International Journal of

Agricultural Research

ISSN 1816-4897

Academic Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 2 (3): 254-260, 2007
ISSN 1816-4897

The Effect of Different Forms of Water Hyacinth (*Eichhornia crassipes*) Organic Fertilizers on Leaf Growth Rate and Yield of Rape (*Brassica napus*)

J. Masaka and S. Ndhlovu
Department of Land and Water Resources Management,
Faculty of Natural Resources Management and Agriculture,
Midlands State University, Private Bag 9055, Gweru, Zimbabwe

Abstract: Although on-farm crop residues and animal manures proved the most widely used organic materials for intensive small-scale vegetable production by resource-poor smallholder farmers in southern African countries their availability has become limited. In an effort to establish alternative sources of organic materials for vegetable gardeners a soil fertility study was conducted at Masvingo Teachers'College (30°52′ E; 20°07′ E, elev. >1100 m above sea level) about 5.5 km southeast of Masvingo city in Zimbabwe. The experimental plots were laid out in a Complete Randomized Design with four replicates, which were subjected to three hyacinth-based organic matter treatments in order to determine the effect of these alternatives to crop residues on leaf growth rate and yield of vegetable rape. Our research results have conclusively shown that the use of water hyacinth as organic fertilizer significantly improved vegetable rape leaf length and yield. Vegetable rape leaves growing on crop stover-free hyacinth matter were 12.3-12.8 mm longer and had about 11.5-67.3% higher rape leaf yield than those in crop stover-based hyacinth compost matter. A vegetable rape yield gain of 1.8 t ha^{-1} was recorded in plots subjected to green hyacinth matter soil treatment compared with rape yield in plots treated with hyacinth compost matter. The use of hyacinth matter significantly retards initial vegetable rape leaf growth rate by about 1.47-5.9% compared with that in the zero organic fertilizer control plots. Laboratory analysis of the two organic materials has shown that hyacinth compost matter was nutritionally inferior to green hyacinth manure. Total N content in the water hyacinth compost was about 72.6% less than that in the green hyacinth. This study has shown that, green hyacinth matter, an obnoxious water weed that greatly reduces the aesthetic quality of public water bodies, is an effective alternative crop residue-free organic fertilizer for small-scale vegetable production.

Key words: Hyacinth matter, organic fertilizer, rape leaf

Introduction

For centuries the use of organic fertilizers has been synonymous with successful and stable agriculture. In recent years an increasing number of health-conscious consumers have expressed preference for foodstuffs grown on soils to which only natural organic materials have been added. Farmers and gardeners who practice what is now known as organic gardening are meeting the demand for these foods (Steffen, 1979). The response of soil to organic fertilizer application depends on many factors, including type and composition, application level and method, soil properties and climatic conditions (Abdel-Sabar and Ebo El-Seoud, 1996). Research results have shown beyond doubt that

Corresponding Author: J. Masaka, Department of Land and Water Resources Management, Faculty of Natural Resources Management and Agriculture, Midlands State University, Private Bag 9055, Gweru, Zimbabwe Tel: +263 54 260450, 263 54 260409 Fax: +263 54 260311

the use of organic materials can significantly improve the physical, chemical and microbial characteristics of cultivated soil and increase crop production (Steffen, 1979; Nishio and Kusano, 1980; Darmody *et al*., 1983; Pera *et al*., 1983).

Rape or canola has been an important arable crop for a couple of decades, grown primarily for its oil in northern Europe and North America and its addible leaves in Africa and Asia (Jensen *et al*., 1997). In Zimbabwe and other southern African countries, rape is commonly grown under irrigation. According to recommendations by extension agents, smallholder farmers should apply about 25-50 t ha^{-1} of cattle manure for the production of rape under small-scale informal irrigation to achieve yield levels of 25-30 t ha^{-1} (Dejong *et al*., 1993). According to ULG (1992) the smallholder farming sector in Zimbabwe had in excess of 40,000 ha under vegetables on small-scale irrigation schemes and wetland gardens. However, the amount of manure available per household has rapidly declined over the last 10 years due to persistent droughts, which have reduced cattle ownership levels not only in Zimbabwe, but also in other southern African countries (Mugwira and Murwira, 1997). The use of crop residues as organic fertilizers by small-scale vegetable growers directly exploits the limited crop residue-based cattle feed stokes especially during the dry season when the natural veld is at its poorest condition. In addition to this constraint, the availability of crop residues to organic farming is not uniform throughout the year (Murugesan *et al*., 1994).

