International Scholars Journals

International Journal of Agricultural Economics and Extension ISSN: 2329-9797 Vol. 3 (5), pp. 151-157, May, 2015. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Production and productivity of maize subjected to modern and traditional methods of weed control options in Federal Capital Territory, Nigeria

Dumisani V. Bulawayo

Department of Agricultural Economics and Extension, Faculty of Agriculture, Midlands State University, Gweru, Zimbabwe.
E-mail: dbula009@msu.ac.zw

Accepted 23 January, 2015

This study was designed to evaluate the implications of using alternative weed control options on viability, production and productivity of maize crop in the Federal Capital Territory (FCT), Nigeria. Data were collected using a structured questionnaire from 451 randomly selected smallholder farmers. Gross margins, regression and correlation analysis were used to analyze the data. About 72% of farmers who grew maize practiced manual weed control while 40% used integrated modern and manual weed control. Results revealed that viability was higher in maize subjected to integrated (119,664.38 naira/ha) than in manual (4211.63 naira/ha) weed control. Seed rate (β = 0.155), variety (β = 0.283), herbicides (β = 0.593), fertilizer (β = 0.100) and labour (β = 0.535) were positive and significant determinants of maize output with a coefficient of determination of 0.823. Productivity of seed, labour, and fertilizer were higher under integrated weed control option than manual weed control. There was a positive association between use of herbicides and resource productivity (seed quantity (r = 0.607), herbicides (r = 0.526), fertilizer (r = 0.347) and labour (r = 0.770). Farmers were therefore encouraged adopt herbicides to improve viability, production and resource productivity. There was need for further research to identify intervention areas for inducing adoption of herbicides by farmers.

Key words: Integrated weed control, manual weed control, gross margins, regression.

INTRODUCTION

Food and Agriculture Organization (FAO) projections in food demand suggest that cereal demand will increase by almost 50% towards 2050 (FAO, 2003). This is in line with the expected increase in population over time, the past 100 years have seen the world's human population increasing by nearly fourfold (UN population Division, 2007) and it is projected to increase from 6.7 billion (2006) to 9.2 billion by 2050.

To increase crop production in line with increasing demand for food, three primary factors should be considered and these are; increased cropland and rangeland area (15% contribution in 1961 to 1999); increased yield per unit area (78% contribution); and greater cropping intensity (7% percent contribution) (FAO, 2006). Thus for food production to keep pace with population demand, there is a need to invest in more efforts to increase yields, continued expansion of cropland by conversion of natural habitats, or by optimizing food or feed energy efficiency from production to consumption.

One of the serious challenges to productivity increases, cropland expansion and intensification is the threat from invasive alien species such as pests and diseases that have been estimated to cause an annual loss of US$12.8 billion in yield of eight of Africa's principal crops and may reduce yields in developing countries overall by around 50% (Nellemann et al., 2009). Rossman (2009) estimated that alien invasive weeds and pathogens are estimated to be responsible for about 8.5 and 7.5% in yield reduction, respectively, equivalent to US$24 billion and US$21 billion of acrop value of US$267 billion. Across Africa and worldwide, a weed species of the genus *Striga* has a direct impact on local livelihoods; it affects more than 100 million people and as much as 40% of arable land in the savannas.

Weed management is thus an important operation in crop production that should be effectively and efficiently carried out to ensure desired production and productivity increases for improved livelihoods and welfare. One of the main objectives in agricultural societies is attainment of an optimally high level of living with a given amount of effort, thus, an increase in the productivity of resources employed in farm production amounts to progress and according to Gianessi (2009), unless weeding is improved among other things, farmers in Africa will not obtain the optimum from their crops. Thus efficiency and efficacy in weed management, is one strategy that can ensure achievement of food production goals.

There are five common methods used in weed management namely manual, mechanical, cultural, biological and chemical weed control (Anyanwu et al., 2003). It is recommended that farmers should chose methods that enhance crop production and profitability. The choice among weed control option by rational individuals is however based on the economic implications of different options of weed control among other factors. Given the various alternatives to weed control, rational farmers are expected to use cost effective methods that are more productive to ensure greater returns from their farming.

