American Journal of Agriculture and Forestry
2016; 4(3): 56-63
http://www.sciencepublishinggroup.com/j/ajaf
doi: 10.11648/j.ajaf.20160403.11
ISSN: 2330-8583 (Print); ISSN: 2330-8591 (Online)

Effects of Inorganic Fertilisers and Sunnhemp (*Crotalaria juncea* [L.]) as a Green Manure Crop on Maize (*Zea mays* [l.]) Growth, Seed Yield and Labour Cost

Mzwandile P. Mabuza*, Oghenetsavbuko T. Edje, Gideon N. Shongwe

Crop Production Department, University of Swaziland, Luyengo, Swaziland

Email Address:
mzmabuza@uniswa.sz (M. P. Mabuza)
*Corresponding author

To cite this article:
Mzwandile P. Mabuza, Oghenetsavbuko T. Edje, Gideon N. Shongwe. Effects of Inorganic Fertilisers and Sunnhemp (*Crotalaria juncea* [L.]) as a Green Manure Crop on Maize (*Zea mays* [l.]) Growth, Seed Yield and Labour Cost. *American Journal of Agriculture and Forestry*. Vol. 4, No. 3, 2016, pp. 56-63. doi: 10.11648/j.ajaf.20160403.11

Received: May 30, 2016; **Accepted**: June 13, 2016; **Published**: June 23, 2016

Abstract: Maize is the staple food in Swaziland but there have been shortfalls in production mainly due to the high cost of commercial fertilisers. One possible means of addressing the problem is the use of sunnhemp (*Crotalaria juncea* L.), a green manuring legume, which is cheap and easy to produce. A field experiment was conducted at the Malkerns Research Station during the 2014/2015 cropping season. The main objective of the study was to evaluate whether sunnhemp can be used as a substitute for inorganic fertilisers. The treatments were (1) maize with 40 kg/ha sunnhemp used as mulch, (2) maize with 80 kg/ha sunnhemp used as mulch, (3) maize with 120 kg/ha sunnhemp used as mulch, (4) maize with 40 kg/ha sunnhemp soil incorporated, (5) maize with 80 kg/ha sunnhemp soil incorporated, (6) maize with 120 kg/ha sunnhemp soil incorporated (7) maize with no fertilisers (8) maize with half rates of inorganic fertilisers and (9) Maize with recommended rates of inorganic fertilisers. The design of the experiment was a randomized complete block design and each treatment was replicated four times. Maize variety SC 403 was used. Data were collected on sunnhemp biomass, cost of placement and rate of mineralisation. Maize data were on growth, yield and yield components. The results on labour cost of placement show that soil incorporation was significantly ($P < 0.01$) higher than mulching with sunnhemp being 29.8 man-days/ha while it was 18.6 man-days/ha for mulching. The amount of mineralised sunnhemp was significantly ($P < 0.05$) higher in incorporated sunnhemp than from sunnhemp used as mulch. Maize grown with 120 kg/ha of sunnhemp yielded 7662.7 kg/ha while maize with 40 kg/ha of sunnhemp was lowest with 7251.1 kg/ha, a yield difference of 5.4%. Maize from soil incorporated sunnhemp yielded 7519.3 kg/ha while maize grown with sunnhemp used as mulch was lower with 7325.0 kg/ha, a yield difference of 2.6%. Maize grown with the recommended rates of fertilisers yielded higher than the rest of the treatments, it yielded 8405.7 kg/ha while maize grown with 80 kg/ha of sunnhemp later used as mulch was lowest with 6945.7 kg/ha. It is concluded that labour cost of sunnhemp placement was significantly ($P < 0.01$) higher for soil incorporation than mulching. Nitrogen mineralisation was significantly ($P < 0.05$) higher when sunnhemp was incorporated than when used as mulch. It is recommended that farmers grow their maize with 80 kg/ha of sunnhemp and use it as mulch seven weeks after planting.

