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Research Article

Performance of Two Rape (*Brassica napus*) Cultivars under Different Fertilizer Management Levels in the Smallholder Sector of Zimbabwe

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Crop response to fertilizer application depends on the physiological and morphological characteristics of the cultivars, thus causing cultivar differences in growth rate and final yield. A study was carried out in the Zvimba smallholder farming area of Zimbabwe, from November 2016 to February 2017, to investigate the performance of two rape (*Brassica napus*) cultivars under different nitrogen fertilizer management levels. An experiment was set up in a randomized complete block design, replicated three times, with two rape varieties, Hobson and English Giant, and 5 ammonium nitrate (AN) (34.5% N) fertilizer application rates (200 kg/ha, 300 kg/ha, 350 kg/ha, and 400 kg/ha) as factors. Nitrogen fertilizer rates had a significant ($p < 0.05$) effect on leaf length at 6 WAP and 7 WAP. Nitrogen fertilizer application levels had significant effects on both in-season and total fresh leaf yield. There were no varietal effects on the leaf length ($p > 0.05$), in-season yield and total leaf yield ($p > 0.05$), and there were also no variety ∗ fertilizer application level interaction effects on leaf length, in-season yield and total leaf yield ($p > 0.05$). From the results of this study, English Giant rape would maintain a longer leaf length than Hobson up to the end of the season, but the two cultivars have similar yield response to fertilizers' application rate. Both the English Giant rape and Hobson rape cultivars can, therefore, be recommended for production in the Mhondoro smallholder farming area of Zimbabwe and other areas with similar climatic and soil characteristics.

1. Introduction

The current food production in Southern Africa and specifically in Zimbabwe is inadequate. Zimbabwe is currently importing much of its food, and most of the basic commodities and agriculture produce are imported and yet there are vast tracts of land in farms and small suitable pockets in the smallholder sector where food production can be practiced. There is need to find new efficient ways to meet these growing food needs without undermining our futures. With the population of 17 million, expected to double in 2050, the demand for food will more than double as a result of urbanization [1]. There are, however, opportunities in increasing agricultural output and profitability through promoting the use of improved and adaptable hybrids and through the application of site-specific rates of nutrient sources. Such gains are likely to catalyze economic growth and subsequent improvement in livelihoods, food security, and employment and thus, meet the Sustainable Development Goals which aim to end poverty and hunger, among other objectives.

Vegetable production in Zimbabwe is a fast expanding enterprise because of the increasing demand resulting from the rapid increasing urban populations [2]. Diversification in crop production by small holder farmers in Southern Africa has the capability of creating employment and increase in income. This, in turn, allows for the purchase of food to increase food security [3]. Vegetables provide nutrients such as vitamins, minerals, and roughage which are essential for a balanced diet [4]. *Brassica napus* and other leaf vegetables are a profitable agricultural enterprise in both local and export markets [2, 5].

Rape is one of the primary vegetable crops in Zimbabwe, grown for its leaves [4], which are rich in vitamin A, thiamine, and ascorbic acid. Rape seed oil is used for baking bread, illumination, lubrication, and the manufacture of soaps [6]. The vegetable is grown all year round in Zimbabwe and is used as a source of income through the selling of the leaf produce [7].

Rape (*Brassica napus*) has a high demand for water due to extensive leaf area and thus needs regular intervals of irrigation. The critical period for rape is the stem-elongation stage when the crop builds the branching structure and strong stems, then produce high yields [8]. Rape is sown for later transplanting at the age of 4–6 weeks after sowing, but the crop can also be grown in situ [6]. The crop has a short life span as compared to other leafy vegetables, making it the most preferred leaf vegetable grown by smallholder farmers in Zimbabwe [9].

According to Musara and Chitamba [10], there are many rape cultivars available in Zimbabwe but the most popular ones are English Giant rape and Hobson cultivars. The characteristics of the two cultivars were summarized by Muchecheti et al. [9]. The English Giant rape cultivar has dark green leaves and medium branches and has an immense growth rate. The English Giant rape has large broad leaves, with a yield potential of the cultivar of 25–40 tons/ha. The cultivar has large broad leaves and is normally preferred for its hardness. The cultivar cooks quicker than its competitor, Hobson. The English Giant rape germination takes 5–10 days and also takes 90 days to mature [11].

