International Journal of Plant & Soil Science
6(2): 93-100, 2015; Article no.IJPSS.2015.100
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

Integration of Cover Crops and No-till Improved Maize Yield in Eastern Uganda

G. Ddamulira[1*], J. S. Tenywa[2] and D. Mubiru[3]

[1]National Crops Resources Research Institute, Namulonge, Horticulture and Oil Palm Program, P.O.Box 7084, Kampala, Uganda.
[2]Department of Agricultural Production, Makerere University Kampala, P.O.Box 7062, Kampala, Uganda.
[3]National Agricultural Research Laboratories Kawanda, Soil Science Program, P.O.Box 7065, Kampala, Uganda.

Authors' contributions

This work was carried out in collaboration between all authors. Author DM designed the study and wrote the protocol. Author GD managed the literature searches, managed the experimental process, analyzed the experimental data and wrote the first draft of the manuscript. Author JST reviewed the manuscript prior and after journal submission. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2015/14376
Editor(s):
(1) Dionisios Gasparatos, Soil Science Laboratory, Faculty of Agriculture, Aristotle University of Thessaloniki, Greece.
(2) Peter A. Roussos, Agricultural University of Athens, Lab. Pomology, GREECE.
Reviewers:
(1) Anonymous, Turkey.
(2) Anonymous, USA.
(3) Anonymous, Cameroon.
(4) Anonymous, Brazil.
(5) Anonymous, Brazil.
(6) Kolawole Gani Oladejo, Crop Production and Soil Science Department, Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, Oyo State, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=954&id=24&aid=8141

Original Research Article

Received 28th September 2014
Accepted 15th January 2015
Published 16th February 2015

ABSTRACT

Aims: The study evaluated the contributions of cover crops and no-till to the expression of crop maize yield.
Study Design: To test this, experiments were conducted for two consecutive years in a randomised complete block design arranged in a split plot with four replications
Place and Duration of Study: Busiu in Mbale district, Uganda between September 2009 and April 2011.

**Corresponding author: E-mail: ddamuliragab@yahoo.co.uk;*

Methodology: Each experiment consisted of two no-till practices; herbicide no-till and slash no-till, four cover crops; mucuna (*Mucuna pruriens* L. DC.), lablab (*Lablab purpureus*), crotalaria (*Crotalaria paulina*), canavalia (*Canavalia ensiformis*) and one weedy fallow (control). No-till practices were allotted to the main plots while cover crops and weedy fallow to split plots. Data on cover-crop biomass, nutrient content, maize gain, cob and stover yields were recorded and analyzed to test for significant differences.
Results: The results showed significant differences in biomass, N, P and K among no-till practices. Biomass, N, P and K recorded in herbicide no-till were high compared to slash no-till. Canavalia and crotalaria produced higher biomass compared with the weedy fallow, mucuna and lablab. Nitrogen levels in all cover crops evaluated were significantly higher than that from weedy fallow. In relation to maize yield, herbicide no-till increased maize grain yield by 2.6 $Mgha^{-1}$ compared to slash no-till. All cover crops increased maize yield compared with the weedy fallow. The average increment in maize yield due to cover crops ranged from 1.1-1.5 $Mgha^{-1}$. The most beneficial combination was between canavalia and crotalaria with herbicide no-till which gave higher maize yield when compared with a combination of the same two cover crops with slash no-till.
Conclusion: The increase in maize yield noted in our findings indicated the potential of canavalia, crotalaria and herbicide no-till to improve maize production in Eastern Uganda.

Keywords: Herbicide; slash; tillage; legumes biomass; maize.

1. INTRODUCTION

Decline in soil fertility is recognized as one of the major causes of decreasing crop productivity in Uganda. This decline is mainly attributed to continuous crop cultivation, a practice which excludes the use of bush fallows that replenish the nutrient capital and help sustain crop production [1].