Keywords: Sunnhemp, Green Manures, Soil Incorporation, Mulching, Mineralisation

1. Introduction

Nitrogen is an essential element for plant growth and development and is frequently the major limiting nutrient in most agricultural soils (Daughtry et al., 2000). Profitable maize (Zea mays L.) production systems require inputs of large quantities of nitrogen fertilisers. Due to high costs, Swazi farmers seldom apply the required amount of nitrogen fertilisers. This has led to the country relying on imports from the Republic South Africa to satisfy local demand. Further worsening the situation is the use of crop residues to feed livestock in winter. This means the nutrients are not being recycled and soil fertility keeps on declining. One possible means of addressing this problem is the use of sunnhemp (Crotalaria juncea L.), a green manuring legume, which is cheap and easy to produce. Sunnhemp is a rapidly growing leguminous crop that produces 150 to 165 kg/ha of N under favourable conditions. It is normally used for fibre production in India and Pakistan (Wang & McSorley, 2013). It is most popular as a green manure crop in many tropical and subtropical areas in the world as an organic nitrogen source (Wang & McSorley, 2013). It improves soil organic matter which will in turn improve the soil's structure, pore spaces, water holding capacity and inogarnic–fertiliser-use efficiency through improved cation exchange capacity. Sunnhemp adds nitrogen, sulphur and phosphorus to the soil. These nutrients improve soil fertility.

In some countries it is grown in rotation with sugarcane (for example, Swaziland), rice, maize and tobacco. (Palm *et al*., 1999). For green manure crop the plant is ploughed in after two or two and a half months when the plants begin to flower as it decompose more rapidly at this stage (Palm *et al*., 1999). This is also the peak stage of nitrogen fixation. Sunnhemp has the ability to fix nitrogen as it has a total organic nitrogen content of about 12.5% (Mthethwa, 2009). Sunnhemp has also gained popularity in the sugar industry where it is used to improve the soil's characteristics (Anon., 2006). Sunnhemp can be grown in marginal soils because it is drought tolerant and resistant to root knot nematodes (Anon., 2006).

According to Miracle (2006), maize has been grown organically using kraal manure over a long period until the introduction of synthetic fertilisers. The increases in the price of inorganic fertilisers and environmental consciousness have renewed interest in organic farming, hence this project.

Swaziland still depends on imported maize in order to meet the country's domestic requirements (United Nations, 2012). This situation is aggravated by the persistent drought that has been experienced in the country. During the 2013/2014 cropping season, maize produced in Swaziland was 86,000 tonnes while the country needed 130 000 tonnes. This means that the country had a shortage of 33% which was imported (Mr. S. Dlamini, Ministry of Agriculture, Personal communication, 24 March, 2014).

Land degradation, including soil organic matter decline, biomass burning, livestock feeding and depletion of vegetation cover and soil fauna have also aggravated the problem of soil infertility in Swaziland (FAO, 2001). According to a report released by the United Nations (2012) Swaziland's food security situation has worsened since the global financial crisis of 2010 and 2011. The report found that rising food prices and reduced incomes had forced Swazis to adopt alternative strategies to cope, including reducing the quality and quantity of food consumed. Most maize growers stopped growing maize because they could not afford the inputs.

2. Materials and Methods

2.1. Experimental Site

This experiment was carried out at the Malkerns Research Station Experimental Farm during the 2014/2015 cropping season. The site is 732 metres above sea level. It has an annual mean temperature of 18°C. It is located at 26.34°S and 31.10°E. The soils are generally the M-set soils (Dlamini, 2007). The soil used for the experiment was sandy loam with a pH of 6.5, organic matter content of 8.54% and Nitrogen content of 0.088%.

2.2. Plot Layout and Planting

Plots with the dimensions of 5 metres long and 6.3 metres wide with a distance of 1 metre between plots were marked. Maize seeds of the variety, SC 403 were planted at rows 90 cm apart and the spacing between plants was 25 cm. The variety, SC 403, was chosen because it has the following attributes: very early maturing (115-130 days to physiological maturity), comparatively high drought tolerance, flinty grain and excellent maize streak virus tolerance. Planting was done on the 3rd of November 2014. Sunnhemp grown in association with maize was drilled in rows 45 cm from the maize row. A compound fertiliser 2:3:2 (22) was applied in treatments eight and nine only. These treatments received half and the full recommended rates, respectively. The application rate for treatment eight was 200 kg/ha of 2:3:2 (22) and 50 kg/ha of LAN. The application rate for treatment eight was 400 kg/ha of 2:3:2 (22) and 100 kg/ha of LAN. Maize treated with synthetic fertilisers was side-dressed with LAN (limestone ammonium nitrate) when the maize was knee high, at the same time when sunnhemp was incorporated into the soil. The LAN (28% nitrogen) fertiliser was applied at the rate of 50 kg per hectare on treatment eight and 100 kg/ha on treatment nine. The spot application method was used. Where sunnhemp was incorporated, it was cut, laid along the maize rows and then covered with soil.

2.3. Data Collection

2.3.1. Data Collected on Sunnhemp

Sunnhemp canopy height was determined by measuring the plant height from the ground level up to the last leaf. This was taken only once at the time of placement. The number of plants per m^2 was also determined by counting the number of sunnhemp plants in the one metre length that was cut during placement of the sunnhemp.