In some cases, the crop residues are composted before application. Composting is a time-honoured practice of encouraging partial rotting and accelerating the rate of humification of plant and animal residues by microorganisms in well aerated, moist heaps. To hasten decay, small quantities of fertilizer, chicken droppings and other organic materials may be added along with a little soil to assure the presence of decay organisms (Salonius, 1972).

Green manuring is an effective contributor to soil organic matter build-up. Availability of green manure N largely depends on quantity and quality of green manure, the time it is turned under and soil properties. During the first year of turning, about 40-45% of organic N in green manures may be expected to become available for plant nutrition (Greenland, 1994). The aquatic weed water hyacinth (Eichhornia crassipes), besides being a nuisance in nutrient-enriched public water bodies, is a low-cost alternative source of organic fertilizer in plentiful supply (Murugesan *et al*., 1994). The potential productivity of water hyacinth in nutrient enriched waters has led to its selection as a biomass source for organic fertilizers (Moorhead and Nordstedt, 1993). This obnoxious water weed's high suitability for use as organic fertilizer may be attributed to its low and narrow margin carbon: nitrogen ratio (C:N) of 1:24.3 with a lignin content of only 9% compared with C: N ratio of 1:80 and lignin content of 17% in wheat straw (Mallik *et al*., 1990).

Although on-farm crop residues and animal manures proved the most widely used organic materials for intensive small-scale vegetable production by resource-poor smallholder farmers in southern African countries their availability has become limited (Mugwira and Murwira, 1997). The search for new off-farm organic substrates to augment the limited existing organic resources for small-scale vegetable production has become obligatory. Accordingly, we report in this paper on an experiment led for 32 weeks with two types of organic materials largely derived from water hyacinth mixed in different combinations with wheat straw and chicken droppings to generate a compost and fresh green water hyacinth which were applied to irrigated vegetable rape. The objective of this study was to determine rape leaf dimension and yield responses to water hyacinth-based organic materials added to a soil in three treatments. We reasoned that additions of different water hyacinth-based organic materials to a soil under rape presented variations in the physical and biochemical properties of the soil, which were responsible for the differences in the leaf biometric characteristics and rape yield.

Materials and Methods

The Field Study Site

The study was conducted in the summer season of 2003 at Masvingo Teachers'College (30°52′ E; 20°07′ E, elev. >1100 m above sea level) about 5.5 km southeast of Masvingo city in Zimbabwe. The soils at the study site are sandy loams derived from granite and classified as Udic Kandiustalf under the USDA system of soil classification (Nyamapfene, 1991). The area lies in Natural Region IV receiving rainfall ranging from 450 to 650 mm per annum (average 550 mm per annum) with a coefficient of variation of 19%. The mean annual temperature is 29°C with insignificant frost occurrence in the months of June and July. The rainfall occurs during a single rainy season extending from November to April.

Preparation of Water Hyacinth Organic Fertilizers

Composting and Green Manuring

Water hyacinth was harvested at flowering stage from a nearby heavily polluted river, which passes through a local municipality and added to successive layers of wheat straw (30-40 cm), chicken droppings (3-5 cm), water hyacinth (15-20 cm) and soil layer (2-3 cm) to produce a composting heap in a 1 by 6 m 9 inch farm brick and mortar wall enclosure with one open end. The layers were repeated until the compost was about 1.5 m high. Water was sprinkled after every layer in order to maintain moisture content of 60% throughout the composting exercise, which lasted for 12 weeks.

Green water hyacinth was also harvested at flowering stage and ploughed under three weeks before planting of rape crop seedlings.