Continuous cultivation unaccompanied by external nutrient inputs has also contributed to the decline in soil-nutrient capital [2]. Typically, nutrients are removed from the soil through harvested crop materials, burning of plant residues, soil erosion and nutrient leaching. The net effect is that nutrient losses far exceed nutrient inputs from natural processes such as deposition and biological nitrogen (N) fixation. As a result, negative nutrient balances of N, P and K of -60, -7, and -60 kg^{-1} ha^{-1} $year^{-1}$, respectively, have been reported under annual cropping in Eastern Uganda [3].

To reverse the effects of negative nutrient balances in Eastern Uganda, mulching using crop waste and animal manure was adopted [4]. However, even with these interventions, farmers are unable to compensate for the lost nutrients because of low quantities of animal manure used, but also because of competing demands on crop residues for fuel and fodder [5]. Furthermore, the use of inorganic fertilizers to replace lost plant nutrients is constrained by their prohibitive costs [6].

Legume cover crops have the capacity to fix N, thereby replenishing nitrogen stocks in the soil [7]. Nitrogen recapitalisation through biological nitrogen fixation remains a primary source of N in small-holder cropping systems in Uganda [8]. However, if cover crop residues are left on the soil surface after killing them, cover crop benefits will be increased, providing soil and water conservation, improved soil structure, increased biological activity, and greater organic matter content near the soil surface. No-till allows farmers to plant seeds at any depth with minimal disturbance to the soil [9]. This protects the soil structure, reduces soil erosion and conserves soil moisture and plant nutrients [10]. Thus cover crops and no-till can complement each other and provide a mechanism for sustaining yields in annual cropping systems. This study was conducted to evaluate the contributions of legume cover crops in no-tillage management with two different types of weed control–slashing or herbicide in eastern Uganda. The specific objectives included; 1) to determine the nutrient content and biomass of cover crops and; 2) assess the effect of cover crops and different weed control methods in a no-tillage system.

2. MATERIALS AND METHODS

2.1 Site and Treatments

This study was conducted on-farm in Busiu, Mbale district, Uganda (1º 15'N, 34º 00'E; 1168 masl) from 2009-2011. The experimental fields had previously been used for cultivating, maize, groundnut and beans for five years. The soil at the four farmers' field was ferralsols with a clay loam texture, containing an average of 0.14% total N, 5.6 mg kg^{-1} P, 0.36 cmol kg^{-1} K, 39% clay, 20% silt and 41% sand, with a pH of 6.4 [11]. The experiment comprised of two main treatments (herbicide application and slashing), four cover crops treatments (*Mucuna pruriens* (L.) DC), *Lablab purpureus*, *Canavalia ensiformis* and *Crotalaria paulina)* and a weedy fallow treatment as sub-plots in a randomized complete block split-plot design with each of the four farmer's field as a replicate.

One month prior to the establishment of the experiment, weeds (dominantly *Cyperus rotundus*, *Amaranthus spp*, *Epimedium sagittatum* and *Oxalis latifolia*) within the experimental fields were killed by applying glyphosate herbicide at a rate of 1 L ha^{-1} or slashed using a hand slasher. At the on-set of the second season rains in September 2009, cover crop seeds were planted at a spacing of 75 cm x 60 cm with 3 seeds per hole. One week after emergence, seedlings were thinned to one plant per hole and weeds controlled by hand pulling in both herbicide-applied and slashed plots.

2.2 Cover-crop Biomass and Nutrient Content

Sixteen weeks after planting (January 2010), the total biomass of cover crops and weeds was determined using a 0.25 m^2 wooden quadrat. The quadrant was randomly thrown four times in each experimental unit and cover-crop plants within the quadrat were cut at ground level leaving the vines that lay beyond the quadrant edge. A few weeds that lay beneath the cover crop in quadrant were carefully sorted out and discarded. The same quadrat method was randomly thrown in weedy fallow (control) and weeds within the quadrant were also cut. The cut cover crop and weed materials were oven-dried at 65ºC for 48 h and weighed for biomass determination. A sample of 0.3 g was taken from ground leaves and analyzed for total N, P and K. Total N was determined by digestion in hot concentrated sulphuric acid and the Kjeldahl technique [12], P by bray-1 method and K by flame photometry [13]. Five days after taking the biomass data, cover crops and weeds were killed either by herbicide application using the same rates mentioned earlier or slashed using a hand slasher. The cut materials and those killed by the herbicide were left in situ for two months to decompose.