Outcomes from experimental trials on weed control have been favouring use of chemical weed control options given the high returns exhibited from experimental trails (Ayoola and Adedzwa, 2005). However, given the differences that exist between experimental situations and real farmer situations there is a need to evaluate and verify experimental outcomes in real (farmer) circumstances. This study was carried out to evaluate implications on viability, production and productivity of alternative weed control options practiced by smallholder maize farmers. The study is instrumental in guiding resource adjustments and policy strategies in weed control for successful crop production.

MATERIALS AND METHODS

Study area

The study was carried out in Federal Capital Territory (FCT) of Nigeria with a total human population of 1,405,201. Out of this population size, the farming population is 446,506 and the total farming households is about 93,092 distributed in 6 council areas (FCTFDP, 2007).

Sampling

Random sampling technique was used to draw a proportionate sample from each council area to build up a total sample of 451 households. A structured questionnaire was used to collect data on crop production, socio-economic environment and weed control practices from farmers with the assistance of Fadama project enumerators.

Data analysis

Descriptive statistics, gross margins, regression, production function and correlation analysis were used to evaluate viability, production and productivity of alternative weed control options in maize crop.

Gross margin analysis

Gross margin budgeting is one technique that can be used to evaluate economic viability of alternative activities and provide a guide in deciding among different options (Vere et al., 1997). In this study, total income (TI) was compared with total variable cost (TVC) to provide a gross margin. A positive margin will imply that the activity is viable and a negative margin implies a non viable activity. Comparing the gross margins under alternative weed control options will provide a guide on the most desirable options.

Regression analysis

Regression analysis was used to estimate the production function of maize including the influence of weed management option on maize output, different forms of production functions were fitted to the maize production data and the best fitting model selected, the model is specified as:

$$Y = F(X_1, X_2, X_3, X_4, X_5, X_6, U) \quad (1)$$

Where output (Y) of maize was expressed as a function of hectares of land cultivated (X_1), amount of seed (X_2), variety of seed (X_3),

Table 1. Crop production in the FCT, Nigeria (N = 451).

Major crops	Percentage of farmers producing
Maize	87.4
Yam	81.8
Sorghum	54.3
Groundnuts	43
Rice	39.1
Cassava	36.9
Okra	18
Millet	16
Pepper	14.2
0thers (sesame, beans, cowpeas, ginger, melon, tomatoes and pumpkins)	20.1

Source: Field survey.

total labour hours used for all operations (X_4), amount of fertilizers used (X_5), and amount of herbicide used (X_6).

The different forms of production function are as specified in Equations (2) to (5) as a linear, Cobb-Douglas, exponential and semi log functions of the inputs respectively.

$$Y = a_0 + a_1 X_1 + a_2 X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 +U \quad (2)$$

$$\text{Log } Y = a_0 + a_1 \log X_1 + a_2 \log X_2 + a_3 \log X_3 + a_4 \log X_4 + a_5 \log X_5 + a_6 \log X_6 + \log U \quad (3)$$

$$\text{Log } Y = a_0 + a_1 X_1 + a_2 X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 +U \quad (4)$$

$$Y = a_0 + a_1 \log X_1 + a_2 \log X_2 + a_3 \log X_3 + a_4 \log X_4 + a_5 \log X_5 + a_6 \log X_6 + \log U \quad (5)$$

Where a_0 to a_6 = unknown parameters. U= Error term. The best fitting equation was chosen on the basis of the magnitude of the coefficient of multiple determination (R^2), significance of coefficients, significance of overall production function as given by F value, and the appropriateness of signs of the regression coefficients based on a priori expectations. The t-test was used to determine the significance of variables in the model.

Productivity analysis

The average physical product for each input was calculated by Y/X_i, the marginal physical product as dy/dx_i and the marginal value product as $(dy/dx_i)P_{maize}$). The ratio of MVP/MFC was used as an indicator of optimality of resource use was determined by dividing the marginal value product by the marginal cost of input (cost per unit input). To determine the significance of any differences in resources productivity between farmers using manual and chemical weed control options, a Z-test was used.

