were found in crop fields in West Africa. Broad-leaved weeds(72%) and grasses (24%) dominated the total weed spectrum, whereas sedges (4%) were minor. Mean weed species richness per field was similar across all agroecological zones and averaged about 16 per field (Chikoye & Ekeleme, 2001).

A survey of smallholder wheat fields in Ethiopia found that the weed population reached 743 weeds per square meter in contrast to a crop stand of only 149 wheat plants per square meter (Tanner & Sahile, 1991). Unweeded fields in Nigeria produced between 17 and 30 tons per hectare of fresh weed weight (Adigun *et al.*, 1991). Weed problems are more severe in African tropical regions than in Europe and North America because weeds grow more vigorously and regenerate more quickly because of the heat and higher light intensity. High humidity and high temperature, conditions characteristic of sub-Saharan Africa, favor rapid and excessive weed growth (Akobundu, 1980b).

Weeds compete with crops for nutrients, space, light and water thus reducing crop yields. Numerous studies have documented the negative effects on yield of season-long weed competition in Africa. Under unweeded conditions, crop losses have been measured for: maize (55-90%), common bean (50%), sorghum (40-80%), cowpea (40-60%), rice (50-100%), cotton (80%), wheat

(50-80%), groundnut (80%), and cassava (90%) (Ambe *et al.*, 1992; Akobundu, 1987; Olowe *et al.*, 1987; Ishaya *et al.*, 2007b; Ngouajio *et al.*, 1997; Chikoye *et al.*, 2004; Dadari & Mani, 2005).

One kilogram of weeds reduced the yield of rice by 500-900 grams in a Nigerian experiment (Adeosun, 2008).

Weeds need to be cleared from a field prior to planting a crop and weeds need to be removed from the field during the growing season for optimal yields to be achieved.

Weed competition is most serious when the crop is young. The critical period of crop-weed competition is approximately equal to the first one-third to one-half of the life cycle of the crop. In weed-crop competition studies, the "critical period" is the stage after which weed growth does not affect crop yields. Keeping the crop free of weeds for the first third of its life cycle usually assures near maximum productivity (Doll, 2003).

African crops have been studied at experimental farms in order to define the weed-free period required to prevent yield reduction: (weed-free period [days] required after planting) maize, 56; rice, 42; sorghum, 35; cassava, 84; cowpea, 40 (Obuo *et al.*, 1999; Akobundu, 1987; Ambe *et al.*, 1992).

Handweeding

Hand weeding is the predominant weed control practice on smallholder farms (Vissoh *et al.*, 2004). Hand weeding is the oldest method of weed control and consists of hand-pulling, hand-slashing and hoeing of weeds. Smallholder farmers spend 50-70% of their total labor time handweeding (Chikoye *et al.,* 2007a).Women contribute more than 90% of the hand weeding labor for most crops (Ukekje, 2004). 69% of farm children between the ages of 5-14 are forced to leave school and are used in the agricultural sector especially at peak period of weeding (Ishaya *et al.*, 2008b).

In Africa, 80% of the cultivated land is currently prepared by hand; on 16% of the land animal draught power is used and only 4% is prepared with mechanical power (Adolfsson, 1999). Family sizes have, in many traditional African societies, been increased to cope with weeding activities (Adegoroye *et al.*, 1989).

The contrast between research recommendations and farmers' practices is particularly stark in the case of weed management. Researchers have produced clear-cut recommendations for optimal time of weeding. Research on experimental plots has indicated that to produce maximum yields, a large number of hours of handweeding must be undertaken: groundnuts (378 hours/ha), maize (276 hours/ha), and sorghum (150 hours/ha) (Akobundu, 1987). 200-400 hours per hectare are required to weed cotton and 200-418 hours/hectare to weed rice (Ishaya *et al.*, 2007a; Mavudzi *et al.*, 2001). A total of 324 and 309 hours of labor are required to hand weed one hectare of sorghum and maize fields respectively in northern Nigeria (Ishaya *et al.*, 2008b).

A recent study of women in African agriculture confirmed that weeding took up more days in the field than any other operation (IFAD, 1998). Minimum estimates of the days spent weeding were 60. In Uganda, this figure increased to as much as 120 because of the country's two cropping seasons. In Zambia, with a single cropping season, the estimated time spent weeding was in the 90-120 day range. For maize, weeding by hand took two to four weeks per acre. Several interviews with specialists confirmed that it was impossible for any woman to keep more than one hectare free of weeds in a typical cropping season (IFAD, 1998).

Research has demonstrated the impacts on yield of performing fewer than the optimal number of handweedings. With three properly spaced handweedings, the highest cotton yields (549 kg/Ha)were obtained; with two handweedings, the yield was reduced by 27%(401 kg/Ha); one handweeding resulted in a loss of 55%(249 kg/Ha); and zero handweeding resulted in yields that were 87% lower(73 kg/Ha) than the optimal yields (Prentice, 1972).

30-90 hours per hectare are required to remove weeds before planting (Kienzie, 2002).

Generally, two properly spaced hand weedings within eight weeks of planting of maize (at three weeks and six weeks) give yields comparable to keeping the crop weed-free for the first eight weeks after planting (Orr *et al.*, 2002). One week's delay in first weeding may reduce maize yields by one-third, and two week's delay in second weeding may reduce maize yields by one-quarter.