Another variety is Hobson rape, which is an improvement of the English Giant rape variety. This variety can be grown throughout the year and is reported to be a high yielding, with the potential of producing 25–40 tons/ha during its production period [12]. The Hobson rape cultivar has a rapid growth and responds well to regular cuttings [13]. The cultivar has pale green leaves and is a very palatable vegetable. It is an excellent variety with a wide sowing window.

Both Hobson and English Giant rape varieties are heavy feeders and respond well to applications of farm yard manure or mature compost, which should, however, be supplemented with either a compound or straight fertilizer [6, 14]. A recommended good practice is to collect soil samples from the land and send for analysis before planting in order to apply the exact amount of fertilizer and manure required by the crop [15]. The condition of the crop will dictate whether further top dressings are needed [11].

The production of leaf vegetables all year round requires land use intensification, and the enterprise is only viable and profitable when nutrients from the soils which are depleted during crop production are replenished [16, 17]. Continuous cropping in most soils in sub-Saharan Africa has led to the deficiency in nitrogen (N), phosphorus (P), or both [18]. The negative nutrient balances have been attributed by the removal of crop residues from the fields, coupled with lower rates of macronutrients applications compared to losses [19].

Rape grows on a wide range of soils, provided the inherent drainage and fertility problems associated with clays and sandy soils are alleviated [11, 20]. The improvement and maintenance of soil fertility is the major constraint to sustainable crop production in the communal smallholder farming areas of Zimbabwe. From a regional assessment carried out in the Chinamhora and Mhondoro communal areas of Zimbabwe, it was revealed that over 40% of the soils had phosphorus deficiency, while 82% had very low nitrogen [21]. In addition, communal area fields show wide ranges in the values of soil properties [21], and this coupled with continuous cropping has led to the deficiency in nitrogen (N), phosphorus (P), or both [18]. The implications are that sustainable crop yield can only be achieved through determination of site-specific variety and nutrient requirements instead of the generalized crop and fertilizer recommendations, an approach that is currently used in Zimbabwe.

The rate of fertilizer use by famers generally depends on various factors, including arable land size, household income, and distance to input purchasing point, fertilizer price, and transport cost [22, 23]. Findings by Murwira [24] were that smallholder communal farmers in Zimbabwe applied an average of 18 kg/ha of Compound D (8:14:7) fertilizer, which was below the recommended rate of 300 kg/ha. Such application of lower than the required amount of fertilizer by the smallholder farmers could be attributable to the blanket recommendations that made by research and extension services on fertilizer application rates [25]. The cost of fertilizer is prohibitively high, difficult to transport, and often in short supply, forcing many farmers to apply less than the recommended rates which eventually leads to low yields [26]. Smallholder farmers usually apply these nutrients, not at site-specific rates but using the general recommendations from agronomic guidelines [25, 27, 28]. Most countries in the region's mineral recommendation rates are geared towards large-scale commercial farmers and thus overlooked the spectrum of farming objectives and returns and investment that typifies smallholder farming systems [27]. Such imperfect fertilizer management has always resulted in the inconsistent and inappropriate application of fertilizer in agricultural production, with consequent environment risks [29].

The generally recommended fertilizer application rates for both English Giant rape and Hobson varieties 600 kg/ha Compound C fertilizer (6N $15P_2O_5 12\ K_2O$) applied as basal before or during transplanting. Ammonium nitrate (AN) is applied as a topdressing at the rate of 200 kg/ha (NTS, 2010). Since the crop is harvested continuously, topdressing is usually split with the first application at three weeks after transplanting and every three weeks, thereafter, as long as picking is continuous [30].

If appropriate fertilizer inputs are combined with suitable varieties, larger increases in crop yields could be achieved on a sustainable basis. It is hypothesized in this study that the two rape varieties, English Giant and Hobson, have similar growth and yield response to varying AN fertilizer application levels. The results of the experiment are useful in minimizing the cost of fertilizers through application of site-specific requirements, instead of using the general recommendation in the general rape agronomy guide.

2. Methods

2.1. Description of the Study Area. The experiment was carried out from November 2016 to February 2017 in a communal area, in Ward 4 of Chegutu District in the Mashonaland West Province of Zimbabwe, where the main economic activity is agriculture. Ward 4 of Chegutu District is located 95 km southwest of the city of Harare, about 60 km southeast of Chegutu, at an altitude of 11280 m [31].