Correlation analysis

In order to ascertain the relevance of herbicides in maize productivity, correlation analysis was used to measure the degree of association between use of herbicides and resource productivity. The correlation coefficient (r) was calculated using the formula:

$$r = \frac{n\sum X_i Y - \sum X_i \sum Y}{(n\sum Y^2 - (\sum Y)^2 (n\sum X_i^2 - (\sum X_i)^2)} \quad (6)$$

Where Y was amount of herbicides used as a measure of use of chemical weed control option. X_i variable representing resource productivity of input i (i=seed, labour, fertilizer and herbicides).

RESULTS

Crop production and maize cropping practices by farmers in the FCT

Farmers were producing a variety of crops. The majority of farmers were producing maize (87.3%), yam (81.8%) and sorghum (54.3%). Other crops produced were groundnuts, rice, cassava, okra, millet, pepper, sesame, beans, cowpeas, ginger, melon, tomatoes and pumpkins in order of decreasing importance (Table 1). Maize was the dominant crop produced, hence it was chosen in the gross margin analysis as a case study. On average 1.2 ha of maize were produced per household and 61.4% of farmers who grew maize used a local variety of maize while 38.6% used improved varieties. The seed rate was on average 16.8 kg/ha.

About 72% of farmers who grew maize practiced manual weed control where weeds were removed by hoes, cutlasses, and hand pulling and 40% used integrated modern weed control methods that involved applying herbicides in addition to manual weeding. Common herbicides used in maize were gramoxozone, 2-4-D and atrazine in order of decreasing importance.

Labour was the major input in maize production. On average labour usage per hectare in all farming operations was 58 labour days. About 71% of farmers did not apply any fertilizer in maize production while 29.4% applied fertilizer at an average rate of 41.2 kg/ha

Gross margins analysis

Average output was higher for users of herbicides than in manual weed control and the margins were very large

Table 2. Maize output, yield and gross margins under manual and chemical weed control.

Variable	Manual (N=282)	Chemical (N=112)	Z-value
Average output (Kilograms)	892.65	3223.57	-7.559**
Average land (Hectares)	1.2	1.5	-1.80
Average labour days	74.84	51.89	3.661**
Average fertilizer use (Kilograms)	32.98	129.2	-3.829**
Average seed (Kilograms)	17.88	19.99	0.994
Average yield (Kilograms/hectare)	743.88	2149.1	-11.882**
Gross margins/ha (1- (2+3+4)	4211.63	119664.38	-10.015**
Value of output	44632.45	161178.75	-7.559**
Cost of labour	37418.35	25947	-3.661**
Cost of fertilizer	1433.40	5616.52	-3.983**
Cost of seed	1569	2578.80	-2.909**
Cost of chemicals	0	7371.88	-8.221**

Source: Field Survey, 2008. **Z value was significant at 1 percent, *Z value was significant at 5%.

Table 3. Impact of herbicide use on maize production.

Coefficients	Linear	Cobb Douglas	Exponential	Semi log
Constant	-111.838 (-1.180)	3.551 (12.649)**	5.811 (103.926)**	1320.835(1.517)
Land	88.009 (1.060)	0.245 (1.192)	-0.315 (-6.435)**	4387.325 (6.886)**
Seed	14.503 (2.165)*	0.155 (2.104)*	-0.00014 (-0.036)	149.671(0.655)
Variety	393.396 (3.586)**	0.283 (4.072)**	0.433 (6.685)**	191.397 (1.282)
Herbicides	238.949 (13.150)**	0.593 (13.794)**	0.173 (16.176)**	467.832 (3.506)**
Fertilizer	5.911 (14.705)**	0.100 (9.078)**	0.0013 (5.270)**	287.046 (8.378)**
Labour	4.988 (2.324)*	0.535 (5.282)**	0.013 (9.956)**	-1038.922 (-3.306)**
R^2	0.783	0.823	0.663	0.623
F	237.089**	299.387**	126.813**	106.709**

Source: Field Survey. **t value was significant at 1%, *t value was significant at 5%.

(2331 kg). Usage of variable inputs (land, fertilizer and seed) was also high for users of chemical weed control option than in manual weed control option. However, use of labour was higher for users of manual methods (74.84 days) than it was for users of chemical control methods (51.89 days).