A delay of the first weeding in cotton by a week increased the initial weed growth 600% and doubled the initial labor demand. Delay of the first weeding by two weeks increased the initial weed growth 2000% and trebled the initial labor demand (Druijff & Kerkhoven, 1970).

Although a lot of energy is expended in removing weeds by hand, crop yields are generally very low due to weed competition, as a result of untimely and ineffective weed control (Chikoye *et al.*, 2004). On most farms, weeding usually competes with other farm activities and is postponed to a later date. Farmers will not weed crops that are sown first until they complete the seedbed preparation and sowing of all other fields. Farmers prefer to go on planting to take advantage of moisture in the soil (Makanganise *et al.*, 1999). This usually results in delayed weeding. Late weeding results in crop losses, especially if it is carried out after the critical period of weed competition.

Poor weed management in cassava fields caused an average yield gap of 5t/ha and restricted production in farmers fields in Kenya in 2004 by 11.6t/ha (Fermont *et al.*, 2009).

Several constraints limit the effective use of hand weeding, including limited cash for hiring labor and labor not being available for hire during peak periods (Johnson, 1995).The supply of labor in rural areas has been significantly reduced in many African countries due to AIDS and migration to urban areas which has led to less weeding of crops (Bisikwa *et al.*, 1997). AIDS is causing the loss of at least 10% of the agricultural workforce in most countries and, in at least five countries, more than 20% (Bishop-Sambrook, 2003).

The scarcity of labor and the concurrent rise in the cost of handweeding make timely removal of weeds by direct labor difficult and expensive. There is an acute shortage of labor at the beginning of the wet season for land preparation, planting and adequate first weedings. No pool of landless rural laborers can be called upon during periods of peak labor demands (Byerlee & Heisey, 1996).There is a shortage of male labor for weeding due to competing labor activities such as wage employment, livestock tending and fencing (Shaxson *et al.,* 1993*).* People usually prefer alternative jobs to hand weeding, if they are available. It is often assumed that family labor is free but labor in all activities has an "opportunity cost."

During the peak period, farmers have little rest. Farmers are often too sick or fatigued to complete weeding (Orr *et al.*, 2002). African women point out that crop management can be neglected during pregnancy, with tasks requiring hard physical work (such as weeding) particularly affected (Webb & Conroy, 1995). In addition to farming responsibilities, African women farmers have considerable family responsibilities- typically caring for six children, elderly parents and sick family members. As a result of these conflicting time demands, weeding is not always carried out in a timely fashion or in the right amounts. Malaria is also a common problem on farms, reducing the availability of productive labor. The scarcity of labor coupled with early season rains often impede timely removal of weeds.

The sowing time of some crops coincides with or just precedes periods of heavy rain, and wet soil conditions do not permit efficient hand weeding or hoeing. For those farmers with heavy soils, excessively wet conditions do not permit efficient handweeding to be done resulting in long periods of crop-weed competition and yield reduction (Chivinge, 1990).

In sub-Saharan Africa, the once readily available and reliable cheap labor force has disappeared in the face of rapid urbanization, improved living standards, and increased educational opportunities. Landless young people have shifted from agricultural activities to off-farm activities

(Vissoh *et al.*, 2004). Labor for handweeding is therefore very scarce and, when available, too expensive for the average farmer to afford (Akobundu, 1979). As a result, it is often impossible to carry out timely weeding by hand. In many instances, labor constraints force farmers to plant their crops after weeds have begun to grow. Such crops are easily smothered by weeds and give an extremely poor yield; in such cases, these fields are abandoned (Ndahi, 1982). Family labor is seriously stretched on farms and has to be deployed continuously for weeding, as the first weeded plots are re-infested by the time the last plots are cleaned.

One effect of the large demand for handweeding labor is that a considerable portion of a farmer's fields may be left fallow and not planted to a crop (Tittonell *et al.*, 2007). The area cultivated is often reduced by 50% because of the farmer's assessment that not enough labor would be available to weed the additional fields (Bishop-Sambrook, 2003).

The principal limiting factor to the size of farms in Africa is the number of necessary weedings during the period following planting (Kent *et al.*, 2001). 80% of farmers said that if weeds were less of a problem, they would increase the area of land under cultivation (Johnson, 1995). African farmers tend to plant as much as they think they will be able to weed. As a result, weeds can be considered as the main constraint on agricultural production.

In Malawi, nationwide survey data suggests that one-third of the area planted to maize by smallholders is either left unweeded or weeded after the critical six weeks (Orr *et al.*, 2002). Maize is generally the first crop to be planted and weeding becomes necessary at a time when labor is critical for planting cash crops such as groundnuts (Mloza-Banda, 1997). Shortage of labor early in the season results in delayed weeding and subsequent maize yield losses of 15-90% due to weed competition (Kibata *et al.*, 2002). In Nigeria, maize farmers' weeding practice (one weeding) resulted in 42% yield loss in comparison to fields weeded three times (Chikoye *et al.,* 2004).

Delayed weed removal is the primary cause of maize yield loss in smallholder agriculture (Rambakudzibga *et al.*, 2002; Chikoye *et al.*, 2005).