The experimental site lies in the natural Agro-Ecological Region 2b of Zimbabwe, where the climate is characterized by an annual rainfall that ranges from 750 to 1000 mm in the months of November to March and a mean annual rainfall of 819 mm [31]. The study area has unreliable rainfall pattern which is not evenly distributed and hence is characterized by seasonal dry spells.

The area records minimum and maximum temperatures for the site area at 2°C and 32°C, respectively. The coldest and the hottest months for the area are July and October, respectively [32]. The main agricultural system in the research area is mainly subsistence farming [33]. Local people rely mainly on agriculture to make their living, cultivating subsistence crops chiefly maize, groundnuts, pulses, tobacco, and horticultural crops and keeping cattle. The soils are mainly granitic sandy soils. The predominant soils in the research area are granitic sand soils which are high in quartz and are light colored. The soils have a low inherent fertility. The soils have low available water-holding capacity and poor structure; this makes them to have high leaching losses as when compared to other soils [33].

2.2. Experimental Design. A two-factor experiment was set up in a randomized complete block design and was replicated 3 times. Factor one was rape variety (English Giant and Hobson varieties), and the second factor was ammonium nitrate (34.5% N) fertilizer application rate (200 kg/ha, 300 kg/ha, 350 kg/ha, and 400 kg/ha). Each plot consisted of three 1 by 10 m beds (30 m^2), and experimental assessments were done in the central bed (10 m^2). The experimental treatments were allocated randomly to the treatment plots.

The seedlings for the experiment were raised from the seed that was purchased from the National Tested Seeds, a company that sells seed for horticultural crops in Zimbabwe. Basal compound (NPK) and topdressing fertilizer as well as lime were applied in accordance with the recommendations made when the soil was sent for analysis (Figure 1). The basal fertilizer used in the experiment was Compound C (6% N; 15% P; 12% K). The Compound C fertilizer was applied during transplanting at the rate of 600 kg/ha. Ammonium nitrate (AN) (34.5% N) was used as a nitrogen source, and it was applied as a top dressing. Ammonium nitrate fertilizer was applied in two equal parts, with the first application done at 2 weeks after transplanting, while the second was done at 5 weeks after transplanting. The standard requirement was 200 kg AN/ha, as recommended by the result of soil analysis (Figure 1).

The experimental plots were hand weeded regularly. Insect pests were controlled to minimize economic losses. During the course of the experiment, the plots were watered 2 times a week at the rate of 30 mm, and this depended on the crop requirements and weather conditions.

2.3. Harvesting. Harvesting commenced on the first week after the second topdressing application. Two parameters, the longest leaf length and the fresh leaf mass, were measured at 5, 7, 9, and 11 weeks after transplanting (WAP). For each treatment, data were collected from 10 plants systematically selected from the central bed and tagged for repeated measurements. At every harvesting period, the longest leaf was measured, and the harvested leaves from the sampled 10 plants were weighed on a digital scale.

2.4. Data Analysis. The statistical package, GenStat Discovery 14th Edition, was used to analyze the data. All data were subjected to an analysis of variance (ANOVA), and treatment means were separated using the least significance difference (LSD) test at $p < 0.05$.

3. Results

There were significant ($p < 0.05$) AN fertilizer application rate effects on the longest leaf length at 5, 7, 9, and 11 weeks after transplanting (Table 1). All the tested AN application rates (300 kg/ha, 350 kg/ha, and 400 kg/ha) had a significant greater ($p < 0.05$) longest leaf length than the standard (200 kg/ha) at all the assessment times (5, 7, and 9 WAP). Generally, longest leaf dimensions increased with the increasing levels of AN fertilizer from 200 to 400 kg/ha. There were no significant ($p > 0.05$) longest leaf length differences between the 350 kg/ha and 400 kg/ha treated plants at 5, 7, and 11 WAP. The two rape varieties, Hobson and English Giant, had no significant ($p > 0.05$) effect on the longest leaf length differences at 7 and 9 WAP. The English Giant rape had a significantly higher ($p < 0.05$) longest leaf at 9 and 11 WAP. There were no significant variety × fertilizer application level interaction effects ($p > 0.05$) on the longest leaf length at all the assessment times (5, 7, 9, and 11 WAP).

