UNITED NATIONS UNIVERSITY
UNU-LRT

UNU Land Restoration Training Programme
Árleynir 22, 112 Reykjavik, Iceland

Final project 2015

THE EFFICACY OF SUNFLOWER SEED CAKE AS AN ORGANIC FERTILIZER

Emmanuel Chidiwa Mbewe
Lilongwe University of Agriculture and Natural Resources
P. O. Box 219, Lilongwe, Malawi
ecmbewe@yahoo.com

Supervisor
Ulfur Oskarsson
Agricultural University of Iceland
ulfur@lbhi.is

ABSTRACT

A study to evaluate the efficacy of sunflower seed cake as an organic fertilizer was carried out using a pot experiment in a greenhouse at Gunnarsholt during the 2015 growing season. The major objective was to evaluate the efficacy of sunflower seed cake as an organic fertilizer used in the growing of maize. The experiment was laid out in a 3 × 3 factorial design with 3 levels of sunflower seed cake at rates equivalent to 0, 92 and 184 kg N/ha of dry matter per pot containing 2000 g of soil, and 3 levels of inorganic fertilizer at rates equivalent to 0, 23 and 46 kg N/ha. A full rate inorganic fertilizer (92 kg N/ha + 20 kg P/ha) was also included to be used for comparison. Results collected 42 days after seeding showed that maize plant height, the chlorophyll in the maize leaves and plant biomass responded positively to the amount of sunflower seed cake and inorganic fertilizer applied, while stem diameter responded positively to the amount of sunflower seed cake only. Significant differences were mainly obtained between the 0 and 184 kg N/ha for the sunflower seed cake. It can be concluded from this study that sole application of sunflower seed cake has the potential of producing maize yield comparable to full rate inorganic fertilizer application.

This paper should be cited as:

Mbewe EC (2015) The efficacy of sunflower seed cake as an organic fertilizer. United Nations University Land Restoration Training Programme [final project]
http://www.unulrt.is/static/fellows/document/Mbewe2015.pdf

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1. INTRODUCTION

1.1 Soil fertility decline, consequences and management

The term soil fertility is generally defined as the soil's inherent capacity to hold in reserve water, oxygen, and plant nutrients and to supply them in adequate amounts and in suitable proportions for plant uptake (Maida 2005). According to Sanchez (1976) an increase in soil cropping may lead to reduction in the inherent soil fertility. This is exacerbated when the nutrients taken up by plants are not replaced. Soil fertility is also negatively affected by loss of organic matter in agricultural fields in the tropics. Organic matter is considered as a very important part of a healthy soil (European Communities 2009). Organic matter is the main contributor to soil fertility by providing food to soil organisms and acting as storage for nutrients in the soil such N, P, and S. Soil erosion is another contributor to soil fertility loss. Studies have shown that loss of topsoil ranks high among the environmental problems in Malawi and that it is on the increase (Malawi Environment 1998)**.** This has been due to deforestation which has left most of the land bare and therefore exposing the topsoil to be washed away by running water, especially during the rainy season. Snapp et al. (1998) reported that a decreasing level of soil fertility is one of the most important factors which reduce production of arable crops by smallholder farmers in Malawi.

One of the main consequences of declining soil fertility is a drastic decline in crop production and food insecurity. However, in sustainable agricultural and horticultural enterprises, efforts must always be made to maintain not only inherent soil fertility but also soil productivity.

There are several traditional methods of managing soil fertility and these entail either the use of inorganic fertilizers or low external input agriculture based on organic sources of nutrients. In Malawi the external input agriculture based on organic inputs includes the use of organic fertilizers, crop rotations, intercropping, biological nitrogen fixation, agroforestry techniques and fallowing (Saka et al. 1995). One of the organic fertilizers that can be used is the seed cake obtained after extracting oil from sunflower seeds. The seed cake is the material that remains after oil extraction and it is reported to be rich in plant nutrients such as nitrogen, phosphorus and potassium. In a research conducted by Gupta et al. (2006) the sunflower seed cake contained 4.8, 1.4, and 1.2% of N, P_2O_4, and K_2O respectively. There has been an increase in the growing of sunflowers in Malawi and this means a lot of seed cake left after oil extraction.

1.2 Problem statement

In Malawi there is increased loss of soil fertility which leads to low crop yields. The extraction of oil from the sunflower seeds when fully advocated will lead to a lot of waste which, if not properly handled or disposed of, may lead to environmental pollution. There is a need to restore the soil fertility so as to increase crop yields since Malawi's economy is agro based. Use of inorganic fertilizers is an option but the high cost of inorganic fertilizers makes it difficult for the majority of smallholder farmers to afford them. The use of the sunflower seed cakes may offer farmers a cheaper source of fertilizer and at the same time help to solve the problem of environmental pollution. Organic fertilizers also have the advantage of improving both physical and chemical properties of the soil. Not much research has been done to evaluate the efficacy of sunflower seed cake as an organic fertilizer. The use of sunflower seed cake as organic fertilizer would offer farmers a wider range of soil fertility enhancement alternatives in addition to the already existing options.

1.3 Project purpose

The overall goal of the project was to evaluate the efficacy of sunflower seed cakes as an organic fertilizer used in the growing of maize. Specifically the project was aimed at:

1. Evaluating the effect of the different levels of sunflower seed cake on the growth and yield of maize.
2. Evaluating the effect of the different combination of sunflower seed cake and inorganic fertilizer on the growth and yield of maize.

The following hypotheses were tested in this research:

1. The applied sunflower seed cake does not influence the growth and yield of maize.
2. Applying a combination of sunflower seed cake and inorganic fertilizer does not affect the growth and yield of maize.