A survey of farmers in Malawi revealed that a majority weeded groundnuts late (later than 30 days after sowing) because their limited labor resources were used for other crops (Luhana *et al.*, 1994). The yield penalty for late weeding groundnuts is up to 40%.

Most Nigerian cowpea farmers rarely weed the crop within the first six weeks of growth because of instability in labor supply, cost and demands on their time for other activities, and hence the low yields on most farms (Olofintoye & Adesiyun, 1990).

Time-of-planting trials have shown the vital importance of planting at the start of the rains. In Zimbabwe one third of the maize is planted late because of labor constraints with a yield loss of up to 75% on late-planted fields (Byerlee & Heisey, 1996).

In West Africa, yields of upland rice with farmers' weed control were 44% lower than on researcher weeded plots (Johnson, 1995). In a survey of rice farmers in Cote d'Ivoire, 53% said that their fields were not always weeded (Johnson & Adesina, 1993). A reason given for this by almost two-thirds of these farmers was that weed infestation in the crop may be so severe that weeding was not always worthwhile; therefore, the field would be effectively abandoned. Other reasons given for not weeding included lack of cash to hire labor, sickness, and lack of labor.

In Uganda, 87% of the farmers believed that they currently lose yield to weeds, mainly due to late or inadequate weeding (Webb & Conroy, 1995). In Zimbabwe, 21% of the cotton farmers abandon more than 20% of their cropped area each year as a result of weed infestation (Mavudzi *et al.*, 2001).Weeds are a major factor in reducing crop yields in Zambia, many farms recording an average 30% yield reduction. Indeed some farmers have lost entire crops due to heavy weed infestation (Masole & Kasalu, 1997).

In Africa, yield losses in farmers' fields range from 25% to total crop failure because farmers are unable to perform the necessary weedings at the optimal times (Vissoh *et al.*, 2004). Weeds are perceived by most smallholder farmers as the greatest yield-limiting constraint (Fofana & Rauber, 1999; Vissoh *et al.*, 2004). In Africa yield losses due to weeds average 30% but losses of 50% or more are frequently reported in some parts of sub-Saharan Africa (Sibuga, 1999).

Since handweeding demands a relatively wider spacing, there is little chance to optimize crop-spacing in favor of higher yields.

An econometric analysis of labor decisions by small scale farmers concluded that farmers are unable to allocate sufficient weeding labor for optimal yields in years when rains are abundant because weed growth is rapid and prolific and labor shortages preclude the availability of sufficient weeding (Fafchamps, 1993). As a consequence of less than optimal weeding, yields do not achieve their full potential- even in years of considerable rainfall. Farmers do not undertake overly ambitious production plans since they are likely to lead to weeding manpower constraints.

There is a widespread belief that weeding can be properly performed only if the worker is bent double and armed with a short-handled hoe (IFAD, 1998). It is common that the handle is short to allow the farmer full control of the hoe while she works around the plants, leaving the other hand free to pull out weeds and shake the roots free from soil (Adolfsson, 1999). Hand hoes and other weeding tools are known for high prevalence of back ache among users. Sharp pains result low in the back from the use of the short-handled hoes (Nwuba & Kaul, 1986). Farmers can be seen to be suffering as they often rise and stretch their backs. To weed one hectare of maize a farmer would have traveled a distance of ten kilometers in a stooped position (Mangosho *et al.*, 1999). Handweeding in a stooped position for long periods of time results in permanent spinal deformation (Oyedemi & Olajide, 2002).

African Weed Science Programs

Weeds are an underestimated crop pest for which government spending in Africa on training, research and education is minimal and appropriate weed management technologies remain largely unavailable and/or undeveloped (Sibuga, 1997). Crop losses caused by weeds are "invisible" and are not as spectacular as those caused by other pest organisms (Labrada, 1996).

In some cases, research in weeds is under the responsibility of researchers in other disciplines of crop protection. Such set-ups relegate weed science as a discipline behind the other plant protection disciplines of entomology and pathology. Likewise, crop protection extension concentrates on solving insect and disease problems with little attention paid to weed problems apart from the emphasis on traditional methods such as weeding using hand tools (Sibuga, 1997).

Because weeds do not strike as violently as insects, there is a tendency to underestimate their economic importance. Even when a farmer is forced to abandon a crop to weeds, such incidents do not attract attention. Consequently, the lowest priority is assigned to weed science research in practically all of Africa. There is a lack of graduate level education in weed science (at the masters and doctoral levels) for nationals from Sub Saharan Africa. Consequently, research in weed science is still lagging behind the other disciplines of plant protection (Sibuga, 1997).

The emphasis on entomology and pathology has led to widespread use of fungicides and insecticides by African farmers. For example, 90-98% of the cotton farmers in Uganda, Zambia, and Zimbabwe spray insecticides (ICAC, 2005). Smallholders rapidly adopted the use of insecticides and fungicides to control pests and diseases of cash crops such as cocoa, coffee, tea, and cotton (Padwick, 1968). Fungicides and insecticides are purchased and applied because they are the only practical way to save an infested crop.

One of the reasons for lack of interest in the weed control problem has been a gross underestimation of the fragile nature of the labor force (Akobundu, 1979). It has generally been

assumed that smallholders have excessive hand labor available. Consequently, research into methods of improving weed control has been assigned a very low priority.