At the on-set of first season rains in April 2010, maize (*Zea mays L.*), variety Longe hybrid 6 was planted in weed-free fields at 75 cm x 30 cm in rows at a rate of 4 seeds per hole. One week after emergence, maize seedlings were thinned to 2 plants per hole. Three weeks after planting, weeds that had emerged in maize fields were controlled either by careful slashing between rows using a slasher or direct application of roundup (glyphosate) herbicide between maize rows at a rate of 1 L ha^{-1} was done. During spraying, a spray guard was used to avoid herbicide contact unto maize. The two weed control practices (herbicide application and slashing) were concurrently undertaken to avoid discrepancies that would have arisen from using different weed-control methods at different times. The second weed control was carried out five weeks after planting using similar procedures. Despite the two weed control regimes executed, weeds with high seed densities in the soil and those with high regeneration ability in herbicide-applied and slashed plots often emerged in the course of maize growing.

In order to determine the effect of regenerated weeds on maize growth, weed densities for the regenerated weeds were determined five weeks after planting. A quadrant procedure described for cover crop biomass determination was employed. Four prominent weed species enclosed in the quadrant randomly thrown in slash and herbicide treatments were counted and computed per 0.25 m^2 basis. The same maize experiment was repeated twice in the second and first season rains of September 2010 and April 2011 respectively using similar procedures adopted from the previous seasons.

2.3 Maize Yield

Maize was harvested 13 weeks after planting; the harvesting was delayed by one week beyond physiological maturity (12 weeks) to allow for more drying of the maize while in the field. All maize plants from an area of 3 x 3 m (net plot) within the centre of each plot were harvested. The maize cobs and stover from each net plot were counted, weighed and recorded. The cobs were then sun-dried on a tarpaulin to 13% moisture content, and weighed. The dried cobs were threshed using a hand sheller and weighed. The grain and stover weight per net plot were extrapolated to per hectare basis.

2.4 Data Analysis

The data were subjected to analysis of variance (ANOVA) using Genstat version 10 [14]. The mean values for cover-crop biomass, nutrient content, weed densities. Maize grain, cob and stover yields were computed. The means were subject to ANOVA to test for significant difference (P < .05). Fisher's Least Significant Difference was used to determine significant differences between means and for the interaction analysis; GLM procedure in Genstat (14) was used.

3. RESULTS

3.1 Biomass and N, P and K Content

In terms of biomass and nutrient content significant (*P* < .001) differences were observed between the two no-till practices studied. On average, high biomass, N, P and K levels were recorded in herbicide no-till compared to slash no-till. In the same way, significant differences (*P* ≤ .05) in biomass, N, P and K content of cover crops and weedy fallow were also observed in the sub treatments (Table 1). Canavalia biomass was significantly (*P* ≤.001) different from that of crotolaria. Similarly, canavalia and crotalaria biomass were significantly (*P* <.001) different from that of weedy fallow, but mucuna and lablab biomass were not significantly different from that of weedy fallow. All cover crops had significantly (*P* ≤ .05) higher level of nitrogen (N) than weedy fallow; canavalia had the highest level of N followed by crotalaria, mucuna and lablab. However, biomass produced by crotalaria was not significantly (P ≤.05) different from that of mucuna. On the other hand, phosphorus (P) level in cover crops was not significantly (P ≤.05) different from that in weedy fallow (Table 1). However, potassium (K) content was also significantly (*P* ≤.05) higher in crotalaria, mucuna and canavalia than weedy fallow and lablab. In relation to biomass, N, P and K, there were no significant (P ≤.05) interactions between no-till and cover crops.

3.2 Effects of no-till and Cover Crops on Maize Yield

The two no-till practices tested; significantly (*P* ≤.05) affected maize grain yield, cob weight and stover. Herbicide no-till increased maize yield, cob weight and stover by 2.6, 2.3 and 2.5 Mg ha^{-1} compared with the slash no-till practice respectively.