2. LITERATURE REVIEW

2.1 The use of organic fertilizers in agricultural production

The use of organic inputs as external source of nutrients has been recommended as a feasible alternative to high cost fertilizers in Africa (Reijntjes et al. 1992). The main advantages for increased use are: (i) the replacement of scarce or non-existent capital for inorganic fertilizers with labour, which is cheap especially in African countries and (ii) the fact that organic inputs, in addition to containing nutrients for plant growth, also contain carbon, which is a source of energy for soil organisms that facilitate nutrient cycling (Sanchez et al. 1995).

The literature is full of examples where the use of organic sources has been used with beneficial effects. The application of organic sources to soils has been shown to enhance crop yields, for instance in a study by (Schlecht et al. 2006) yield increases differed depending on the agro-ecological setting and the amount of amendments applied. Organic sources have also been shown to have the positive impact of increasing both the biomass and activity of microbes in soils (Vinten et al. 2002); this implies a microbial community which reacts quickly in such soils. Apart from improving soil fertility status, Esilaba et al. (2000) report that applying organic residues has also been shown to reduce both the occurrence and abundance of *striga* weed. Gruhn et al. (2000) indicated that using organic manures guarantees proper management of soils because they provide nutrients in the right amounts and proportions that are not detrimental to the environment. If organic materials that have low C/N ratios are applied timely, the release of nutrients may coincide with plant demand, especially in crops with a short growing cycle such as maize. This will lead to reduced demand for inorganic fertilizers which are needed for such high nutrient demanding crops (Burie 1992). The application of green manures has been shown to have a positive impact on both the physical and chemical properties of soil as evidenced in a study by Chukwuka and Omotayo (2008). Studies in south-eastern Nigeria by Oguike et al. (2006) showed rice mill waste utilized as a soil amendment displayed a relatively higher potential in improving the physico-chemical properties of nutrients depleted by Haplic Acrisols compared to NPK fertilizer.

In summary it can be said that the use of organic sources as soil amendments has been shown to have many benefits. These include improving the soil fertility status, controlling weeds, increasing the availability and activity of soil biota, increasing crop yields and improving both the physical and chemical properties of the soil, just to mention a few.

Although the organic sources have been shown to have a lot of benefits they also have their own disadvantages. As reported by Palm (1995) and Palm et al. (1997) these include: (a) their concentration of nutrients is on the lower side when compared to inorganic fertilizers, and (b) the nutrients they contain vary widely. Manures from plant and animal material contain up to 4% N on a basis of dry mass, while 20 to 46% N is found in inorganic fertilizers and the inorganic fertilizers are already in dry form. In addition, organic inputs supply very little P since they also have a low P concentration (Palm 1995; Palm et al. 1997).

2.2 Sunflower production

Sunflower (*Helianthus annuus* L.) is a plant belonging to the plant family Asteraceae. It is reported to have been domesticated in eastern North America and Mexico. Sunflower is grown in many parts of the world including Argentina, Canada, central Africa and Russia (Angadi & Entz 2002). As reported by Stone et al. (2002) sunflower is adapted to drought conditions because it has long roots which can extend up to 2 m depth. It is therefore easily adapted in semi-arid regions of the world. It is reported that sunflower has also been used in rotations with shallow rooted crops in the US (Angadi & Entz 2002; Johnston et al. 2002).

Rosa et al. (2009) reports that sunflower is mainly grown for its seed which is rich in oil and proteins. They contain from 36–52% and 28–32% oil and protein, respectively. At present the sunflower varieties that are produced in Malawi contain on average 40% oil (NES [National Export Strategy] 2013). Johnston et al. (2002) add that sunflower is also used for confectionery and bird feed markets. Sunflower seeds and the seed cake that remains after oil extraction are also used as animal fodder due to the high protein content. The seed cake also contains essential plant nutrients such as N, P, and K and can therefore be used as an organic fertilizer (Gupta et al. 2006). In Malawi, the literature indicates that only one third of the seeds can be extracted as oil (NES 2013). In a study conducted in India by Gupta et al. (2006) the sunflower seed cake contained 4.8, 1.4, and 1.2% of N, P_2O_4, and K_2O respectively. In that study the researchers concluded that the efficiency of sunflower seed cake on eucalyptus plant height and diameter improvement was better than farmyard manure and a chemical fertilizer.

Due to increased demand for oil seeds to meet dietary requirements for the human population, sunflower production has been on the increase. FAO (2004) indicates that in Africa the increase has been both in the amount of sunflower produced and the total area under sunflower production; the rate of increase has been reported to be 5% and 21% between 2001 and 2003, respectively. In Malawi the area under production of sunflower has also been increasing between 2005 and 2013, especially between the years 2008 and 2013, as shown in Figure 1.

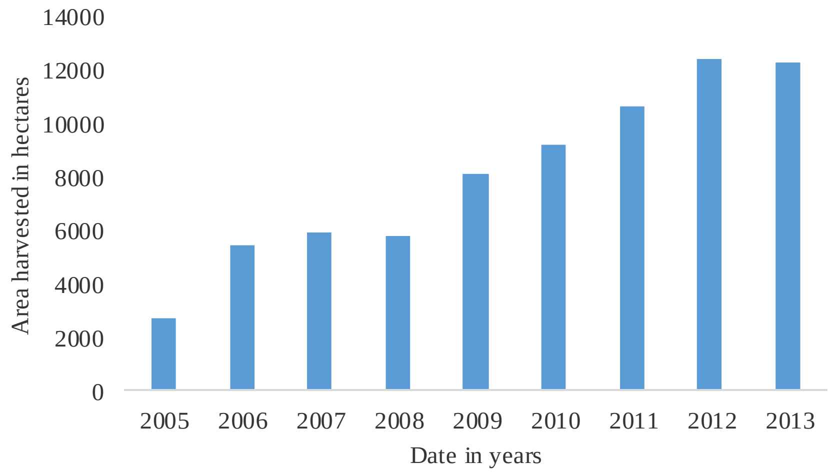

Figure 1. Sunflower seed area harvested in hectares in Malawi from 2005–2013. (Fact fish 2015).