Weeding is seen as women's work of little importance and does not receive priority attention. In much of Africa, weeds are accepted as the natural consequences of crop production efforts and little thought is given to improving their control (Akobundu, 1980b).

Less has been done for weeds because (i) weeds as crop pests are largely taken for granted and their biology is poorly understood, (ii) weeding is largely done by women and children, (iii) weed control as a science is in its infancy, and (iv) there is an absence of trained weed scientists to address weed problems in the region (Akobundu, 1991).

Herbicides

The spraying of chemical herbicides to remove weeds is an alternative to handweeding African fields. Herbicides can be used before planting to remove weeds from a field, they can be applied to the bare soil at-planting for residual control of germinating weed seeds, and they can be directly applied to weeds during the growing season. Residual herbicides applied to the soil before the crop and weeds emerge from the ground remain active in controlling germinating weeds until the critical period of weed competition has passed.

Experiments with herbicides to control weeds in crops have been conducted in Sub-Saharan Africa since the 1950s (Idris, 1970). Most of the early herbicide work was focused on the needs of the large-scale commercial farmers (Chivinge, 1990).

In Africa, herbicides have been widely-adopted on large plantations of cash crops: coffee, cotton, sugarcane, cocoa, and tea. Herbicides are widely-used on government-run large farms (Berhanu, 1985). Faced with rising costs and scarcity of labor for handweeding, these plantations largely adopted herbicide technology in the 1960s-1970s (Terry, 1996). Estate farmers have been able to use herbicide technology because they employ their own researchers/agronomists

(Magyembe, 1997). Herbicides have been widely adopted in East Africa for weed control especially in fruit orchards and flower production (Njoroge, 1999). State-run farms consider herbicides an essential component of wheat production (Tanner & Sahile, 1991).

Smallholder farmers in Africa generally do not use herbicides with less than 5% adoption (Overfield *et al.*, 2001; Mavudzi *et al.*, 2001). In some countries (such as Uganda) the adoption of herbicides is very low at .1% of the acres treated (Magyembe, 1997). Herbicides are used on 5-10% of Zambia's and Zimbabwe's cotton acres (ICAC, 2005). A recent survey determined that 4% of groundnut growers in Ghana use herbicides (Bolfrey-Arku *et al.*, 2006).

Herbicides have been extensively studied in weed control research in Africa. However, there has been no mechanism to disseminate the technology to smallholders once the research process was over. This scenario has led to the non-adoption of the herbicide technologies on the small-scale farms even though the research has shown that the herbicide technologies were cost-effective and yielded higher returns than conventional methods (Muthamia *et al.*, 2001).

This research has shown that herbicides produce greater yield at less cost than the typical practice of handweeding (Chikoye *et al.*, 2007b). Comparisons of the economics of different weed control technologies indicate that herbicides reduce the labor requirement for control to between one-tenth and two-thirds of the requirement for manual weeding (Benson, 1982). The overall reduction in production costs associated with herbicides is caused by a massive reduction in the labor required for weeding from 39.2 to 1.3 person-days per hectare (Overfield *et al.*, 2001). The use of herbicides to remove weeds required only 2 hours of labor per hectare (Gouse *et al.*, 2006). Research with maize herbicides in Nigeria demonstrated that the use of herbicides reduced the need for labor at the peak period by 29-42% (Ogungbile & Lagoke, 1986).

Some people have expressed the concern that herbicides are too costly to be used by the majority of farmers in sub-Saharan Africa. However, increasing labor costs and the unavailability of

labor at critical times are rapidly causing the use of herbicides to become more economical than hand labor.

Chemical control is a better alternative to manual weeding because it is cheaper, faster and gives better weed control (Chikoye *et al.*, 2005). Numerous experiments have been conducted that demonstrate the potential positive impacts of the use of herbicides by smallholders:

- Maize yields doubled and production costs fell by 61% in Nigeria when atrazine was used (Benson, 1982).
- In Zimbabwe, research with herbicides resulted in yield increases of up to 55% in maize and 75% in cotton (Chivinge, 1990).
- A recent maize experiment in Kenya determined that chemical weeding was one-third the cost of two hand weedings (Maina *et al.*, 2003).
- The use of preemergence herbicides in cowpea resulted in yields equivalent to those from two handweedings (Ishaya *et al.*, 2008a).
- In a Nigerian experiment, preemergence herbicides kept cowpea plots virtually weed free up to 35 days after planting (Olowe *et al.*, 1987).
- An Ethiopian study showed that herbicides resulted in 97% greater wheat yield in comparison to the farmer practice of one handweeding (Tanner & Sahile, 1991).
- The weed control labor requirement for groundnut production in Zimbabwe was estimated at 107 hours/ha on a plot without herbicide application and .4 hours/ha on a plot treated with herbicides. (The yields were not significantly different) (Benson, 1982).
- In a weed control experiment in Nigeria the cost of weed control with herbicides was .5 and .25 times the cost of using labor for handweeding (Adekpe *et al.*, 2007).
- Groundnut yield with herbicides was equal to yield with three handweedings (Ayeni, 1997).