Use of cover crops also led to significant (*P* ≤.05) increase in grain yield when compared with the weedy fallow (Table 2). The average increment in maize yield due to cover crops ranged from 1.1 - 1.5 Mg ha^{-1}. Similarly, cob weight was also affected by cover crops (Table 2). A significant (P ≤.05) increment in cob weight was observed for maize planted in mucuna, lablab and canavalia plots as compared to maize obtained in crotalaria and weedy fallow plots. Nonetheless, cover crops did not have significant (*P* ≤ .05) effect on maize stover (Table 2).

Table 1. Mean cover crop and weed biomass with their nutrient contents at Busiu, Mbale district, Eastern Uganda

Treatments	Biomass	Nitrogen	Phosphorus	Potassium
	……………………Mg/ha………………………………………..			
Crotalaria	3.7a	98.4a	3.45a	82.9a
Mucuna	2.9b	88.2a	5.21a	75.6a
Lablab	2.7b	57.5b	3.40a	34.5b
Canavalia	4.5c	126.7c	5.23a	71.4a
Weedy fallow	2.4b	22.2d	3.15a	25.4b

Means followed by similar letter(s) in a column are not significantly different (P >.05)

Table 2. Maize yield components and grain at Busiu, Mbale district, Eastern Uganda

Treatments	Cob weight	Stover	Grain
	………………………Mg ha^{-1}……………………………		
Crotalaria	4.7a	4.3a	4.9a
Mucuna	5.7a	4.2a	5.1a
Lablab	5.3a	3.9a	4.9a
Canavalia	5.1a	4.0a	4.7a
Weedy fallow	3.8b	3.2a	3.6b

Means followed by similar letter(s) in a column are not significantly different (P >.05)

3.3 Regeneration of Weed Species in no-till

Despite the two weed control regimes done in herbicide no-till and slash no-till, some weed species regenerated and the effect of the regenerated weeds in no-till on maize yield was determined. Mean weed densities of Cyperus *rotundus*, A*maranths spp*, *Epimedium sagittatum* and *Oxalis latifolia* in slash no-till were significantly (P ≤.05) higher compared to mean densities in herbicide no-till (Table 3). For all the four weed species, mean densities in slash no-till were atleast three-folds more than in herbicide no-till.

3.4 Effects of no-till Practice Combination with Cover Crops on Maize Yield

A combination of no-till practices and cover crops was significant (*P* ≤.05) for grain yield but not for cob weight and maize Stover. The combination between canavalia, crotalaria and herbicide no-till gave higher maize yield compared with a combination of the same cover crops with slash no-till (Fig. 1).

4. DISCUSSION

The study revealed that herbicide no-till increased biomass production of cover crops, nutrient content and maize grain yield compared with slash no-till.

The higher cover crop biomass in herbicide no-till compared to slash no-till was partly attributed to effective control of weeds by herbicide during the cover crop growth. Though weed control was done at the same time, interval and number of times in herbicide and slashed plots, weeds propagated through sprouts and roots multiplied after slashing which increased the weed densities in slash no-till plots. Weeds are known to use the soil nutrients, available moisture, and compete for space and sunlight with cover crops, which result in cover crop biomass reduction [15]. Hence the low cover crop biomass observed in slash no-till compared to herbicide applied plots was possibly explained by competition from weeds.

Table 3. Population densities of four weed species that regenerated three weeks after planting maize under slash and herbicide applied treatments at Busiu, Mbale district eastern Uganda.

No-till	Mean weed densities in $0.25m^2$			
	Cyperus rotundus	***Amaranthus* spp**	***Epimedium sagittatum***	***Oxalis latifolia***
Slash	45a	25a	21a	43a
Herbicide	10b	6b	7b	9b

Means followed by similar letter(s) in a column are not significantly different (P >.05)