3. MATERIALS AND METHODS

3.1 Study site

A pot experiment was designed and carried out in a greenhouse at Gunnarsholt during the 2015 growing season. Gunnarsholt is situated in South Iceland (63°51'N, 20°18'W) at about 50–60 m above sea level.

3.2 Treatments, experimental layout

The pot experiment included exclusive application of sunflower seed cake and a combination of sunflower seed cake and inorganic sources of N in the soil. The experiment was set out in a 3 × 3 complete factorial arrangement in a completely randomized design replicated five times. The three levels of sunflower seed cake were 0, 92 and 184 kg N/ha, while the three levels of inorganic fertilizer were 0, 23, and 46 kg N/ha. The levels were chosen based on the fact that 92 kg N/ha is the recommended rate for maize growing in Malawi. Therefore 184 kg N/ha is double the recommended rate and 23 and 46 kg N/ha are respectively the quarter and half rates. The double rate was chosen considering that organic fertilizers are slow releasers of plant nutrients.

The mass of seed cake and inorganic fertilizer per pot was derived from the ratio of soil mass used in the pot and the mass of soil per hectare in the top 20 cm. The mass of soil used per 2 L capacity pot was 2000 g. The mass of sunflower seed cake to be added in each pot was calculated as follows:

Mass of soil per hectare: Area of the field × soil depth × bulk density of the soil
(10000 cm × 10000 cm) × (20 cm) × (1.00 g/cm^3) = 2,000,000,000 g of soil.
Using sunflower seed cake with 4.5% N (this value was just an estimate using a value of the 4.8% found in the literature (Gupta et al. 2006)), to achieve 92 kg N/ha; the amount of sunflower seed cake required was: (100/4.5) × 92 kg = 2044 kg = 2, 044,000 g.

Since 2000 g of soil was be used in each pot then the mass of sunflower seed cake to be used was: (2000 g/2,000,000,000 g) × 2,044,000 g = 2.0 g. Using simple proportion the mass of sunflower seedcake required for a rate of 184 kg N/ha was calculated.

Therefore the sunflower seed cake (SSC) was applied in the soil as follows:

SSC_0 = 0 g seed cake per pot
SSC_1 = 2.0 g seed cake pot
SSC_2 = 4.0 g seed cake pot

For the calculation of amount of inorganic fertilizer (OPTIC KAS 27% N) to be applied the following calculations were used:
Using OPTIC KAS with 27 % N, to achieve 23 kg N/ha, the amount of OPTIC KAS required per hectare was: (100/27) × 23 = 85 kg = 85,000,000 mg
Therefore, for 2000 g of soil: (2,000 g/2,000,000,000 g) × 85,000,000 mg = 85 mg. For the other rate of 46 kg N/ha, simple proportion was used.

Therefore the three levels of inorganic N fertilizer (IF), OPTIC KAS (27% N), were applied as follows:

IF_0 = 0 mg fertilizer per pot
IF_1 = 85 mg fertilizer per pot
IF_2 = 170 mg fertilizer per pot

There was also one treatment as an external treatment which consisted of the full rate of inorganic fertilizer (92 kg N/ha + 20 kg P/ha). Just like the factorial treatments, the full rate inorganic fertilizer treatment was also replicated five times. This treatment was included because it is the recommended rate of fertilizer used for the growing of maize in Malawi. It was also included so that it could be used for comparison with the other treatments.

The schematic presentation of the treatments layout is shown in Table 1.

3.3 Soil and sunflower seed cake quality assessment

Sunflower seed cakes and soil were analysed for total organic carbon, essential elements such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, sodium, zinc, copper, manganese and iron. The C/N ratio of the material was calculated using the results of total organic carbon and total nitrogen of the same material. Carbon and nitrogen were analysed with the carbon analyser called vario MAX CN at Keldnaholt. This machine measures % N (as N_2) and % C (as CO_2). The soil texture was determined by the field method as described by FAO (2006).

The determination of P, K, Ca, Mg, S, Na, Zn, Cu, Mn, Zn, and Fe was done at the Agricultural University of Iceland Headquarters in Hvanneyri. Samples were dried to a constant weight at 60°C and then ground before analysis. Each sample was digested in 60% nitric acid at 125–128°C for 24 hours, and after cooling down to room temperature, the mineral elements were measured in an ICP Mass Spectrometer (Sequential Inductively Coupled Plasma Spectrometer, Jobin Yvon Ultima 2).

Table 1. Schematic presentation of the treatment combinations layout for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season.

Pot Number	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
1	SSC_1IF_1	SSC_0IF_1	SSC_1IF_2	SSC_2IF_2	SSC_2IF_0
2	SSC_2IF_0	SSC_1IF_2	SSC_1IF_1	SSC_1IF_1	SSC_0IF_2
3	SSC_2IF_2	SSC_2IF_0	SSC_2IF_0	SSC_1IF_2	SSC_0IF_0
4	SSC_0IF_1	SSC_2IF_2	SSC_0IF_2	SSC_2IF_1	SSC_1IF_1
5	SSC_0IF_2	SSC_1IF_1	SSC_0IF_0	SSC_2IF_0	SSC_2IF_1
6	SSC_1IF_2	SSC_2IF_1	SSC_2IF_2	SSC_0IF_2	SSC_1IF_2
7	SSC_2IF_1	SSC_0IF_0	SSC_2IF_1	SSC_0IF_1	SSC_1IF_0
8	SSC_0IF_0	SSC_0IF_2	SSC_1IF_0	SSC_1IF_0	SSC_2IF_2
9	SSC_1IF_0	SSC_1IF_0	SSC_0IF_1	SSC_0IF_0	SSC_0IF_1

3.4 Experimental procedure and processes

Each pot was filled with 2000 g of soil. The soil was taken from a non-reclaimed area in Gunnarsholt. The properties of the soil as analysed at the laboratories at Keldnaholt and Hvanneyri are given in Table 2. As can be seen from the table, the soil had a sandy loam texture. This soil was particularly chosen because most soils in Malawi are sandy in nature. The other reason was that sandy loam soil promotes decomposition due to good aeration compared to clay soils (Maida, 2005).