Organic Fertilizer Analysis

Samples from the compost and green water hyacinth were air-dried, ground to pass a 2 mm sieve, analyzed for organic C (Nelson and Sommers, 1982) and total N using the Kjeidahl procedure (Bremner and Mulvaney, 1982). These parameters were used to compute C: N ratios of each material. The organic fertilizers were also analyzed to determine P, Ca, Mg, K and the major micronutrient contents using laboratory methods consistent with established standards. The pH_{H_2O} values in filtrates from samples of each substrate were determined using a pH meter.

Preparation of Plots for the Field Experiment

Soil samples were collected from the plough layer of the experimental site using soil augers. Ten sub-samples were thoroughly mixed in a plastic bag after which a composite sample was taken for laboratory analysis. Labile P, exchangeable K, Mg, Ca, Na contents in the experimental soil was determined using laboratory methods. The soil samples were also analyzed for organic C (Nelson and Sommers, 1982) and total N using the Kjeldahl procedure (Bremner and Mulvaney, 1982).

The plots were dug by hoe and levelled by garden rack to produce a good tilth. Standard beds measuring 1.2 by 6 m were marked out using a tape measure and hoe.

Treatments and Trial Management

The soil fertility field experiment was carried out in order to establish alternative organic fertilizer effect on the biometric characteristics of vegetable rape. The plot sites had been under continuous grain maize production for several years using conventional tillage systems. The experimental plots were laid out in a Complete Randomized Design (CRD) with four replicates, which were subjected to three organic fertilizer treatments in order to determine the effect of alternative organic fertilizer additives on leaf growth rate and yield of vegetable rape. The three treatments included: Treatment 1-zero organic fertilizer, control (T_1), Treatment 2-water hyacinth compost (T_2), Treatment 3-green water hyacinth manuring (T_3). Compost and green water hyacinth matter was evenly spread over the soil surface and immediately incorporated into the soil at 25 t ha^{-1} about four weeks before planting. Rape seedlings were transplanted onto the beds at four weeks when at least four leaves had developed on the plants. The seedlings were planted at 450 mm intra row and 150 mm inter row spacing to give a population of 84 plants plot^{-1}. The plots were weeded at two and four weeks after transplanting. Dimethoate 40 EC was applied as a general cover spray at a rate of 75 mL 100 mL^{-1} of water to protect the crop against aphids. All plots were frequently irrigated as per recommendation.

Determination of Leaf Dimensions and Yield of Rape Vegetable

Five weeks after planting, when vegetable rape leaves were distinctly developed, leaf lengths of five randomly selected rape plants from each plot were measured using a tape measure and recorded. The measurements were repeated every week until commencement of the first harvesting at horticultural maturity in the ninth week. Nine weeks after transplanting, five randomly selected plants were uprooted from each plot for vegetable rape leaf yield determination. The leaves were carefully harvested from each plant, weighed; total weights for each plot were then computed and recorded.

Results and Discussion

Table 1 to 4 show selected experimental soil, hyacinth matter and vegetable rape biometric characteristics. There was a relatively discernible pattern of treatment effect on rape leaf biomass characteristics and yield (F = 0.003). Results of the laboratory analysis of the soil on the experimental site show that the soil is loamy (Brady, 1990) with relatively high exchangeable Mg, Ca and available P and low total N and exchangeable K content for the production of an economic yield of rape (de Jong *et al*., 1993).

Table 1: Selected properties of the experimental soil

Percentage content by mass											
Clay	Slit	Sand	Total N	Labile P	Ca^{2+}	Mg^{2+}	K^{2+}	Na^{2+}	Organic C	C/N ratio	pH
18	42	40	0.05	2.12	5.04	3.33	0.16	0.10	0.48	9.6	5.8

Table 2: Analysis of water hyacinth plant and compost

	Nutrient content by mass										
Organic	Total N (%)	P (%)	K (%)	Mg (%)	Ca (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Bo (ppm)	Cu (ppm)	Org. C (%)	C:N ratio
Green	2.48	0.46	2.89	0.48	1.16	2983	1075	49	33	29	44.64	17.57
Compost	0.68	0.74	0.50	0.54	2.88	10163	513	210	35	34	40.13	59.28

Table 3: Length of rape leaf (mm) after planting

	Days after planting				
Treatments	35	42	49	56	63
Control	159.3	169.5	183.5	188.5	190.5
Green Hyacinth	150.5	159.5	187.5	211.3	212.3
Hyacinth compost	152.5	165.8	180.8	198.8	199.5