- About 61% of labor time required in sorghum for traditional hoe-weeding was saved by the use of herbicides (Ogungbile & Lagoke, 1989).
- Research with metolachlor in cowpeas resulted in yields comparable to those receiving the recommended two weedings (Lagoke *et al.*, 1982).
- In a cotton experiment, the use of a complete herbicide program for field preparation, at-planting preemergence, and postemergence treatments reduced the number of hours by 700 per hectare, while the use of the preemergence treatment with handweeding for field preparation and postemergence reduced the labor requirement by 255 hours per hectare (Lagoke *et al.*, 1992).
- A maize study in Zimbabwe compared the cost of herbicide usage versus handweeding and determined that the herbicide treatments plus one-handweeding cost 50% less than two handweedings (Chivinge, 1990).
- The cost of weed control in rice with herbicides was 50% lower than hoe weeding in an experiment in Nigeria (Shave & Avav, 2004).
- Labor use decreased by 54-96% in Nigeria by switching from hoe weeding to chemical control in cassava, yams, and soybeans. Chemical control gave 38-55% higher crop yields, and had a 28-50% lower cost than farmer control methods (Chikoye *et al.,* 2007a).
- In maize-cassava, maize-yam, and maize-cassava-yam intercropping systems, a single application of an atrazine-metolachlor herbicide mixture was observed to be as effective as three handweedings in minimizing weed competition (Akobundu, 1980b).
- In cassava, research showed that chemical weed control was over three times cheaper than two timely handweedings (Akobundu, 1980a).

- Two properly timed handweedings were enough to reduce loss caused by weeds in maize plots. However, this weeding method was nearly three times as expensive as the combined cost of herbicide and labor for spraying (Akobundu, 1980a).
- Recent experiments with preemergence herbicides in sorghum resulted in yields 45% higher than yields resulting from three handweedings (Ishaya *et al.*, 2007b). The herbicide treatments reduced the weed weight from 8.4 t/hectare to .4 t/hectare while sorghum yield increased from .2t/hectare to 5.3 t/hectare. Three handweedings reduced the weed weight to1.7 t/hectare with a sorghum yield of 3.7t/hectare.
- Use of herbicides in Kenyan weed trials resulted in 33% higher maize yields than farmer practice of hand-weeding due to better weed control (Muthamia *et al.*, 2001).

The greatest obstacle between herbicide technology and African farmers is lack of awareness and training. In 1998 and 1999, herbicide evaluation trials in Zimbabwe were funded by the Rockefeller Foundation (Makanganise *et al.*, 1999). In these trials, a residual herbicide was banded down the crop row at planting and controlled weed emergence for eight weeks. Forty-nine farmers participated in the demonstration trials and 690 attended field day demonstrations. The use of the herbicides reduced weed dry matter by 47% and increased maize yield by 16% in comparison with farmer practice (Makanganise *et al.*, 1999). The use of the herbicide reduced weeding time and cost 75% less than hand weeding labor. Farmers wondered why they were not being taught about herbicide technology. Some had not even heard about herbicides before. Farmers asked for more demonstrations in order to gain practical experience. The study determined that lack of knowledge is the most limiting factor in the adoption of herbicide technology (Makanganise *et al.*, 1999). The study concluded that if the smallholder farmers are given technical support, they would take advantage of herbicide technology and improve crop production (Makanganise *et al.*, 1999).

Herbicide use is highest among smallholders who live near agricultural research stations where there are staff who can answer their questions about proper application (Tanner & Sahile, 1991). A recent survey of rice farmers in the Senegal River Valley determined an average cost of 20€/hectare for herbicides (Demont *et al.*, 2009). Farmers using herbicides in rice reduced the necessary amount of manual weeding labor from approximately 64 person-days per hectare to 13. Manual weeding labor was estimated at 1€ per day which means that the 20€ expenditure for herbicides substituted for 51€ per hectare of weeding cost.

Herbicide use is also high among smallholders who farm in cooperatives. For example, in Northern Cameroon an extensive program of weed control with hand sprayers was introduced by the national cotton organization which has an established extension network for farmers (Matthews & Clayton, 1999). Herbicides are used on 70% of Cameroon's cotton acres (ICAC, 2005). Research in cotton in Cameroon demonstrated that herbicides resulted in an increased yield of 400kg/hectare at a reduced cost of 50% and a reduction of 12 days/hectare of labor (Matthews & Clayton, 1999).

Recently, the breeding of a traditional West African rice species (*O. glaberrima*) with the Asian rice species (*Oryza sativa*) resulted in a series of new varieties known as New Rice for Africa (NERICA). One of the characteristics of the NERICA varieties is that they are more competitive with weeds requiring 25% less labor for weeding (Ekeleme *et al.*, 2009). With no weeding, the NERICA varieties yield 40% more than unweeded traditional varieties. Optimal yield of the NERICA varieties requires two weedings which increases yield by 220% over NERICA varieties unweeded. One weeding increases NERICA yield by 57% over unweeded NERICA plots (Ekeleme *et al.*, 2009). Although the NERICA yields approach their potential when weeded twice, most rice farmers are known to avoid a second weeding owing to insufficient time and high labor costs. Research has shown that a pre-emergence herbicide application plus one handweeding is sufficient to control weeds in fields growing NERICA (Akintayo, 2007).