The sun flower seed cake, whose nutrient status is indicated in Table 2, was added to the pots before seeding the maize, which was the test crop. The sunflower seed cake was thoroughly mixed with the soil. This was done on 27th June, 2015. Three maize seeds were seeded in each pot and these were thinned to one a few days after emergence. The inorganic fertilizer was applied one week after emergence. The soil was watered before planting and the moisture content was maintained at field capacity throughout the period of the experiment. The temperature ranged between 15 and 30°C during the period of the experiment.

Table 2. Soil texture and chemical properties and sunflower seed cake chemical properties used in the pot experiment at Gunnarsholt as analyzed at the Keldnaholt and Hvanneyri laboratories.

Property	Soil sample	Sunflower seed cake
Texture	Sandy loam	
pH	6.9	
C	0.222%	64%
N	0.014%	3.6%
C/N ratio	15.9	17.8
P	3.2 mg/kg	0.94%
K	155 mg/kg	0.64%
S	11.8 mg/kg	0.28%
Ca	1927 mg/kg	0.16%
Mg	511 mg/kg	0.43%
Na	139 mg/kg	0.01%
Mn	20.2 mg/kg	28 mg/kg
Zn	4.6 mg/kg	82 mg/kg
Cu	3.14 mg/kg	20.5 mg/kg
Fe		57 mg/kg

3.5 Growth and yield data collection

The growth data collected in this research were plant height and maize stem diameter. Chlorophyll levels were used as an indicator of nutrient status in the plants, in particular nitrogen. The yield data were dry plant biomass after harvest.

Maize plant heights were collected every week starting 21 days after seeding (DAS). The height was measured using a metre rule from the soil surface up to the highest leaf. Maize plant stem diameter was collected every week starting 28 days after planting. The diameter was measured at a height of 2 cm from the soil surface using a venier caliper.

Chlorophyll levels were collected 28 days after seeding and at the time of harvesting. The measurements were taken on the upper-most collared leaf halfway from the leaf base to the tip and halfway from the midrib to the leaf margin. This is according to the description by Schlemmer et al. (2005). Three measurements were taken per pot and the results were then averaged, resulting in a single value to represent that pot. The chlorophyll levels were measured using a chlorophyll metre (OPTI SCIENCES CCM 200 plus).

The total dry plant biomass was done by harvesting both the below- and above-ground biomass. The roots were washed thoroughly and dried in the oven at a temperature between 70°C and 80°C before calculating the biomass per kg of soil.

3.6 Data analysis

The data from the experiment were analysed using the SAS Enterprise Guide 6.1 computer package. The effect of treatments on the means of plant height, stem diameter, chlorophyll levels and dry plant biomass were analysed using ANOVA. When significant differences were observed, a test for differences among the treatments was carried out by the Tukey least significance differences test (LSD) at $p<0.05$ level.

The mathematical model used was:

Y_{ijk} = $\mu + A_i + B_j + AB_k + e_{ijk}$ where:

Y_{ijk} = an observation,

μ = overall mean,

A_i = ith factor A (sunflower seed cake) effect

B_{kj} = jth factor B (inorganic fertiliser) effect

AB_k = kth interaction between factor A (sunflower seed cake) and factor B (inorganic fertiliser) effect

e_{ijk} = error term

4. RESULTS

4.1 Maize plant height

Maize plant heights collected 21 days and 28 days after seeding (DAS) were not significantly affected by the sunflower seed cake, inorganic fertilizer and the interaction of these two. However the maize plant heights obtained 35 days and 42 days after seeding were significantly affected by the sunflower seed cake and inorganic fertilizer applied. The interaction of sunflower seed cake and inorganic fertilizer was not significant (Table 3). For both days, the sunflower seed cake as well as the inorganic fertilizer had a positive effect on the maize plant height. For the sunflower seed cake, significant differences were observed between the 0 and 2 g of sunflower seed cake per kg of soil 35 days after seeding while 42 days after seeding the plant height increased with the increase in sunflower seed cake applied (Table 4). For the inorganic fertilizer significant differences were observed between the treatments 0 and 47.5 mg/kg of soil on both days. These results are given in Table 5.

Table 3. ANOVA output showing F values for maize plant height 28, 35 and 42 days after seeding (DAS) for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Significant levels are presented by: ***: p<0.001, **: p<0.01, *: p<0.05, and NS: not significant.

Source of variation	**Degrees of freedom**	**F values**		
		28 DAS	**35 DAS**	**42 DAS**
SSC	2	1.38^{NS}	6.26**	18.29***
IF	2	0.51^{NS}	12.12***	3.45*
SSC × IF	4	0.87^{NS}	2.30^{NS}	1.40^{NS}

Table 4. Mean maize plant height 35 and 42 days after seeding (DAS) as affected by different levels of sunflower seed cake for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Means with the same superscript in the same column are significantly different at p<0.05.

Sunflower seed cake in g/kg soil	**Maize plant height in cm**	
	35 DAS	**42 DAS**
0	19.81^{b}	22.4^{c}
1	21.49^{ab}	24.6^{b}
2	22.47^{a}	26.7^{a}
p value	0.0047	<0.0001

Table 5. Mean maize plant height 35 and 42 days after seeding (DAS) as affected by different levels of inorganic fertilizer for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Means with the same superscript in the same column are significantly different at p<0.05.