Output and average yields per hectare were higher for users of chemical weed control than for manual weed control. Overally, maize crop subjected to chemical weed control had higher gross margins (119,664.38 naira) than in manual weed control (4211.63 naira). This can be attributed to high cost and usage of labour among other things. In manual weed control about 44% of farmers had negative gross margins while in chemical weed control, maize production was viable for all the farmers. Table 2 is the summary of the gross margin analysis.

Impact of use of herbicides on maize production

The Cobb-Douglas production function was the best fitting equation and thus formed the basis of this analysis. Land (β = 0.245) was positively associated with output but the relationship was not significant at 5%. Seed (β = 0.155), variety (β = 0.283), herbicides (β = 0.593), fertilizer (β = 0.100) and labour (β = 0.535) were all positively associated with output and the relationships were significant at 5%. All the explanatory variables together explained about 82.3% of the total variation in value of output of maize (Y) as indicated by value of R^2 of 0.823. Table 3 is a summary of results from the regression analysis.

Productivity of maize under manual and chemical weed control

Productivity of seed, labour, and fertilizer were higher under chemical weed control option than manual weed control with margins, APP_{seed} (111 kg), APP_{labour} (59 kg) and $APP_{fertilizer}$ (6 kg). The same applied to MPPs and MVPs as they are derived from APPs according to formula in the methodology. At the prevailing prize of maize output of 50 naira per kilogram, the MVPs were

Table 4. Resources productivity in maize crop under traditional and modern weed control options.

Resource	Traditional	Modern	Difference (margin)	Z-value	R
Seed					
N	282	112			
APP_{seed} (kg)	53.15	163.77	110.62		
MPP_{seed} (kg)	8.24	25.38	17.14	-13.380**	0.607**
MVP_{seed} (naira)	411.90	1269.22	857.32		
MVP/MFC	6.11	11.42			
Labour					
N	282	112			
APP_{labour} (kg)	2.58	61.55	58.97		
MPP_{labour} (kg)	6.73	32.93	26.2	-23.288**	0.770**
MVP_{labour} (naira)	336.51	646.37	309.86		
MVP/MFC	0.42	2.06			
Fertilizer					
N	57	59			
$APP_{fertilizer}$ (kg)	13.85	19.90	6.05		
$MPP_{fertilizer}$ (kg)	1.39	1.99	0.6	-6.445**	0.347**
$MVP_{fertilizer}$ (naira)	69.24	99.48	30.24		
MVP/MFC	1.39	1.99			
Herbicides					
N		112			
$APP_{herbicides}$ (kg)		556.64			
$MPP_{herbicides}$ (kg)		330.09			0.770**
$MVP_{herbicides}$ (naira)		16504.44			
MVP/MFC		13.73			

Source: Field Survey, 2008; **-value was significant at 1%, *-value was significant at 5%. r = Correlation coefficient between resource productivity and use of herbicides.

also higher for maize under chemical weed control than manual weed control. The differences were significant at 5 percent level across all inputs (Table 4).

The MVP_{seed}/MFC_{seed} ratio was 6.11 under manual weed control and 11.42 under chemical weed control and the differences were significant at 5%. The $MVP_{labour}/MFC_{labour}$ ratio was 0.42 under manual weed control and 2.06 under chemical weed control and the differences were significant at 5%. The $MVP_{fertilizer}/MFC_{fertilizer}$ ratio was 1.39 under manual weed control and 1.99 under chemical weed control and the differences were significant at 5%. The ratio of MVP/MFC of herbicides was 13.73 (Table 4). This indicated inefficiency in the use of all variable resources by all farmers.There was a positive association between use of herbicides and resource productivity (seed quantity (r = 0.607), herbicides (r = 0.526), fertilizer (r = 0.347) and labour (r = 0.770). The relationships were significant at 5% level (Table 4). This indicated the significant role played by herbicides in improving resource productivity.