Grand mean 180.63, F = 0.003, LSD 18.735, SED 8.830, cv 4.0%

Table 4: Mean rape leaf yield

Treatments	kg plot $^{-1}$	t ha^{-1}
Control	7.45^{a}	10.4
Green		17.4
Hyacinth	12.49^{b}	
Compost		15.6
Hyacinth	11.24^{c}	

Grand mean 123.7, F<0.001, LSD 0.16, SED 6.71, cv 17.1%, N.B. Figures with superscripts a, b and c are significantly different from each other

Total N content in the water hyacinth compost was about 72.6% less than that in the green hyacinth (Table 2). This trend in the content of total N was particularly surprising especially after considering that a high N containing material such as chicken droppings was added to the water hyacinth compost, which, logically should have amplified the content of N in the hyacinth compost. The addition of chicken droppings, which contains about 15.0 kg Mg^{-1} compared with range of 6.5-11.5 kg Mg^{-1} for other farm animal organic manures (Brady, 1990), should have triggered a bulge in N content in the compost materials. Such, however, was not the case in this study. The steep decline in the content of total N was, perhaps, caused by the presence of low N containing wheat straw material in the compost, which had the effect of diminishing the contribution of N from chicken droppings and hyacinth in compost dry matter.

In contrast to the content of N, there was a P percentage bulge from 0.46% in green to 0.74% in the compost hyacinth, representing a 60.9% increase. The soil compost component had, notably, a comparatively high content of P, which obviously introduced an additional source of P in the compost matter observed in this study. For the same reason, similar patterns in the content of Mg and Ca, which had their contents magnified by 0.06 and 1.72% points, respectively in the compost matter, were observed in this study.

Compost K content was about 82.7% lower than that in green hyacinth. Both subordinate organic substrates added to hyacinth compost had low K content, which effectively ($F<0.005$) diminished the contribution of K to compost dry matter composition. Data on the content of micronutrients in the green and compost hyacinth was less convincing and did not have clearly detectable patterns ($F>0.005$).

The narrow margins in the organic C contents of 44.64 and 40.31% in the green and compost hyacinth were matched by wide margins of C: N ratios of 1:17.57 and 1:59.28, respectively. Logically, comparably similar organic C contents should have scored relatively similar margins of C: N ratios. In this study, such, however, was not the case. This disparity in the C: N ratios against an almost similar content of organic C in green and compost hyacinth are, perhaps, explained by the fact that the addition of C-rich wheat straw to the hyacinth compost boosted the content of C against an almost static content of N thereby widening the margins in the C: N ratios between the two organic materials. Although the addition of wheat straw to hyacinth compost amplified the content of organic C, this did not push the C: N ratio of the compost matter far beyond the 1:24 C: N ratio necessary for net mineralization of organic N (Brady, 1990), which is vital for N nutrition of vegetable rape.

Study results show that there was a distinct trend of treatment effect on rape leaf growth pattern ($F = 0.003$). The zero hyacinth matter plots clearly out performed hyacinth fertilized plots in leaf growth rate in the first 7 weeks of rape crop growth and development (Table 3). During the first 49 days of rape growth, control plots rape leaves grew 2.7-10.0 mm longer than those of the rape crop in the hyacinth treated plots. In the eighth and ninth weeks, rape leaves in the hyacinth matter plots were 10.3-22.8 and 9.0-21.8 mm longer, respectively than rape leaves of the control plots. This finding was not particularly surprising as it reconfirmed the reported negative plant biomass responses associated with late first season applications of organic fertilizers. Despite the comparatively narrow C: N ratios favourable for net mineralization of organic N in compost and green hyacinth, the microbial decomposition processes in the two organic materials requires time for the net release of nutrients for effective plant growth (Greenland, 1994). The period between hyacinth matter application and rape seedling transplanting onto experimental plots did not give enough time space for effective mineralization of nutrients from organic forms to available forms. In addition to that, in the early stages of organic matter microbial decomposition in the soil, abundance of organic C in the hyacinth matter triggered a rapid microbial biomass increase, which temporarily immobilized mineralized organic N and other important nutrients into micro-biotica matter thereby depriving relatively under developed rape seedlings of growth nutrients. This, inevitably, led to subdued growth of rape seedling leaves in the hyacinth matter-treated plots in the first few weeks of growth and development of vegetable rape observed in this study. Over time, the nutrient supplying and favourable physical effect of hyacinth matter application to soil begun to show on the rapid growth of rape leaf (Table 3).