Inorganic fertilizer in mg/kg soil	**Maize plant height in cm**	
	35 DAS	**42 DAS**
0	20.3^{b}	23.8^{b}
47.5	23.4^{a}	25.6^{a}
85	20.4^{b}	24.2^{ab}
p value	0.0047	<0.0001

The means of the main factor sunflower seed cake for the maize plant height obtained 42 days after seeding were compared with the maize plant height for the full rate inorganic fertilizer. The full rate inorganic fertilizer is the one referred to in section 3.2 which was included because it is the recommended rate of fertilizer used for the growing of maize in Malawi. The results of the analysis indicated a significant (F value = 10.77***, degrees of freedom = 3) difference among the treatments. However, only the treatment with 2 g of sunflower seedcake per kg of soil produced a maize plant height that was not significantly different from the maize stem diameter of the full rate of inorganic fertilizer. Figure 2 presents the results of this comparison.

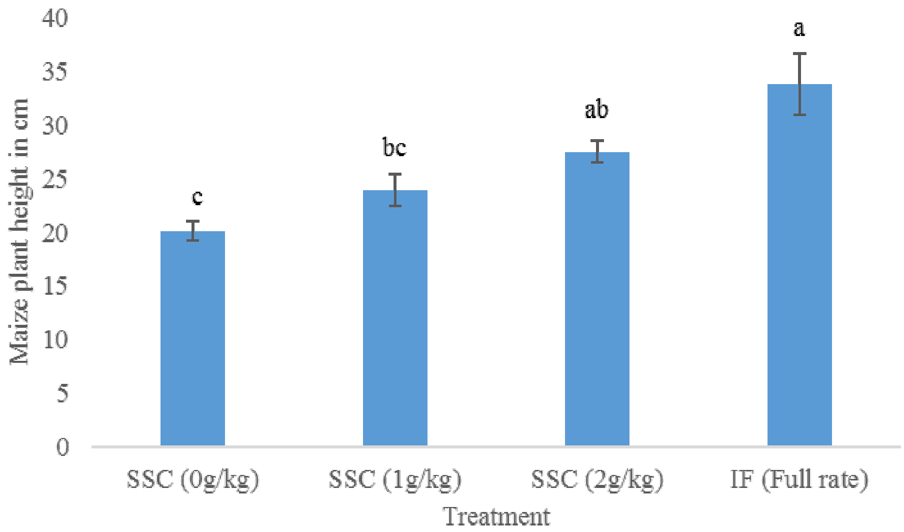

Figure 2. Mean maize plant height (42 DAS) for a pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. The vertical bars indicate standard error (n = 5). Means with different letters are significantly different at p<0.05.

4.2 Maize stem diameter

The maize plant stem diameter at 2 cm taken 28 days after seeding was not affected by either the sunflower seed cake or the inorganic fertilizer applied. The interaction of the sunflower seedcake and inorganic fertilizer did not also have a significant effect on the maize plant stem diameter. When the same analysis was done 35 and 42 days after seeding, sunflower seed cake had a significant effect on the maize stem diameter. The inorganic fertilizer and interaction between sunflower seed cake and inorganic fertilizer did not significantly affect the maize stem diameter (Table 6). An increase in sunflower seed cake led to an increase in stem diameter. As indicated in Table 7 the maize stem diameter differed significantly between 0 g/kg and 2 g/kg of sunflower treatments on both days.

Table 6. ANOVA output showing F values for maize stem diameter 28, 35 and 42 days after seeding (DAS) for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Significant levels are presented by: ***: p<0.001, **: p<0.01, *: p<0.05, and NS: not significant.

Source of variation	Degrees of freedom	F values		
		28 DAS	35 DAS	42 DAS
SSC	2	1.06^{NS}	4.56*	5.30**
IF	2	0.35^{NS}	0.99^{NS}	1.70^{NS}
SSC × IF	4	0.37^{NS}	0.50^{NS}	0.56^{NS}

Table 7. Mean maize stem diameter 35 and 42 days after seeding (DAS) as affected by different levels of sunflower seed cake for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Means with the same superscript in the same column are significantly different at p<0.05.

Sunflower seed cake in g/kg soil	**Maize stem diameter in mm**	
	35 DAS	**42 DAS**
0	38.26^{b}	42.6^{b}
1	42.60^{ab}	50.7^{ab}
2	46.27^{a}	53.6^{a}
p value	0.017	0.0091

As was the case with the maize plant height, the maize stem diameter for the sunflower seed cake collected 42 days after seeding was compared with the full rate of inorganic fertilizer. Figure 3 illustrates this. The statistical analysis of the results gave a significant difference (F = 11.77***, degrees of freedom = 3) among the treatments. It was further shown however that only 2 g/kg sunflower treatments gave a stem diameter that was not significantly different from that given by the full rate of inorganic fertilizer.