DISCUSSION

The results indicated that there were higher yields, output and gross margins in using chemical weed control as compared to manual weed control in smallholder maize production. This implied that chemical weed control improved viability of smallholder maize production. This outcome was similar to research findings by Ayoola and Adedzwa (2005) which proved that use of herbicides was most effective in soybean and cassava in terms of high yields, least cost of production and high margins than hoe weeding and intercropping. Similar research findings in Kenya by Kibata et al. (2002) also proved that herbicides increased net benefits by 61% in a maize/bean intercrop and 46% in a maize monocrop. The higher gross margin under chemical weed control confirms the role of modern technology in improving viability of farming. Johnson (1995) discovered that 80% of smallholder farmers would increase the size of their cultivated land if weeds were less of a problem. In addition, when using manual weeding, weed infestation in crops may be so severe that weeding is not always worthwhile; therefore, fields are effectively abandoned. In Malawi, nationwide survey data reports one third of the area planted to maize by smallholders was either left unweeded or incompletely weeded (Orr et al., 2002). Similarly, in Zimbabwe, 21% of cotton farmers abandon more than 20% of their crops each year as a result of weed infestation (Mavudzi et al., 2001).

The higher margins from users of chemical weed control can thus be associated with higher yields obtained as weeds are controlled effectively and within the critical growth stage. According to Indian Council of Agriculture Research (ICAR) (2006) chemical weed control is easier, faster and in many cases less costly. Manual weed control is labor intensive, time consuming, causes chronic pain, spinal deformation and is usually avoided or delayed such that by the time it is done, considerable yield loss would have occurred. Chikoye et al. (2004) expressed that although a lot of energy in consumed in removing weeds manually, crop yields are generally very low due to weed competition caused by untimely and ineffective weed control by this method. Use of time is of prime importance to the smallholder farmer as there is competition for labor between weeding and other farm and non-farm operations, if the farmer can use time saved from manual weeding to carry out other profitable operations, then there is a good case for using herbicides (Benson, 1982). Thus it is evident from this analysis that the benefits from herbicides use are more than the direct yield benefits as there are other productivity benefits accruing from labor saved for other farm and off farm operations.

Another reason why it was less viable in manual weed control was that smallholder farmers spend 50 to 70% of their total labor time weeding (Chikoye et al., 2007) given the demand nature of weeding manually, with the high cost of labor in Nigeria's FCT of about 800 naira per day, the cost of production becomes too high. Furthermore, in Africa, women contribute more than 90% of the hand weeding labor (Ukekje, 2004). In addition seven out of every 10 farm children between the ages of 5 and 14 are forced to leave school and work in the agricultural sector at the peak period of weeding (Ishaya et al., 2008). Thus besides the potential benefits of herbicide use in the current study of increased incomes and reduced drudgery, there are also social benefits salient to women, children and the poor for example when children are able to attend school because they are not needed to weed fields.

The production function indicated that the efficacy for herbicides, variety, seed, fertilizer and labour were positive and significant at 5% hence these inputs are important determinants of maize productivity. Summing up the coefficients of all explanatory variables ($\sum B_i$ = (0.283 + 0.593 + 0.1 + 0.535 + 0.155 + 0.245) = 1.911) revealed increasing returns to scale implying that additional inputs of productive resources resulted in larger increases in product than the preceding unit. This outcome indicates that there is potential for farmers to increase production and efficiency by inputting more factors of production, however smallholder farmers are constrained in most cases cannot attain the optimal levels of production (Gianessi, 2009). There is therefore, a need to investigate other constraints related to input usage that is preventing attainment of optimal utilization of inputs among smallholder farmers.

The benefits associated with use of herbicides of higher yields associated with its effectiveness and efficiency in weed control as earlier alluded to in the discussion is a major explanation to the positive association between output and use of herbicides. The outcomes from this research implies that improved use of herbicides have potential to increase crop output. The crop will be subjected to less competition from weeds as weeding can be done on time within the critical stages of weeding as prescribed by ICAR (2006) and this will yield higher output. Another possible explanation why herbicides use in maize production is positively associated with higher output is the complementarities of the technology with conservation agriculture that is being promoted of late. As a way of mitigating the effects of soil degradation and climate change, conservation agriculture based on integrated weed control, minimum tillage, residue retention and rotations has been proposed (Thierfelder and Wall, 2009) and if tillage is abandoned, weed control becomes a major challenge for smallholder farmers which calls for an integrated approach to control the weeds (Steiner and Twomlow, 2003). Mazvimavi et al. (2012), highlighted that small holder yields under conservation agriculture are higher and gross margins are subsequently higher under conservation agriculture which is based on minimal mechanical working of the soil than conventional methods with output elasticities indicating positive responses for labor and seed in CA, and negative responses in conventional farming (Mazvimavi et al., 2012).