Amongst the two hyacinth materials, green hyacinth manure treated plots produced 12.3 mm and 12.8 mm longer leaves at eight and nine weeks respectively. In addition to that, vegetable rape yield in green hyacinth treated plots was about 11.5 and 67.3% higher than that in the hyacinth compost and control plots respectively (Table 3 and 4). And this was indeed for a good reason. Hyacinth compost was nutritionally inferior to green hyacinth (Table 2). The high content of lignin polyphenols in wheat straw affect the release of N necessary for protein synthesis for microbes involved in the mineralization of organic N and C by forming stable complexes with proteins (the tanning effect) thereby rendering both the N and C inaccessible to decomposer micro-biotica. Berg and Staaf (1980) reported similar trends in a study on the decomposition rate and chemical changes of Scots pine needle litter. This, perhaps, explains the low nutrient content in the hyacinth compost and the related shorter leaves and lower vegetable rape yield observed in the compost hyacinth plots in this study. Green hyacinth matter is relatively low in polyphenol content (Moorhead and Nordstedt, 1993) and is therefore more readily biodegradable with the associated release of nutrients necessary for rapid growth and development of vegetable rape observed in this study.

Our research results have conclusively shown that the use of water hyacinth as organic fertilizer can increase vegetable rape leaf length and yield. The positive crop yield responses to applied organic materials against a background of diminishing groundwater quality caused by their excessive use have attracted fierce debate especially in Europe and North America. However, it has become relatively clear to soil fertility managers that the use of organic residues is a viable proposition in developing countries where environmental considerations come second to production of adequate food. The use of crop residue-based organic fertilizers in developing countries has placed three fundamental limitations in that they are not in plentiful supply; directly exploit the already limited crop residue-based cattle feeds and are not available throughout the year. In addition to that, our study has clearly shown that crop stover-based organic fertilizers have lower rape crop responses than crop stover-free green hyacinth matter. Crop stover-free hyacinth matter supported 12.3-12.8 mm longer rape leaves and had about 11.5-67.3% higher rape leaf yield than those in wheat straw-based hyacinth compost matter.

Our study has also established that the use of hyacinth matter as organic fertilizer retards initial vegetable rape leaf growth rate by about 1.47-5.9% compared with the control plots. In the explanation of our findings, we relied on research results from elsewhere. In a study on the decomposition of *Eucalyptus* litter Skene *et al.* (1997) reported that the strongest determinants of effective organic matter decomposition are not only the content of total C and N, but the relative amounts of polyphenols, which upon complexing with proteins, render both the N and C comparatively inaccessible to decomposer microbes thereby diminishing the nutrient release rate of the added organic material. The hyacinth compost material contains relatively higher amounts of polyphenols in the wheat straw component (Mallik *et al.*, 1990) and for this reason we concluded that this was why they had diminished effect on vegetable rape leaf dimensions and yield. In addition to that, our results have shown that total N content in the water hyacinth compost was about 72.6% less than that in the green hyacinth. Application of green hyacinth matter to soil significantly increased rape yield by 1.8 t ha^{-1} when compared with rape yield in plots treated with hyacinth compost matter ($F<0.001$). Green hyacinth matter, an obnoxious water weed that greatly reduces the aesthetic quality of public water bodies, is an effective alternative cropresidue-free organic fertilizer for small-scale vegetable production.

Acknowledgments

This manuscript is based on portion of a series of studies carried out at Masvingo Teachers College under the supervision of Mr. Chirinda, who was instrumental in the project proposal formulation. Our sincere gratitude goes to the college principal and Mr. Mhazo, lecturer in the Department of Agriculture, who offered land to carry out trials. The Department of Natural Resources (Masvingo Provincial Office) deserves mention for their material support in the study.