Constraints on Herbicide Use

Chemical weed control has great potential and will become more widely-adopted by smallholders as solutions to the major constraints limiting herbicide use in Africa are found. These constraints include (a) inadequate knowledge of which herbicide to use in a given weed-crop situation, (b) poor timing of application (c) unavailability of herbicides in farmer-usable packages (d) uncertainty of availability of herbicides (e) limited knowledge of herbicides and their use (f) lack of extension services and (g) scarcity of trained personnel in weed science (Mavudzi *et al.*, 2001).

For herbicides to be successfully introduced, several major infrastructure systems must be improved (Benson, 1982):

- The credit system: The low-income farmer often needs inexpensive credit.
- The extension system: The effectiveness of the extension system depends on the level of training and competence of its agents, the frequency of visits, demonstrations, and communications and its credibility.
- Transport and distribution: In order for herbicides to be useful, they must be available on time. Also, they must be available in quantities suitable for use on small farms.
- Marketing and storage: Crops must be transported to market quickly and be sold at a fair price.

Recommendations on how to use herbicides are dependent on which weeds are present and many agronomic, soil and crop factors-all of which need careful study and communication to farmers.

Training of personnel for research and extension is essential to weed control. There is a need for subject matter specialists capable of evaluating each country's weed problems and formulating herbicide recommendations (Akobundu, 1980b). Weed scientists are scarce in most African

countries which has limited the necessary research. In some countries, the number of professionally trained weed scientists is too few to make any meaningful impact on research, extension or policy. There are more weed scientists in the state of California than in all of Africa (Akobundu, 1980b).

There is a need to train extension workers on herbicide technology, who would in turn train the farmers. There is a need to develop extension materials for farmers. If the smallholder farmers are given technical support, they would take advantage of herbicide technology and improve crop production (Makanganise *et al.*, 1999).

The lack of well-trained weed specialists and the limited funding available for related research and extension activities are major constraints that need to be overcome in the near future. Field projects are required to develop research and extension and raise awareness among agricultural officials and farmers of the problems caused by weeds (Labrada, 1996).

Efforts must be made to enlighten governments on the role of weed science in the crop production equation so as to bring governments to bear on the need to address the problem with plans of action on training, research and extension (Sibuga, 1997).

The Universities do not have adequate weed science curricula. What is urgently needed is graduate-level education in weed science (at the master's and doctoral degree levels) for nationals from the region (Akobundu, 1991). The need for better and more readily available extension advice on weed control remains a perennial recommendation (Mloza-Banda, 1997). The government agricultural extension agencies are ill-staffed with professionally trained chemical weed control specialists who can demonstrate the effectiveness of herbicides and effectively transfer the technology to the farmer (Ayeni, 1997).

There are many US-funded agricultural development projects in Africa with several US universities as contracting institutions. Nearly all of them have training in agricultural economics,

plant breeding, and agronomy, but hardly any of the projects have included training in weed science for any of the nationals (Akobundu, 1991).

A systematic study of the biology and ecology of important weeds in the individual countries and use of this knowledge is necessary in developing efficient weed control methods (Sibuga, 1999).

Fertilizer Usage Potential

Increased use of fertilizers has been promoted for several decades as a way of significantly increasing crop yields in sub-Saharan Africa. At the African Fertilizer Summit of 2006, the African Union member states set a goal of increasing fertilizer use by 500% by 2015 (IFDC, 2007). Current use of inorganic fertilizers is low in sub-Saharan Africa with only 5% of smallholder farmers applying them. Application rates are typically far below recommended rates (50kg/ha vs 250-350 kg/ha) (Dar & Twomlow, 2004). Fertilizer tends to be used mainly on cash crops and plantation crops.

The benefits of fertilizer applications are dependent on weed control. Applying fertilizer is a labor intensive task with farmers in a stooped position applying fertilizer directly to the plants by hand. Applying fertilizer competes for labor with weeding and planting of additional crops. As a result, fertilization is either not done or performed at the wrong time and crops may not respond to fertilizer applied late (Makanganise *et al.*, 1999).

Many weeds absorb nutrients faster and in larger amounts than crops (Okafor, 1987). In an experiment in Zimbabwe, weeds removed three times as much potassium and two times as much nitrogen from the soil as did maize. Maize trials in South Africa ascertained that increased fertilization on weedy plots increased yield losses caused by weeds by 62% (Benson, 1982).

A Nigerian sorghum experiment found that the application of 60 and 120 kg N/ha caused increases of 32% and 78% respectively in weed dry weights (Okafor & Zitta, 1991). In an

experiment in Ethiopia, wheat receiving 138 KG of N per hectare required 23 more work days for hand weeding than non-fertilized wheat. The application of 41 kg/ha of N increased the weed population by 500,000 per hectare (Tanner *et al.,* 1993*).* Fertilizer application increased the labor required during peak season by 64 hours per hectare in sorghum which included increased weeding time (Wubeneh & Sanders, 2006).

Handweeding only can take place when the weeds reach a manageable size-say 2-4 weeks after crop planting. Those fertilizer quantities which have been taken up by weeds during those first 2-4 weeks are utilized by the weeds at the expense of the crop (Makanganise *et al.*, 1999).

In 2006/7 the government of Malawi provided subsidies for smallholders to purchase fertilizers which led to widespread use. An evaluation of the Program showed that the cost of weeding increased an average of 22-57% (Dorward *et al.*, 2008).