The comparative analysis of resources productivity between maize crops subjected to chemical weed control and manual weed control indicated that all resources productivity (APP, MPP, and MVP) were significantly higher for maize subjected to chemical weed control option than the one subjected to manual weed control options. The differences in performance of farmers may be directly and entirely related to differences in productivity of inputs caused by differences in technology and managerial efficiency. The role of technology and technology transfer in inducing sustainable agriculture development is supported through productivity increases attained by adopters of modern technology to weed management.

The ratio of MVP/MFC compared for all inputs between the two groups was used as an indicator of optimal utilization of resources. In both groups, the ratios for all inputs (seed, labour and fertilizer) were not equal to one indicating non optimal use of resources. Herbicides that were only limited to chemical weed control were also inefficiently utilized. This could be attributed to poor application methods and techniques, herbicide resistance by some weed species among others. This outcome is consistent with developmental theories that states that agricultural development can only be induced through multiple faceted interventions. There is a collaborative and interactive efforts of institutional innovation, improvements in human capital as well as changes in the availability of biological and physical capital (Kanyenze et al., 2011) that collectively work together to ensure economic utilization of resources. The productivity differences in agriculture are increasingly a function of scientific and industrial capacity and in the education of people rather than natural resource endowments. Thus advancement of modern technologies such as seeds, fertilizers and herbicides alone is not enough but will require complementary institutional and human capital investments to ensure effective utilization.

The significant positive association between use of chemical control and resource productivity of all the inputs (seed, labour, fertilizer, chemicals) signifies the importance of herbicides in improving returns to production. The association implied that an increase in use of herbicides will result in an increase in productivity of other resources. This outcome indicates complementarities of resources used in production systems as explained earlier by Kanyenze et al. (2011). Rukuni (2006) further emphasized the need to raise rural incomes through increased agricultural productivity requires the expanded use of productivity enhancing inputs and technologies. The use of purchased inputs like herbicides in this study was found to be associated with improved productivity of complementary inputs implying higher output per unit input and more income to farmers.

The paper concludes that it is economically rational for farmers to move from traditional to chemical weed control in maize production to improve effectiveness and efficiency. Extension practitioners from government, private and non-governmental organizations who have been promoting use of herbicides should continue to encourage farmers to use herbicides to obtain higher output, yields and profits from production. However, there is a need to step up extension efforts as adoption of appropriate production technology is low in smallholder agriculture, herbicide use is less than 5% and smallholder farmers in Africa generally do not use herbicides (Magyembe, 1997). Furthermore, research to explore causes of non optimal resource allocation in maize production and appropriate socio-economic environment for adoption of advanced technologies such as herbicides will be instrumental in improving efficiency and providing policy direction for improve weed control through adoption of herbicides.

REFERENCES

Anyanwu AC, Anyanwu BO, Anyanwu VA (2003). A Textbook of Agricultural Science For Schools and Colleges. 6th Edition, Ibadan, AFP Publishers. pp. 357-361.

Ayoola JB, Adedzwa DK (2005). A partial budget analysis for evaluating economic viability of integrated management options for imperata cylindrical in small holder farms of Benue state, Nigeria. PAT. Int. J. Agric. Res. 2(1):1-8.

Benson JM (1982). Weeds in Tropical Crops: Review of Abstracts on Constraints in Production Caused by Weeds in Maize, Rice, Sorghum-millet, Groundnuts and Cassava. FAO Plant Prod. Protect. 32(1):33-38.

Chikoye DF, Ekeleme F, Akobundu IO (1997). Weed composition and population dynamics in intensified smallholder farms in West Africa, The 1997 Brighton Crop Protection Conference, Weeds.

Chikoye D, Schultz S, Ekeleme F (2004). Evaluation of integrated weed management practices for maize in the Northern Guinea Savanna of Nigeria. Crop Protect. 23:895-900.