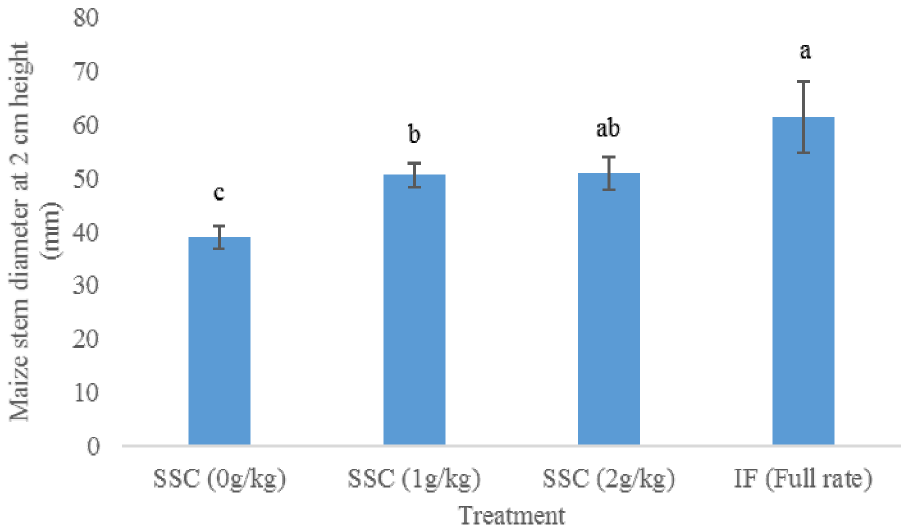

Figure 3. Mean maize stem diameter 42 days after seeding for a pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. The vertical bars indicate standard error (n = 5). Means with different letters are significantly different at p<0.05.

4.3 Chlorophyll levels in maize leaves

Twenty-eight days after seeding the chlorophyll levels were significantly affected by the amount of sunflower seed cake and inorganic fertilizer applied. The interaction of sunflower seed cake and inorganic fertilizer did not affect the chlorophyll levels in maize leaves 28 and 42 days after seeding (Table 8). As illustrated in Table 8 the levels of chlorophyll in maize leaves 42 days after seeding were significantly affected by the amount of sunflower seed cake only. The amount of sunflower seed cake and inorganic fertilizer had a positive effect on the amount of chlorophyll levels in the maize leaves. On both days there was a positive effect of sunflower seed cake with a significant difference observed between 0 g and 2 g of sunflower seed cake per kg of soil, as shown in Table 9. For the inorganic fertilizer the chlorophyll levels increased with an increase in inorganic fertilizer applied. 0 mg/kg of inorganic fertilizer differed significantly from the other two levels of inorganic fertilizer, which were not significantly different from each other (Table 10).

Table 8. ANOVA output showing F values for chlorophyll levels in maize leaves 28 and 42 days after seeding (DAS) for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Significant levels are presented by: ***: p<0.001, **: p<0.01, *: p<0.05, and NS: not significant.

Source of variation	**Degrees of freedom**	**F values**	
		28 DAS	**42 DAS**
SSC	2	6.19*	12.39***
IF	2	9.05**	1.80^{NS}
SSC × IF	4	0.62^{NS}	0.5740^{NS}

Table 9. Mean chlorophyll levels in maize leaves 28 and 42 days after seeding (DAS) as affected by different levels of sunflower seed cake for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Means with the same superscript in the same column are significantly different at p<0.05.

Sunflower seed cake in g/kg soil	**Chlorophyll levels**	
	35 DAS	**42 DAS**
0	4.06^{b}	4.3^{b}
1	4.29^{b}	5.8^{ab}
2	6.06^{a}	7.2^{a}
p value	0.020	0.004

Table 10. Mean chlorophyll levels in maize leaves 28 days after seeding (DAS) as affected by different levels of inorganic fertilizer for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Means with the same superscript in the same column are significantly different at p<0.05.

Inorganic fertilizer in mg/kg soil	**Chlorophyll levels**
0	3.4^{b}
47.5	5.1^{a}
85	6.0^{a}
p value	0.0070

When a comparison was done for chlorophyll levels in maize leaves collected 42 days after seeding for the sunflower seed cake and the full rate of inorganic fertilizer, there was a significant difference (F value = 11.06***, degrees of freedom = 3) between the treatments. It was indicated however that both 1 g/kg and 2 g/kg of sunflower seedcake were not significantly different from the full rate of inorganic fertilizer. These results are shown in Figure 4.

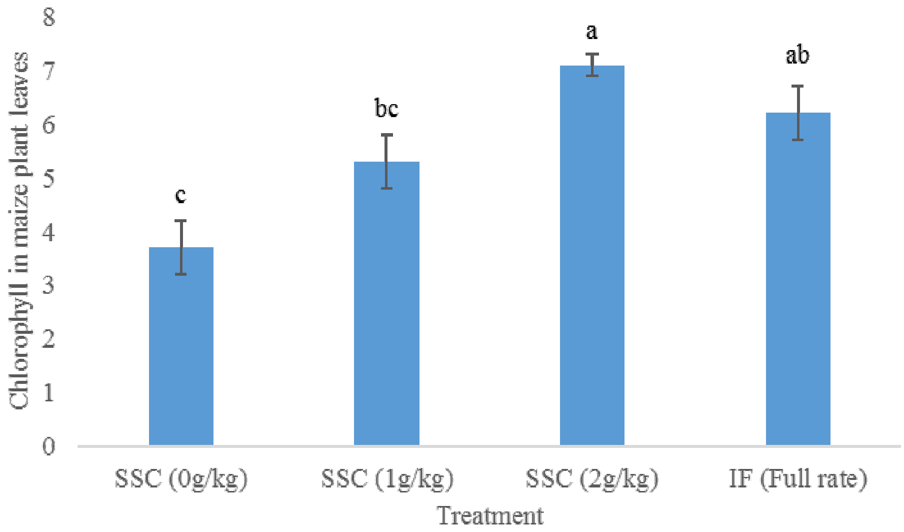

Figure 4. Mean maize chlorophyll levels in maize leaves 42 days after seeding for a pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. The vertical bars indicate standard error (n = 5). Means with different letters are significantly different at p<0.05.

4.4 Maize plant biomass

Maize plant dry biomass was only affected by the main factors, i.e. sunflower seed cake and inorganic fertilizer. There was no interaction effect observed (Table 11). The sunflower seed cake and inorganic fertilizer had a positive effect on the amount of maize plant dry biomass. As can be seen from Table 12, maize plant biomass was shown to be significantly different between 0 and 2 g/kg of sunflower seed cake treatments. The 1 g/kg of soil sunflower seed cake also differed significantly from the 2 g/kg treatment.