Without weed control, increased fertilization simply leads to more weeds with the subsequent need for more labor to pull them. Farmers are reluctant to increase fertilizer use because of the need for more handweeding. African farmers will not use greater amounts of fertilizer until the weed problem is brought under control.

Potential Impacts of Herbicide Use

By reducing the labor requirement for weed control, herbicide use could allow additional resources to be invested in food crops to the benefit of food security in the area (Mavudzi *et al.*, 2001). The potential benefits of herbicide use include increased incomes, reduced drudgery, and improved food security and nutrition. These benefits accrue to women, young people, and the very poor who often bear the brunt of weeding (Chikoye *et al.,* 2007a). A social benefit is realized when herbicide use releases children from the daily drudgery of weeding crops so that they may attend school. The small number of farmers who use herbicides send a higher proportion of their children to school (Overfield *et al.*, 2001). Millions of women have been destined to spend most of their

lives in the endless drudgery of manual weed control. Herbicide use would provide release from much of this toil, enabling more time for education and other activities and alleviation of chronic back pain and spinal deformation. It is unnecessary for herbicidal control to be complete. A very considerable reduction in weeding labor is obtained by controlling 80-90% of the weeds.

One concern is that herbicide use in African countries will tend to increase unemployment. This may have been true in regions with large farms, employing a substantial work force, but not for the vast majority of small-scale farmers who do not employ outside workers (Labrada & Parker, 2003). Rather, farm families spend a large proportion of their time in weeding operations, time which could be more productively used (Labrada & Parker, 2003).

The economic benefits of herbicides can be realized if the labor released from hand weeding is gainfully employed elsewhere. There is ample work in other crops which is delayed or often skimped due to lack of labor. Additionally, in cotton and groundnuts, there is much work other than hand weeding which requires hand labor early in the season. Better attention to such work should result in higher yields from all crops (Idris & Thomas, 1970). Increasing the area that is harvested through improved weed control will provide more employment opportunities for hired labor during the harvest (Mavudzi *et al.*, 2001).

Farmers in participatory weed control trials in Kenya were all in favor of herbicide use and said that the saved labor is used in some other farm activities (Muthamia *et al.*, 2001). In Kenyan maize experiments, there was no appreciable differences between the total labor requirements on the herbicide-treated and the control plots. This was because the time saved in weeding was used up in harvesting increased yield on the herbicide plots (Ogungbile & Lagoke, 1986). A system of chemical weed control in tea has evolved in East Africa which has cut weeding costs by 75%. Harvesting the increased crop has absorbed all the labor released by the cessation of manual weeding; productive work has replaced the drudgery of handweeding (Willson, 1972).

Using herbicides in groundnut production would save two to three weeks of time, allowing timely attention to other tasks including potentially significantly increasing the area planted with groundnuts (Schilling, 2003).

If farmers used herbicides they could alleviate their labor bottleneck during the peak period with labor being released for operations on other crops (Tanner & Sahile, 1991).

It is the use of time and the return to family labor that is of prime importance to the African farmer. If the farmers can use time saved from manual weeding to carry out other profitable operations (extension of farmed area, more timely sowing of later crops, planting and tending a cash crop) then there is a good case for using herbicides (Benson, 1982).

Herbicides can be useful to the smallholder using family labor even though there is no direct saving in labor cost since they may be used to increase the production of cash crops by releasing labor from the food crops at the correct sowing periods. Labor is the most limiting resource for the household (Tittonell *et al.*, 2007).

The results of a research program in Kenya indicated that herbicides can improve the economic returns of smallholder farms (Kibata *et al.*, 2002). The main reasons for this were increased yields of maize and beans due to more effective weed control during the critical period of crop growth when there is a shortage of labor for manual weeding. The removal of this constraint by use of herbicides increased the yields by 53% in maize and 94% in beans in the maize/bean intercrop and 38% in the maize monocrop. The net benefits increased as a result of reduction in production costs associated with herbicides. The herbicides allowed large reductions in labor required for weeding. The net benefits increased by 61% in the maize/bean intercrop and 46% in the maize monocrop. The potential impact of these findings is that herbicide use in maize can improve the economic status of rural communities, enhance food security and improve livelihoods. The reduced drudgery

for weeding would also increase the ability of farmers to cultivate more land with higher economic returns.

The various possible benefits of herbicide use include (Parker & Vernon, 1982):

1. improved yields due to more effective weed control especially early in the crop's life, when the critical period of weed competition occurs and when wet conditions may preclude effective removal by manual weeding.
2. an increased area of crops within the scope of a single family
3. an indirect increase in yields achieved by releasing labor from one crop, in which herbicides have been used, for the more timely planting or improved care of another crop, such as cotton
4. improved yields achieved by permitting a larger area to be planted at the optimum time, instead of having to spread out planting to avoid having too large an area requiring weeding at any one time.

Evidence from on-farm participatory trials conducted in Kenya and Uganda indicate that herbicides can increase the net benefits to farmers of cultivating maize by up to 80%. When this is combined with their ability to alleviate seasonal and gender-based labor constraints, their potential contribution to a more successful and economically sustainable farming system is substantial (Overfield *et al.*, 2001).