FAO (2006). World Agriculture, towards 2030/2050. FAO, Rome. Available online at: http://www.fao.org/es/ESD/AT2050web.pdf [Accessed on the 20 January 2009].

FAO (2003). World agriculture: towards 2015/2030. FAO, Rome. Available online at: ftp://ftp.fao.org/docrep/fao/004/y3557e/y3557e.pdf [Accessed on the 20 January 2009].

Federal Capital Territory Fadama Development Project (FCTFDP), (2007). FCT Fadama II Project of Agriculture and Rural Development (ARD) project: Our Legacy/ Achievements. P. 54.

Gianessi L (2009). Solving Africa's weed problem: Increasing crop production and improving the lives of women. Crop Protection Research Institute 202-872-3865. www.croplifefoundation.org.

Indian Council of Agriculture Research (ICAR), (2006). Handbook of Agriculture. 5th Edition, pp. 481-508. New Delhi 110 012. India. pp. 466-480.

Ishaya DB, Dadari AS, Shebayan JAY (2008). Evaluation of herbicides for weed control in sorghum (Sorghum bicolour) in Nigeria, Crop Protection, 26, pp 1697–1701.

Johnson DE (1995). Weed management strategies for smallholder rice production, The 1995 Brighton Crop Protection Conference, Weeds, pp 1171-80.

Kanyenze G, Kondo T, Chitambara P, Martens J (2011). Beyond the Enclave. Towards a Pro-Poor AND Inclusive Development Strategy for Zimbabwe. Weaver Press, ANSA, LEDRIZ and ZCTU. pp. 30-72.

Kibata GN, Maina JM, Thuranira EG, Musembi FJ, Nyanya G, Muthamia JGN, Okuro JO, Mutura I, Amboga S, Micheni AN, Mureithi F, Overfield D, Terry PJ. (2002). Participatory development of weed management strategies in maize based cropping systems in Kenya, Thirteenth Australian Weeds Conference. pp. 343-344.

Nellemann C, MacDevette M, Manders T, Eickhout B, Svihus B, Prins AG, Kaltenborn BP (Eds). (2009). The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal, www.grida.no.

Mavudzi Z, Mashingaidze AB, Chivinge OA, Ellis-Jones J, Riches C (2001). Improving weed management in a cotton-maize system in the Zambezi Valley, Zimbabwe, The 2001 Brighton Crop Protection Conference, Weeds. pp. 169-74.

Mazvimavi K, Ndlovu PV, An H, Murendo C (2012). Productivity and Efficiency Analysis of Maize under Conservation Agriculture in Zimbabwe Selected Paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil.

Magyembe JM (1997). Herbicide use in Uganda, 16th East African Biennial Weed Science Conference Proceedings, pp. 165–169.

Orr A, Mwale B, Saiti D (2002). Modeling agricultural 'performance': smallholder weed management in southern Malawi. Int. J. Pest Manage. 48(4):265-278.

Rossman A (2009). The impact of invasive fungi on agricultural ecosystems in the United States. Biological Invasions 11 (1):97-107.

Rukuni M (2006). The evolution of agricultural policy: 1890-1990. In: Rukuni M, Tawonezvi P, Eicher CK, Munyuki-Hungwe M, Matondi P (eds), Zimbabwe's agricultural revolution revisited. University of Zimbabwe Publications, Harare.

Steiner KG, Twomlow S (2003). Weed management in conservation tillage systems. African conservation tillage network Information Series P. 8.

Thierfelder C, Wall PC (2009). Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. Soil. Tillage Res. 105:217-227.

Ukekje E (2004). Modernizing Small-holder Agriculture to Ensure Food Security and Gender Empowerment: Issues and Policy, Intergovernmental Group of Twenty Four, http://www.g24.org/ researchpapers.html.

UN Population Division (2007). UN 2006 population revision. UN, New York. Available online at: http://esa.un.org/unpp/ [Accessed on the 20 January 2009].

Vere DT, Jones RE, Griffith GR (1997). An integrated economic methodology for evaluation of impacts of weeds in agricultural production systems and the farm and industry benefits of improved weed management. C.R.C for weed management systems, Waite campus, University of Adelaide, Australia. 2:33.