Table 11. ANOVA output showing F values for maize plant dry biomass 42 days after seeding for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Significant levels are presented by: ***: p<0.001, **: p<0.01, *: p<0.05, and NS: not significant.

Source of variation	**Degrees of freedom**	**F value**
SSC	2	17.17***
IF	2	20.84***
SSC × IF	4	1.62^{NS}

Table 12. Mean maize plant dry biomass 42 days after seeding as affected by different levels of sunflower seed cake for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Means with the same superscript in the same column are significantly different at p<0.05.

Sunflower seed cake in g/kg soil	**Maize plant dry biomass in mg/kg soil**
0	163^{b}
1	225^{b}
2	366^{a}
p value	<0.0001

For the inorganic fertilizer maize plant dry biomass increased with an increase in inorganic fertilizer applied (Table 13).

Table 13. Mean maize plant dry biomass 42 days after seeding as affected by different levels of inorganic fertilizer for the pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. Means with the same superscript in the same column are significantly different at p<0.05.

Inorganic fertilizer in mg/kg soil	Maize plant dry biomass in mg/kg soil
0	140^{c}
47.5	245^{b}
85	369^{a}
p value	<0.0001

A graphical presentation of the comparison between sunflower seed cake and the full rate of inorganic fertilizer for maize plant dry biomass collected 42 days after seeding is shown in Figure 5. The analysis of variance gave a significant difference (F value = 11.92***, degrees of freedom = 3) among the treatments. Further scrutiny however indicated that all the three sunflower seed cake treatments produced maize plant biomass that was significantly different from the full rate of inorganic fertilizer.

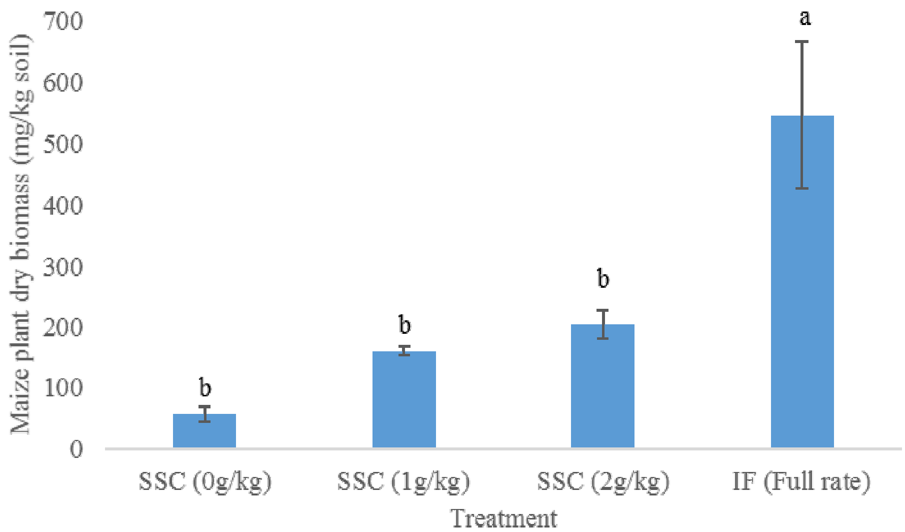

Figure 5. Mean maize plant biomass 42 days after seeding for a pot experiment involving the use of sunflower seed cake (SSC) and inorganic fertilizer (IF) at the Gunnarsholt greenhouse during the 2015 growing season. The vertical bars indicate standard error (n = 5). Means with different letters are significantly different at p<0.05.

5. DISCUSSION

Plant height and stem diameter are among the critical parts that contribute to maize crop yield biomass. Although these are genetic traits, they are also affected by a number of factors including availability of nutrients, how the crops are managed and the weather. The fact that an increase in sunflower seed cake corresponded with an increase in both maize plant height and stem diameter, especially after 35 days after seeding, was an indication that abundant nutrient supply is directly correlated to growth. This might be accredited to N availability which is necessary for the growth and development of plants. Ghafoor and Akhtar (1991) reported similar results. It was indicated in their study that applying high rates of N significantly affected maize plant height and stem diameter. The increase in plant height with the increase in inorganic fertilizer could be based on the fact that nitrogen enhances growth of plants and leads to a rise in both the number and the length of internodes which eventually results in increased height of plants. Similar results were reported by Gasim (2001). Improved maize growth as indicated by increased maize plant height and stem diameter due to application of sunflower seed cake agrees with the work of other researchers. As reported by Khalid et al. (2003) growth of rice plants improved with the use of nitrogen (N), potassium (K) and phosphorus (P) fertilizers.

The increase in chlorophyll levels with increase in sunflower seed cake and inorganic fertilizer could be attributed to more nitrogen available when more sunflower seed cake was applied. Blackmer and Schepers (1995) reported that there is usually a strong relationship between N concentration and chlorophyll content. Similar results were reported by Argenta et al. (2004). Nitrogen is a constituent of the enzymes that are involved in the synthesis of chlorophyll (Chapman and Barreto 1997) and the comparative status of N in a crop and quantity of yield is indicated by chlorophyll concentration (Blackmer & Schepers 1995)