References

Abdel-Sabar, M.F. and M.A. Ebo El-Seoud, 1996. Effects of organic-waste compost addition on sesame growth, yield and chemical composition. J. Agric. Ecosys. Environ., 60: 157-164.

Berg, B. and H. Staaf, 1980. Decomposition Rate and Chemical Changes of Scots Pine Needle Litter. 2. Influence of Chemical Composition. In: Structure and Function of Northern Coniferous Forests. An Ecological Study. Persson, T. (Ed.), Ecology Bulletin Stockholm, 32: 373-390.

Brady, N.C., 1990. The Nature and Properties of Soils. In: The Nature and Properties of Soils. Kupchik, A. (Ed.), Collier Macmillan Publishers, London.

Bremner, J.M. and C.S. Mulvaney, 1982. Nitrogen-Total. In: Methods of Soil Analysis. Page, A.L. (Ed.), Agronomy Series No. 9, Part 2, American Society of Agronomy, Madison, M.I., pp: 595-622.

Darmody, R.G., J.E. Foss, M. McIntosh and D.C. Wolf, 1983. Municipal sewage sludge compost-amended soil: Some spatiotemporal treatment effects. J. Environ. Qual., 12: 231-236.

De Jong, J., B. Maphosa and I. Marunda, 1993. Farm Management Handbook. Department of Agricultural Technical and Extension Services, Government Printers, Harare, Zimbabwe.

Greenland, D.J., 1994. Soil Science and Sustainable Land Management in Tropics. In: Soil Science and Sustainable Land Management in Tropics. Syers J.K. and D.L. Rimmer (Eds.), CAB International, pp: 1-15.

Jensen, L.S., T. Christensen, T. Mueller and N.E. Nielsen, 1997. Turnover of residual 15N-labelled N in soil following harvest of oilseed rape (*Brassica napus* L.). Plant and Soil, 190: 193-202.

Mallik, M.K., U.K. Singh and N. Ahmed, 1990. Batch digester studies on biogas production from *Cannabis sativa* bioga, water hyacinth and crop wastes mixed with dung and poultry litter. Biol. Wastes, pp: 315-319.

Moorhead, K.K. and R.A. Nordstedt, 1993. Batch anaerobic digestion of water hyacinth: Effects of particle size, plant nitrogen content and inoculum volume. Bioresour. Technol., 44: 71-76.

Mugwira, L.M. and H.K. Murwira, 1997. Use of Cattle Manure to Improve Soil Fertility in Zimbabwe: past and Current Research and Future Research Needs, Soil Fertility Network for Maize-based Cropping Systems in Malawi and Zimbabwe, Working Paper 2, pp: 1-33.

Murugesan, A.G., N. Vijayakshmi, Sukumaran and C. Mariappan, 1994. Utilization of water hyacinth for oyster mushroom cultivation. Bioresour. Technol., 51: 97-98.

Nelson, D.W. and L.E. Sommers, 1982. Total C, Organic C and Organic Matter. In: Methods of Soil Analysis. Page, A.L. (Ed.), Agronomy Series No. 9, Part 2, pp: 539-579.

Nishio, M. and S. Kusano, 1980. Fuctuation patterns of microbial numbers in soil applied with compost. J. Soil Sci. Plant Nutr., 26: 581-593.

Pera, A., G. Vallini, I. Sireno, M.L. Bianchin and M. De Bertoldi, 1983. Effect of organic matter on rhizosphere microorganisms and root development of sorghum plants in two different soils. Plant Soil, 74: 3-18.

Salonius, P.O., 1972. Microbial response to fertilizer treatments in organic forest soils. Soil Sci., 114: 12-19.

Skene, T.M., J.O. Skjemstad, J.M. Oades and P.J. Clarke, 1997. The influence of inorganic matrices on the decomposition of Eucalyptus litter. Aust. J. Soil Res., 35: 73-87.

Steffen, R., 1979. The value of composted organic matter in building soil fertility. Compost and Land Utilization, 20: 34-37.

ULG., 1992. An overview of present horticulture production. Part II, Smallholder Sector. In: Horticultural Export Marketing Study, Vol. I. Warwick, ULG Consultants, Ltd., pp: 11-12.