The AN fertilizer application rate effects on the rape fresh leaf yield were significant ($p < 0.05$) at all the assessment times (5, 7, 9, and 11 WAP) (Table 2). All the tested AN application levels (300 kg/ha, 350 kg/ha, and 400 kg/ha) had a significantly greater ($p < 0.05$) in-season fresh yield than standard treatment (200 kg/ha) at all the assessment times (5, 7, 9, and 11 WAP). Generally, in-season fresh leaf yield increased with the increasing levels of fertilizer from 200 to 400 kg AN/ha. In-season fresh leaf yield for 300 kg and 350 kg/ha AN-treated plants was statistically similar at 5, 7, and 9 WAP, but lower than that from the 400 kg/ha AN-treated plants. The 200 kg/ha, 300 kg/ha, 350 kg/ha, and 400 kg/ha AN/ha treated

ALYTICAL CHEMISTRY SERVICES DIVISION
TEST REPORT NO: 165165

CLIENT ADDRESS: AGRITEX
BOX 130
MUBAIRA

Attention: GANYA SEBASTIAN

LIME & FERTILISER GUIDELINES

			SUGGESTED FERTILISERS						
LAB REF	YOUR REF	CROP	FERTILIZER	N	P_3O_3	K_3O	RATE (kg/ha)	APPLICATION TIME	LIME (kg/ha) SEE NOTES
165165	SAMPLE 1	RAPE	COMPOUND C	6	15	12	600	AT PLANTING	600
			AMMONIUM NITRATE	34.5	0	0	200	3 AND 6 WAP	

WAP········WEEKS AFTER PLANTING

Figure 1: Site-specific results of soil analysis.

Table 1: Effect of variety and AN fertilizer application rate on rape longest leaf lengths at 6, 7, 8, and 9 weeks after transplanting.

AN fertilizer application rate	5 WAP	7 WAP	9 WAP	11 WAP
0 kg/ha	37.49a	32.79a	36.4a	20.85a
200 kg/ha	47.16b	43.79b	46.4b	35.37b
300 kg/ha	50.99c	47.01c	49c	41.27c
350 kg/ha	50.44c	46.15bc	49.6c	42.28cd
400 kg/ha	52.52c	48.11c	51.6d	44.92d
p-fert	<0.001	<0.001	$p < 0.001$	<0.001
English Giant	48.59	49.63	44.2b	47.5b
Hobson	46.85	47.6	42.94a	45.8a
Pvar	0.07	0.195	0.011	0.003
pvar * fert	0.223	0.848	0.714	0.279
Lsd-fert	2.999	3.122	1.97	3.328
Lsd-var			1.25	2.105

Table 2: Effect of variety and AN fertilizer application rape fresh leaf yield (g/plant) at 6, 7, 8, and 9 weeks after planting.

AN fertilizer application rate	5 WAP	7 WAP	9 WAP	11 WAP
0 kg/ha	84.2a	84.2a	61.7a	38a
200 kg/ha	176.7b	176.7b	158.3b	194b
300 kg/ha	182.5b	182.5b	163.3b	150b
350 kg/ha	208.3b	208.3b	191.7b	172b
400 kg/ha	248.3c	248.3c	231.7c	205b
p-fert	<0.001	<0.001	<0.001	<0.001
English Giant	449.3	386.3	163.3	162
Hobson	433.7	381.7	159.3	142
Pvar	0.785	0.505	0.679	0.382
pvar * fert	0.833	0.991	0.991	0.497
Lsd-fert	31.04	32.52	31.64	72.8

plants had statistically similar in-season fresh leaf yield at 11 WAP.

There were no significant ($p > 0.05$) in-season fresh leaf mass differences between the two rape varieties, Hobson and English Giant, and there were also no significance ($p > 0.05$) on the variety x fertilizer level interaction effect on in-season fresh leaf yield all the assessment times (5, 7, 9, and 11 WAP).