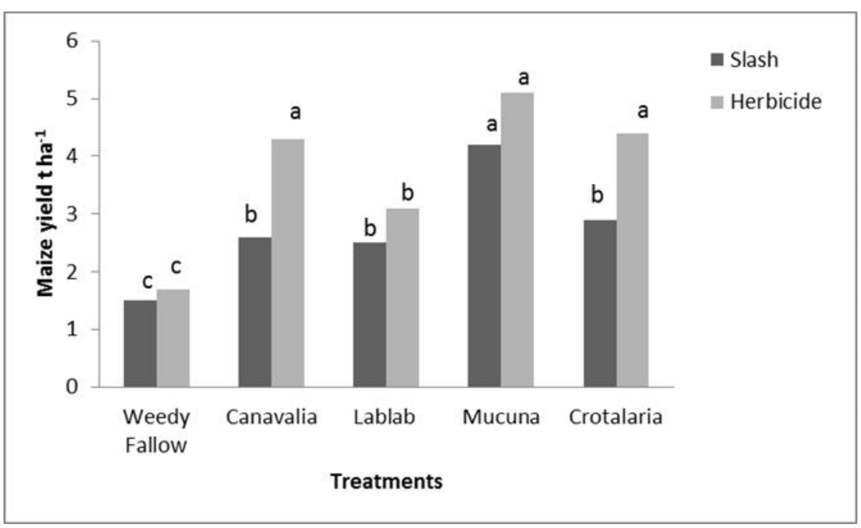

Fig. 1. Interaction effects of cover crops, weedy fallow and no-till treatments on maize yield in Busiu, Mbale district, Eastern Uganda. Means, for each cover crop and weedy fallow followed by similar letter are not significantly different

The higher biomass for canavalia compared with mucuna, lablab and the weedy fallow was partly attributed to its large seed pods which contributed to its total above-ground biomass [16]. In contrast, mucuna and lablab have small seed pods which are associated with low harvestable biomass. Equally weeds which constituted the weedy fallow have minute seeds enclosed in very small pods which also contributed to their reduction in biomass. Hence similar morphological attributes possibly explained the lack of significant difference in biomass among mucuna, lablab and weedy fallow. On the other hand, the high biomass for canavalia and crotalaria compared to weedy fallow could also be attributed to their deep rooting depth and tolerance to moisture stress [17]. Moisture stress was experienced by all cover crops during their early stages of establishment but the high canavalia and crotalaria biomass could be attributed to their capacity to extract more water under stressful conditions. Earlier studies have shown that deep rooting during early growth stages of canavalia and crotalaria allow them to extract more water from the soil which enhances their biomass production compared to the shallow-rooted weed species that constituted the weedy fallow [18].

The high nitrogen (N) content exhibited by cover crops compared to weeds in the weedy fallow can be attributed to N accumulation being proportional to the amount of biomass produced [19]; thus canavalia with the highest biomass, accumulated the most N. Unlike N, K was not proportional to biomass as crotalaria which had the highest level of K did not yield the highest biomass, possibly because in legume crops K is mostly used in improving quality and resistance against diseases, with little contribution towards quantitative traits such as biomass [20]. On the other hand, P levels in cover crops and weedy fallow were not significantly different indicating that use of cover crops may not have an added advantage over weeds in enhancing P levels in the soil when both are used as soil amendments.

Use of herbicide no-till increased maize grain and yield components (cob weight and stover). The increment in the three parameters was partly attributed to reduced weed density in herbicide applied plots during maize growth. Different weed control methods are used in maize crop among which chemical weed control is the most economical and effective method to suppress weeds in order to get healthy and vigorous crop stand [15]. Our findings concurred with earlier studies because for the herbicide applied before and three weeks after planting substantially reduced the weed density in herbicide no-till based treatments compared to slash no-till treatments. The results were further supported by Schans [21] who obtained best weed control and higher maize yield in herbicide treated plots [22]. Similarly, Ali [20] concluded that herbicide application increased maize yield and decreased weed biomass significantly. Effective control of weeds in maize is known to reduce on the competition of maize with weeds for growth resources Ojiem [18].

On the other hand, the reduced grain yield in the slash no-till based treatments could have been due to high weed densities arising from regeneration of weeds (Table 3). Most weeds in the experimental plots had the ability to regenerate, yet presence of weeds during growth cycle of maize is reported to create competition for growth resource [23]. The competition from the regenerated weeds possibly contributed to reduction in grain yield in slash no-till plots compared to herbicide slash.