A 2009 assessment from the US National Academy of Sciences identifying technologies to benefit farmers in sub-Saharan Africa pointed out that lightweight herbicide sprayers would transform agriculture in the region (NRC, 2009). The Report noted that a woman can farm twice the area and farm with far less drudgery with an herbicide sprayer than with hand weeding, and the yields are greater. The Academy Report also noted that herbicide-tolerant maize has been released in South Africa and is increasingly popular among small scale farmers because the use of herbicides

has eliminated drudgery associated with hand weeding, allowed cultivation of larger areas, and substantially increased yields (NRC, 2009).

Recent Demonstration/Control Projects

The parasitic weed *Striga* is the focus of considerable stand-alone research and treatment programs including the breeding of resistant cultivars and use of herbicide seed treatments (Ejeta & Gressel, 2007).

Oxfam has provided herbicides to African farmers in areas where AIDS has reduced the available supply of labor for weeding. In Malawi, Oxfam initially supplied herbicides to 1450 farms in 81 villages (Oxfam).

Herbicides are being supplied in programs that promote reduced tillage (Seward, 2007). There are many groups such as Sasakawa Global 2000, Monsanto, and Winrock International that have promoted conservation tillage with herbicides replacing tillage for clearing weeds from fields before planting (Findlay, 2004). Labor requirements and erosion have been shown to be reduced under the conservation tillage program while crop yields have increased. It was estimated that in 2000, no-till was used by 100,000 small scale farmers in Ghana (Ekboir *et al.,* 2002).

In 2008, 25 herbicide demonstration plots were established in both Kenya and Malawi through a network of agrodealers supported by CNFA. The Project was coordinated by the CropLife Foundation with funds from four multinational herbicide Companies. 3700 farmers visited the demonstration plots during field days. The plots with herbicides yielded 26% more maize than the plots that were handweeded. The cost of herbicides was 50% lower than the cost of handweeding and there was a reduction of 150 hours of labor per hectare in the herbicide-treated plots (Gianessi & Kiingi, 2009).

Potential Aggregate Impacts of Herbicide Use

There are approximately 180 million one-hectare smallholder farms in sub-Saharan Africa. Of these approximately 20% are cultivated with tractors or animals. The remaining 80% are cultivated by hand. Herbicides are currently-used on approximately 5% of the smallholder farms. The assumption is made that 75% of the smallholder farms representing 135 million hectares are handweeded. It is assumed that one woman is responsible for handweeding each hectare which implies that 135 million women are currently handweeding.

The optimal amount of handweeding required per hectare is estimated to be 400 hours which implies that 54 billion hours of handweeding would be required to produce optimal crop yields. However, it is assumed that only one-half of the optimal weeding is currently performed which means that 27 billion hours of handweeding is currently undertaken. It is estimated that herbicide use would eliminate the need for 90% of the labor in weeding for an aggregate reduction of 24 billion hours.

Approximately 70% of the 250 million tons of crops grown in sub-Saharan Africa is produced on smallholder farms. 75% of the smallholder farms are handweeded. It is estimated that 131 million tons of crops are currently produced on the 135 million hectares that are handweeded. It is assumed that crop yield loss on handweeded hectares due to poorly-controlled weeds averages 30% in sub-Saharan Africa. By preventing this yield loss through the use of herbicides, an additional 40 million tons of crops could be produced.

It is believed that the estimate of potential crop production increase is conservative since it does not account for the planting of additional fields and the use of fertilizer; both practices would increase as a result of herbicide use and further increase aggregate crop production.

Summary

Weed infestation and reinfestation are heavy and rapid allowing no breathing space for the African farmer. The subsistence nature of African agriculture can be largely attributed to the presence of weeds and the absence of improved methods of controlling them (Adegoroye *et al.*, 1989). The inability to control weeds by hand, declining labor availability due to AIDS, food shortages, and the drudgery involved in weeding in wet conditions means that the use of herbicides is going to be increasingly justified (Mashingaidze *et al.*, 2003).

Even when other inputs such as fertilizer and improved seeds are available, it will be difficult to raise agricultural output much above subsistence level as long as the hand-hoe remains the primary means of tillage and weeding (IFAD, 1998). African farmers are reluctant to use fertilizer because of worsening weed problems and higher labor demands.

Shortage of labor for weeding limits total arable land that can be cultivated and this limits total food production (Akobundu, 1991). It is difficult to imagine how African countries can achieve economic, industrial and educational development if the majority of its populace is engaged in the provision of back-breaking labor for food production such as weeding..

If weed management is not improved, sustainable food production will not be realized and farming in general will continue to be full of drudgery and unattractive to the younger generations (Akobundu, 1991). This is one of the underlying reasons for urban migration.

Herbicides have great potential for solving the weed problem in Africa. Herbicides are less expensive than the hiring of labor for handweeding. Herbicides reduce the need for labor during planting time allowing for more fields to be planted and fertilizer to be used. Herbicides are more effective than the current practice of handweeding; thus, crop production would increase with herbicide use. Herbicide use would improve the lives of women by eliminating the need for back breaking labor which leads to lifetime back deformities.

Herbicides are used on more than 90% of the cropland in developed countries- the US, EU countries, Japan Australia. Herbicides are used by more than 90% of large-scale commercial farmers in Africa. It is the smallholder farmer in Africa that currently is not benefitting from herbicide technology. If given the choice, African smallholders are likely to adopt herbicide usage as their counterparts have all over the world.

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