There was a significance ($p < 0.05$) of AN fertilizer application rate effects on the total rape fresh leaf yield (Figure 2). All the AN application rates (200 kg/ha, 300 kg/ha, 350 kg/ha, and 400 kg/ha) had a significant greater ($p < 0.05$) total fresh yield than the negative control treatment (0 g Nm^{-2}). Total fresh leaf yield for 300 kg/ha and 350 kg/ha AN-treated plants had statistically similar fresh leaf yield with the standard (200 kg/ha) (Lsd = 2.643), while fresh leaf yield from the 400 kg/ha AN-treated plants was significantly greater than all the tested AN fertilizer rates (Lsd = 2.646). There were no significant ($p > 0.05$) total fresh leaf mass differences between the two rape varieties, Hobson and English Giant, and there were also no variety x fertilizer level interaction effects on total fresh leaf yield.

4. Discussion

Rape growth increased as levels of increased nitrogen concentration was increasing with the increase in the nitrogen rate from 0 to 400 kg/ha in spite of the time of application showing that there are additional yield benefits that could be realized if higher levels of N are applied to both varieties. According to Wang and Li [34], vegetable yields are increased continuously to a certain threshold rate, and any excess input of fertilizer more or less reduced plant growth, leading to yield decline harvests. As argued by Kant et al. [35], the increases in rape leaf yield with nitrogen availability showed that nitrogen favoured more vegetative growth producing plants with a higher leaf count and subsequently higher total green leaf area per plant. Low nitrogen fertilizer of ammonium nitrate treatments might have negatively affected the photosynthesis process leading to reduced growth rate and consequently yield [36], while high rate of nitrogen increasing leaf area development increases overall crop assimilation [37]. while high rate of nitrogen increasing leaf area development increases overall crop assimilation [38] According to Öztürk [38],

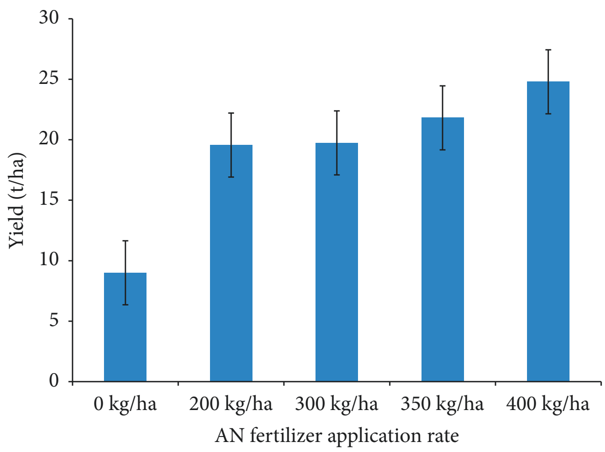

Figure 2: Average yield (t/ha) for the different fertilizer application levels.

ammonium nitrate at optimal rates of 100 to 150 kg/ha was more appropriate on rape than comparative rates using ammonium sulphate and urea, thus highlighting the practical importance of adequate fertilizer application and even suitable source in both seed and leaf yield. However, the accumulation of nitrates is one of the major disadvantages of high-level fertilizer application in rape [39]. However, NO_3–N concentration increased with supply under drought but was unaffected by supply under irrigation [40], making the practice of optimum water application a necessity.

The Giant rape and Hobson rape had similar leaf length response to AN application rate under the subtropical Zvimba District conditions. As argued by Bacha et al. [41], the genotype × environment × E interaction effects make it difficult to select the best performing as well as the most stable genotypes, and so, its efficient interpretation is an important issue in plant improvement. This similarity of the two rape cultivars to application rate could be an indication of similarity in the breeding history, may be with a common parentage.

The general decline trend in rape leaf yield in all treatments from the first to the last harvest may be attributed by changes in B napus developmental stages and declining in nutrient supply [4]. The general yield potential of both varieties is 24–40 tons/ha (National Tested Seeds, Zimbabwe). However, the average yield produced from the research was 19.3 tons/ha far below the expected yield probably to the excessiveness of 920 mm of rainfall and the above 22°C received during the nine weeks of the experiment. The excessive rains received could have caused the leaching of nitrogen fertilizers; as a result, this reduced the yield of rape [42].

5. Conclusion and Recommendations

5.1. Conclusion. The results showed that the highest vegetative growth rates, as measured by the longest leaf, as well as the highest fresh leaf yield were obtained from the 400 kg/ha AN-treated plots. This drives home the point that the higher growth rate and yield are obtained when nitrogen fertilizer is applied in large quantities. Also, the results showed no cultivar effect on growth and yield of rape vegetable. However, English Giant rape growth rate started on higher threshold levels and then subsequently declined as the harvest progressed, whereas Hobson rape showed the opposite results, it started at low levels and then increased as the harvesting progressed.