Generally, the variation in maize yield which followed the planting of cover crops and weedy fallow was possibly due to biomass left in situ after cover crops were killed by herbicide application and slashing. The biomass decomposed and partially contributed to the nutrient supply especially N required for maize growth [7]. The increase in maize yield by cover crops when compared to weedy fallow was further explained by the fact that cover crops on average contained higher N (92.7 Mg ha^{-1}) than N (22.2 Mg ha^{-1}) in weeds. The four-fold N contributed by cover crops compared to weedy fallow possibly validated the difference in maize yield observed. Earlier studies conducted in Kenya indicated that application of mucuna green manure in no-till increased maize grain yield by 1.5 Mg ha^{-1} compared to non-legume cover crops [24]. Similarly, in Cameroon maize grain yield increase of 4 Mg ha^{-1} was obtained after a short fallow of mucuna [25].

No-till practice and cover crop interaction was highly significant with a combination of crotalaria and canavalia with herbicide no-till giving high maize yield compared to canavalia and crotalaria combination with slash no-till practice. The high canavalia and crotalaria biomass accumulated in herbicide no-till during canavalia and crotalaria growth and its eventual decomposition possibly released N which boosted maize growth. Nitrogen released during canavalia and crotalaria decomposition is known to improve soil nitrogen status [26] and their residues can retain conserved moisture and hence increase maize yield [27]. In this combination it is anticipated that canavalia and crotalaria possibly provided N on decomposition which enhanced available N for maize uptake while herbicide no-till effectively reduced weed densities and minimized maize competition with weeds for growth resources. On the other hand, even though N from decomposing cover crops was released in slash no-till and availed to maize in the subsequent season, the regeneration ability of the slashed weeds possibly competed with maize for growth resources. This explained the reductions in maize yield from canavalia and crotalaria combination with slash no-till.

5. CONCLUSION

The study provided evidence that among the cover crops tested canavalia and crotalaria produced more biomass and accumulated the most N. Also cover crops had significant effects on maize grain yield compared to weedy fallow. Furthermore, a combination of herbicide no-till with canavalia and crotalaria increased maize yield. Based on our findings, combining herbicide no-till with canavalia and crotalaria has a potential of improving maize yield among small holder farmers in Eastern Uganda.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ofori CS. Need for long-term soil management in Africa. In: Lal R, Stewart BA (Eds.) Soil management: Experimental basis for sustainability and environmental quality, CRC Press, Boca Raton, Florida, USA; 1995
2. McNeely JA, Scherr SJ. Common ground, common future. How Eco agriculture can help feed the world and save wild biodiversity. The World Conservation Union, Future Harvest; 2001.
3. Wortmann CS, Kaizzi CK. Nutrient balances and expected effects of alternative practices in the farming systems of Uganda. Agric. Eco. and Environ. 1998;71:117-131
4. Maroko JB, Buresh RJ, Smithson PC. Soil nutrient availability as affected by fallow-maize systems on two soils in Kenya. Biol. and Fert. Soils. 1997;26:229-234.
5. Palm CA, Meyers RJ, Nandwa SM. Combined use of organic and inorganic nutrient resources for soil fertility maintenance and replenishment. In: RJ Buresh, Sanchez PA, Calhoun F (Eds.) Replenishing Soil Fertility in Africa. SSSA, Special publication No. 51. SSSA, Madison, USA; 1997.
6. Bekunda MA, Bationo A, Ssali H. Soil fertility in Africa. A review of selected research trials In: Buresh RJ, Sanchez PA, Calhoun F (Eds.) Replenishing Soil Fertility in Africa. SSSA, Special Publication No. 51. SSSA, Madison. Wisc USA; 1997.
7. Kang BT, Akobundu JO. Potential role of herbaceous legumes for improvement of soil fertility and productivity paper for RMR soil processes workshop. IITA; 1990.
8. Nyende P. Effect of soil fertility and weed management on the performance of finger millet in Eastern Uganda. M. Sc. Thesis, Makerere University, Kampala, Uganda; 2001.
9. Trigo E, Cap E, Malach V, Villarreal F. The case of zero tillage Technology in Argentina. IFPRI Discussion paper; 2009
10. Bwaya M, Friedrich T. Conservation agriculture in development: The case of Africa. International conference on Animal Traction and Conservation Agriculture in Jinja, Uganda; 2002.
11. Isabirye M, Mbeera D, Ssali H, Magunda M, Lwasa J. Soil resources information and linkages to agricultural production. Uganda journal of agricultural sciences. National Agricultural Research Organisation NARO, Uganda. 2004;9:215-221
12. Anderson JM, Ingram SJ. Tropical soil biology and fertility: A handbook of methods. C.A.B International. Wallingford, UK; 1993.
13. Okalebo JR, Gathua KW, Woomer PL. Laboratory methods of soil and plant analysis: A working manual. 2nd edition. TSBF-CIAT and SACRED Africa, Nairobi, Kenya; 2002
14. Payne RW, Murray DA, Harding SA, Baird DB, Soutar DM. Gen Stat for windows (10th eds) introduction. VSN International, Hemel; 2007.
15. Abdullah, Gul Hassan, Ijaz Ahmad Khan, Sheraz Ahmad Khan, Hussain Ali. Impact