The observed significant increase in plant biomass with the application of sunflower seed cake could be attributed to the essential nutrient elements contained in the sunflower seed cake that are associated with increased photo-synthetic efficiency. This finding corroborates the report of Okoruwa (1998) who observed significant increases in dry matter accumulation in maize with successive increases in organic manure rates. This could be due to the ability of the organic manure to supply the nutrient elements required to enhance greater vigorous growth, optimize activities that are meristematic and physiological in nature in the plants, as well as enhance the properties of the soil and thereby leading to the formation of increased photo-assimilates that improve the yielding ability of maize. The increased maize plant dry biomass with increased inorganic fertilizer use could be attributed to higher levels of nitrogen. Similar results were produced by Ashraf and Rehman (1999) who reported improvement in the growth of maize as resulting from an increase in the supply of N. Ashraf et al. (2002) found that biomass production of wheat responded positively as a result of increasing N levels. This was revealed in their study, which involved evaluation of the effects of sub- and supra-optimal N regimes on wheat. Smolders et al. (2007) also reported that onion biomass and yield were increased with increase in the levels of nitrogen. Nitrogen nutrition has the effect of increasing metabolic processes which eventually have an effect on the physico-chemical environment at the interface of soil and roots. The increase in the metabolic processes also changes the conditions of the rhizosphere and interacts with cations and anions. In addition, it also improves the action of different systems of enzymes (Fernandes & Rossiello 1995). It was also observed from this research that stem diameter and plant height increased with increased application of sunflower seed cake. These two directly contribute to the total dry biomass of the plants.

The effectiveness of sunflower seed cake as an organic fertilizer witnessed in this research may be contributed to its low C/N ratio which has a direct effect on the decomposition of organic materials which leads to release of essential plant nutrients. According to Danga et al. (2010), when organic materials which have a C/N ratio greater than 30:1 are added to the soil, immobilization of soil nitrogen occurs during the early stages in the process of decomposition. For C/N ratio between 20:1 and 25:1, neither immobilization nor release of mineral nitrogen occurs. However, if the organic materials have a C/N ratio of less than 20:1, there are most of the times mineral nitrogen release in the early stages of the process of decomposition. The same observation was also reported by several other researchers including Walley & Yates (2002) and Baddock (2007). The sunflower seed cake used in this research had a C/N ratio of 18:1 (Table 2) hence the material readily decomposed and released nutrients easily. The other contributing factors could be the pH of the soil. Studies have shown that in strongly acid or highly alkaline soils, the growing conditions for micro-organisms are poor, resulting in low levels of biological oxidation of organic matter (Maida 2005). Reports indicate that the activities of bacteria which are mainly responsible for organic matter decomposition are negatively affected when the soil pH drops below 6. The pH of the soil used in this research had a pH of 6.9 (Table 2).

The lack of interaction between the sunflower seed cake and the inorganic fertilizer is indicative of the fact that organic fertilizer (sunflower seed cake) alone was capable of providing enough of the nutrient elements. This may be due to the fact that the sunflower seed cake had all the essential elements, as indicated in Table 2. The other contributing factor could be the low C/N ratio of the sunflower seed cake. The lack of effect for both the sunflower seed cake and inorganic fertilizer during the early days of the experiment could be attributed to the fact that the soil and the maize seed held enough nutrient reserves for the early growth of maize seedlings.

6. CONCLUSIONS

Basing on the study findings and the objectives that were investigated using the pot experiment the following conclusions are made:

i. Sunflower seed cake can be effectively used as an organic fertilizer for the growing of maize.
ii. Using only sunflower seed cake at about 4 tonnes per hectare (2 g/kg of soil) has the potential of producing yields comparable to a full rate of inorganic fertilizer.
iii. For smallholder farmers, sunflower seed cake will be a favourable source of nutrients as it is cost effective, locally available and also effective in increasing the availability of essential plant nutrients.
iv. The use of sunflower seed cake as an organic fertilizer could offer smallholder farmers a better source of organic fertilizer with manageable rates of residues as compared to other sources of organic fertilizer. For instance the rates used in this research were between 2 tons/ha and 4 tons/ha as compared to about 15 tons/ha for farmyard manure.

From the conclusions drawn from the study findings, the following recommendations are made:

i. In order to gain yield potentials when using only sunflower seed cake as an organic fertilizer, the amount of the residues to be applied should be in excess of 4 tonnes per hectare. The amount to be applied will of course depend on the amounts of essential elements available in the residues used. This therefore necessitates the analysis of the sunflower seed cake to determine the amounts of essential elements available before the residues are applied.

ii. The research needs to be repeated in the field and under rain fed conditions so as to investigate the effectiveness of the sunflower seed cake as an organic fertilizer under uncontrolled conditions.

iii. When doing pot experiment using maize it is important to use bigger pots of at least 5 L capacity. This is so because when the pots are small root development is restricted and this may affect crop growth.

iv. When doing soil fertility experiments it is important to analyse the soil both before seeding and after harvesting. This was not done in the current research due to limited time and resources.

ACKNOWLEDGEMENTS

I feel indebted to the following people for their contribution to this research. First and foremost to my supervisor Ulfur Oskarson. I wish to thank him for his guidance throughout my study period. Without his untiring effort this work would not have been a success. Many thanks should also go to Berglind Orradottir for her directives in the course of carrying out the project.

I also wish to thank Magnus H. Johannson for allowing me to use the greenhouse at Gunnarsholt for my research work. He should also be thanked for providing the inorganic fertilizer used in this research work. Brita Berglund, Bardur Jon Sigfusson, and the staff at Agricultural University of Iceland laboratories in Hvanneyri should also receive my sincere thanks for assisting with analysis of essential nutrients in the sunflower seed cake and soil used in this research.

Muhammad Azfar Karim and members of our mastermind group, namely Harrington, Bulgan and Uuganzaya, also deserve my gratitude for their assistance and knowledge shared during the mastermind meetings.

Let me also extend my heartfelt gratitude to the management of the UNU LRT programme for giving me this opportunity to be one of the 2015 fellows. The management should also be thanked for the provision of funds used in this research work.

Lastly but not least the almighty God for the gift of life and the good health I enjoyed while undergoing the training in Iceland.

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