5.2. Recommendations. It is recommended that farmers should be encouraged to grow either of the two varieties as they showed that they have no effect on the growth rate and yield of rape. Both varieties indicated that they perform very well under high nitrogen levels. It also recommended that further research should be done to ascertain the hazards of nitrates in vegetables to human health and their effect to the environment. Also, another research to assess the chemical content and the taste of rape vegetables after application of higher nitrogen fertilizer levels needs to be investigated.

Data Availability

The raw and processed data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interests regarding the publication of this paper.

References

[1] IndexMundi, "Zimbabwe Population growth rate," 2018, https://www.indexmundi.com/Zimbabwe.

[2] E. Kuntashula, P. L. Mafongoya, G. Sileshi, and S. Lungu, "Potential of biomass transfer technologies in sustainable vegetable production in the wetlands (DAMBOS) of eastern Zambia," *Experimental Agriculture*, vol. 40, no. 1, pp. 37–51, 2004.

[3] P. Drechsel and D. Kunze, *Waste Composting for Urban and Peri-Urban Agriculture, Closing the Rural-Urban Nutrient Cycle in Sub-Saharan Africa*, International Water Management Institute, Food and Agriculture Organization and CABI Publishing, Wallingford, UK, 2001.

[4] I. W. Nyakudya, L. Jimu, M. Marashe, and C. A. T. Katsvanga, "Comparative growth and yield responses of rape (*Brassica napus L.*) to different soil fertility management amendments," *Electronic Journal of Environmental, Agricultural and Food Chemistry*, vol. 9, no. 1, pp. 207–214, 2010.

[5] B. Loehr, A. A. Seif, and B. Nyambo, "Vegetable IPM in Africa: current status and future prospects with emphasis on eastern and southern Africa," *Acta Horticulturae*, no. 513, pp. 99–104, 1998.

[6] G. W. Ware and J. P. McCollum, *Producing Vegetable Crops*, The Interstate Printers and Publishers, Danville, IL, USA, 1975.

[7] H. C. Thompson and W. C. Kelly, *Vegetable Crops*, McGraw-Hill Book Co., New York, NY, USA, 4th edition, 1957.

[8] G. U. Xiao-bo, L. I. Yuan-nong, D. U. Ya-dan, and Y. I. N. Min-hua, "Ridge-furrow rainwater harvesting with supplemental irrigation to improve seed yield and water use

efficiency of winter oilseed rape (*Brassica napus L.*)," *Journal of Integrative Agriculture*, vol. 16, no. 5, pp. 1162–1172, 2016.

[9] F. Muchecheti, I. C. Madakadze, and P. Soundy, "Production of rape (*Brassica napus L.*) on soils amended with leguminous tree prunings: yield responses in relation to the chemical composition of the tree prunings," *African Journal of Agricultural Research*, vol. 7, no. 24, pp. 3541–3549, 2012.

[10] C. Musara and J. Chitamba, "Growth rate and yield of *Brassica napus* in response to *Acacia angustissima* leaf biomass application," *Journal of Animal & Plant Sciences*, vol. 25, no. 2, pp. 510–518, 2015.

[11] J. M. Tweedie and A. J. Mullins, *Kale-Rape, Agric Handbook*, Department of conservation and extension, Harare, Rhodesia, 1962.

[12] C. H. Oldham, *Brassica Crops and Allied Cruciferous Crops*, Biotech Books, Delhi, India, 1999.

[13] ICRAF: 2006, World Agroforestry Centre, http://www.worldagroforestrycentre.org/sea.

[14] S. P. Baliyan, P. S. Baliyan, and K. S. Madhava Rao, "Response of different combinations of manure and fertilizers to the yield of rape crop," *International Journal of Agricultural Research, Innovation and Technology*, vol. 2, no. 2, pp. 44–47, 2012.

[15] Washington University Extension (WSUE), *A Home Gardener's Guide to Soils and Fertilizers*, Washington State University Extension EM063E, Pullman, WC, USA, 2014.

[16] P. M. Kormawa, A. Y. Kamara, S. C. Jutzi, and N. Sanginga, "Economic evaluation of using mulch from multi-purpose trees in maize-based production systems in Southern-Western, Nigeria," *Experimental Agriculture*, vol. 35, no. 1, pp. 101–109, 1999.