of planting methods and herbicides on weed biomass and some agronomic traits of maize. Weed Sci. Res. 2008;14:121-130.
16. Aleman R, Flores M. Some data about canavalia (*Canavalia ensiformis*). Centro internacional de informacion sobre cultivos de Cobertura (CIDICCO); 1993.
17. De Jesus Huz M. The use of canavalia ensiformis and other leguminous species as mulches for farming in Yucatan. In: HD Thurston, M Smith, G Abawi and S Kearl (Eds.) Slash/ Mulch: how farmers use it and what researchers know about it .Cornell International Institute for Food, Agriculture and Development (CIFAD), Cornell University, Ithaca, New, USA; 1994.
18. Fischler M. Legume green manures in the management of maize-bean cropping systems in eastern Africa with special reference to crotalaria (chroleuca G. Don). PhD thesis, ETH Zurich; 1997.
19. Hesterman OB, Griffen TS, Williams PT, Harris GH, Christenson DR. Forage legume-small grain intercrops: N production and response of subsequent corn. J. Prod. Agric. 1992;5:340–348.
20. Ali R, Khalil SK, Raza SM, Khan H. Effect of herbicides and row spacing on maize (*Zea mays* L.). Pak. J. Weed Sci. Res. 2003;9:171-178.
21. Schans D, Bleumer E, Schooten H. More efficient weed control in maize possible. Praktijkonderzoek Rundvee. Schapen en Paarden. 1997;10:24-28.
22. Khan SA, Hussain N, Khan IA, Khan M, and Iqbal M. Study on weed control in maize. Sarhad J. Agric. 1998;14:581-586.
23. Hussein F, Abouziena IME, Metwally and Desoki EREL. Effect of plant spacing and weed control treatments on maize yield and associated weeds in sandy soils. American-Eurasian. J. Agric & Environ Sci. 2008;4:09-17
24. Ojiem JO, Mureithi JG, Okwuosa EA. Integrated management of legume green manure, farmyard manure and inorganic nitrogen for soil fertility improvement in western Kenya. In: Mureithi JG (Eds) Participatory Technology Development for Soil Management by Smallholders in Kenya. Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research network projects Mombasa, Kenya; 2000.
25. Hauser S, Nolte C. Biomass production and N fixation of five *Mucuna pruriens* varieties and their effect on maize yields in the forest zone of Cameroon. J. Plant Nutr. Soil Sci. 2002;165:101-109.
26. Chalk PM, Dynamics of biologically fixed N in legume-cereal rotations: A review. Aust. J. Agric. Res. 1998:49:303–316.
27. Kue S, Jellum EJ. Influence of winter cover crop and residue management on soil nitrogen availability and corn. Agron. J. 2002;94:501–508.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=954&id=24&aid=8141