[17] T. Losak, J. Hluseki, S. Kracmar, and L. Varga, "The effects of nitrogen and sulphur fertilization on yield and quality of Kohlrabi (*Brassica olarracea*)," *Revista Brasileira de Ciência do Solo*, vol. 32, no. 2, pp. 697–703, 2008.

[18] P. L. Mafongoya, K. E. Giller, and C. A. Palm, "Decomposition and nitrogen release patterns of tree prunings and litter," *Agroforestry Systems*, vol. 38, pp. 77–97, 1998.

[19] W. Bedada, *Compost and fertilizer—alternatives or complementary? Management feasibility and long-term effects on soil fertility in an ethiopian village. Faculty of natural resources and agricultural sciences department of soil and environment*, Ph.D. thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, 2015.

[20] A. Shumba, "Integrated soil fertility, residue and tillage management for improved soil quality and maize (Zea mays, L.) production in urban agriculture in Harare and Chitungwiza," *Master of Philosophy Degree in Agriculture (MPhil) Thesis, Soil and Agricultural Engineering, Department, Faculty of Agriculture*, University of Zimbabwe, Zimbabwe, 2018.

[21] J. Nyamangara, L. M. Mugwira, and S. E. Mpofu, "Soil fertility status in the communal areas of Zimbabwe in relation to sustainable crop production," *Journal of Sustainable Agriculture*, vol. 16, no. 2, pp. 15–29, 2000.

[22] E. Bhondayi, "An investigation of the determinants of fertilizer use by communal farmers in drought prone areas of Zimbabwe, a study of Buhera District," Research Project Report, Department of Agricultural Economics and Extension, University of Zimbabwe, Harare, Zimbabwe, 2004.

[23] F. Zinyama, "A comparative analysis of the use of pit-stored manure on vegetables and field crops: the case of Mangwende Communal Area in Murehwa District," Research Project Report, Department of Agricultural Economics and Extension, University of Zimbabwe, Harare, Zimbabwe, 2003.

[24] H. K. Murwira, "Ammonia losses from Zimbabwean cattle manure before and after incorporation into soil," *Tropical Agriculture*, vol. 72, pp. 269–276, 1995.

[25] J. Dimes, L. Muza, G. Malunga, and S. Snapp, "Trade- offs between investments in nitrogen and weeding. On farm experimentation and simulation analysis in Malawi and Zimbabwe," in *Integrated approaches to higher maize productivity in the New Millennium; Proceedings of the Seventh Eastern and Southern Africa Regional Maize Conference, (February 2001)*, D. K. Friesen and A. F. E. Palmer, Eds., pp. 452–456, CIMMTY (International Maize and Wheat Improvement Center) and KARI (Kenya Agricultural Research Institute), Nairobi, Kenya, 2004.

[26] O. Svubure, *Fertilizer Management for Optimum Maize Yields in Sandy Soils of Zimbabwe*, Agritex, Harare, Zimbabwe, 2000.

[27] D. Hikwa and L. Mukurumbira, "Highlights of previous, current, and proposed soil fertility research by the Department of Research and Specialist Services (DRSS) in Zimbabwe," in *Report on the First Meeting of the network Working Group. Soil Fertility Research Network for Maize Based Farming Systems in selected Countries of Southern Africa. Rockefeller Foundation Southern Africa Agricultural Science Program and the International Maize and Wheat Improvement Centre Maize Program, Lilongwe and Harare*, S. R. Waddington, Ed., pp. 1-2, 1995.

[28] S. F. M. Kazombo-Phiri, "Main cause of declining soil productivity in Malawi: effects on agriculture and management technologies employment to alleviate the problem," in *Sustainable Agriculture Systems for the Drylands, Proceedings of the International Symposium for Sustainable Dryland Agriculture systems, (December 2003)*, O. Go and D. Pastemak, Eds., p. 336, Niamey, Niger, 2005.

[29] X. T. Ju, C. L. Kou, F. S. Zhang, and P. Christie, "Nitrogen balance and groundwater nitrate contamination: comparison among three intensive cropping systems on the North China Plain," *Environmental Pollution*, vol. 143, no. 1, pp. 117–125, 2006.

[30] Department of Meteorological Services, *Climate Handbook of Zimbabwe*, Department of Meteorological Services, Harare, Zimbabwe, 1981.

[31] A. Turner and O. Chivinge, *Production and Marketing Of Horticultural Crops in Zimbabwe: A survey of Smallholder Farmers in the Mashonaland East province*, CIIFAD, NY, USA, 1999.

[32] Surveyor General, *The Climate of Zimbabwe*, Government of Zimbabwe Printers, Harare, Zimbabwe, 1995.

[33] AGRITEX, *Natural Regions and Farming Areas, Agritex planning Branch*, Government Printers, Harare Zimbabwe, 1983.

[34] Z. Wang and S. Li, "Effects of nitrogen and phosphorus fertilization on plant growth and nitrate accumulation in vegetables," *Journal of Plant Nutrition*, vol. 27, no. 3, pp. 539–556, 2007.

[35] S. Kant, Y. M. Bi, and S. J. Rothstein, "Understanding plant response to nitrogen limitation for the improvement of crop nitrogen use efficiency," *Journal of Experimental Botany*, vol. 62, no. 4, pp. 1499–1509, 2011.

[36] R. Fox, *The sewage solution. Practical Hydroponics and Greenhouse Magazine*, Casper Publications, 2008, http://www.hydroponics.com.au/back-issues/issue20.html.

[37] J. K. Yayock, G. Lombin, and J. J. Owonubi, *Crop Science and Production in Warm Climates*, Macmillan Publishers Ltd., London, UK, 1988.

[38] Ö Öztürk, "Effects of source and rate of nitrogen fertilizer on yield, yield components and quality of winter rapeseed (*Brassica napus L.*)," *Chilean Journal of Agricultural Research*, vol. 70, no. 1, pp. 132–141, 2010.

[39] E. Chakwizira, P. Johnstone, A. L. Fletcher, E. D. Meenken, J. M. de Ruiter, and H. E. Brown, "Effects of nitrogen rate on nitrate–nitrogen accumulation in forage kale and rape crops," *Grass and Forage Science*, vol. 70, no. 2, pp. 268–282, 2015.

[40] C. Fallovo, M. Schreiner, D. Schwarz, G. Colla, and A. Krumbein, "Phytochemical changes induced by different nitrogen supply forms and radiation levels in two leafy *Brassica* species," *Journal of Agricultural and Food Chemistry*, vol. 59, no. 8, pp. 4198–4207, 2011.

[41] T. Bacha, S. Alemerew, and Z. Tadesse, "Genotype X environment interaction and yield stability of bread wheat (*Triticum aestivum L.*) genotype in Ethiopia using the ammi analysis," *Journal of Biology, Agriculture and Healthcare*, vol. 5, no. 11, 2015.

[42] O. Balodis and Z. Gaile, "Influence of agro ecological factors on winter oil-seed rape (*Brassica napus L.*) autumn growth," in *Research for Rural Development*, Z. Gaile, K. Špoģis, A. Kaķītis et al., Eds., pp. 36–44, International Scientific Conference Proceedings, Jelgava Latvia, 2009.

[43] P. Brady, *Soils and their Improvement*, Agrobios, Jodhpur, Rajasthan, 1990.

[44] H. A. Elwell and M. A. Stocking, "Loss of soil nutrients by sheet erosion in a major hidden farming cost," *Zimbabwe Science News*, vol. 22, no. 7-8, pp. 79–82, 1988.

[45] Food and Agriculture Organization (FAO), *Fertiliser Use by Crops*, Food and Agriculture Organization of the United Nations, Rome, Italy, 2006.

[46] K. E. Giller, M. H. Beare, P. Lavelle, A. M. N. Izac, and M. J. Swift, "Agricultural intensification, soil biodiversity and agroecosystem function," *Applied Soil Ecology*, vol. 6, no. 1, pp. 3–16, 1997.

[47] P. L. Mafongoya, A. Bationo, J. Kilharaj, and B. S. Waswa, "Appropriate technologies to replenish soil fertility in Southern Africa," *Nutrient Cycling in Agroecosystems*, vol. 76, no. 2-3, pp. 137–151, 2006.

[48] K. Webster and R. R. Wilson, *Tropical Agriculture*, CAB International, Tucson, AZ, USA, 1998.