Sunnhemp fresh and dry biomass were determined for sunnhemp (at the time of incorporation and mulching). A one-metre length of sunnhemp was cut and its fresh mass taken and expressed in kg/ha. Dry mass was determined in an oven set at 72°C for 72 hours. The oven dried mass was then converted to kg/ha using the formula: [Dry matter (g) x 10]/ area (m^2).

Labour cost of placement was determined by recording the amount of time taken to mulch and that taken to incorporate the sunnhemp. A stopwatch was used to count time spent in minutes. Labour cost was then expressed in man-days per hectare.

The amount of organic nitrogen in sunnhemp was determined using the Kjeldah distillation method. This was done on samples that were collected daily for two weeks commencing three days after mulching and soil incorporation. The following formula was used to calculate the amount of organic nitrogen: mL acid titrated-mL blank titrated x acid N x 0.014 X 100 mass of sample (g).

2.3.2. Data Collected on Maize

Chlorophyll content was determined using a CCM-200 portable chlorophyll metre at 5, 6, 7, 8, and 9 weeks after planting. Five upper leaves were randomly selected per plot. A chlorophyll metre calculates a unitless chlorophyll content index (CCI) value from the ratio of optical absorbance at 655 nm and to that at 940 nm. During measuring, the midrib and veins from obvious damage were avoided. All measurements were taken in the shortest time possible (not exceeding two hours).

Leaf area was determined by measuring the length and width of all the leaves in one plant per plot. Leaf area was then calculated using the formula: leaf area = average leaf length × average leaf width × 0.75 × number of leaves per plant.

LAI was calculated using the ratio of leaf area over ground area occupied by the five sampled plants. The following formula was used:

LAI = Leaf area (cm^2)/Ground area (90 cm × 25 cm × 5)

Days to beginning of tasseling (5% flowering) was observed and full tasseling (90% flowering) were also observed.

Shelling percentage was calculated after harvesting. Unshelled cobs were weighed then shelled to obtain the mass of seeds. The ratio was then multiplied by 100 to obtain the shelling percentage. The following formula was used:

Shelling% = Dry mass of shell seeds (g) x 100

Dry mass of unshelled cobs (g)

The crude protein content from maize stover was calculated by first determining the amount of nitrogen from the maize stover. It was done using the Kjeldahl distillation method. The amount of nitrogen was then converted to crude protein content by multiplying by the factor; 6.25. This gave an indication of the feeding value of the maize stover.

Harvest index which is the measure of a plant's ability to partition its photosynthates into seed production was determined at the end of the harvesting period for each treatment. The harvest index was determined using the following formula:

HI = Seed mass (g)/Total plant mass above the ground (g)

This was determined from net plot area. Seed yield was calculated using the formula:

Net plot fresh mass x factor (10) x 100 – moisture content at harvesting (100-desired moisture content) x Net plot area (m^2).

2.4. Data Analysis

Data were statistically analysed using Mstat C statistical package, version 2.0 (Russel & Freed, 1989). The LSD was used for mean separation at P < 0.05 and P < 0.01 depending on applicability. The least significant difference (LSD) test at 5% or 1% level of probability was used to test the differences among mean values (Steel *et al*., 1997).

3. Results

3.1. Sunnhemp Data

3.1.1. Canopy Height at Placement

Sunnhemp canopy height was the highest (70.1 cm) in the treatment which was planted at 120 kg/ha. The least canopy height was recorded in the treatment which was planted at 40 kg/ha. It had 67.5 cm (Figure 1). These were however, not significant.

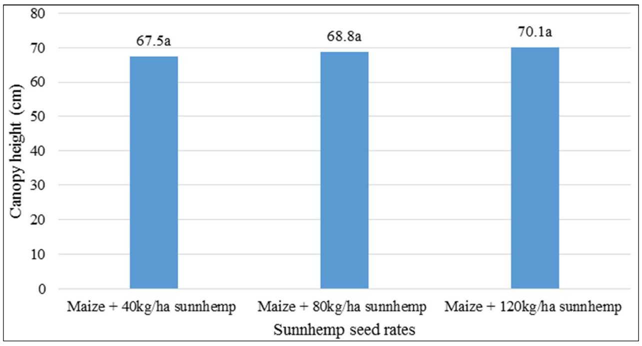

Figure 1. *Sunnhemp canopy height (cm) at placement (7 WAP).*

3.1.2. Number of Sunnhemp Plants

As one would expect, the number of plants was lowest in the treatment that was planted at 40 kg/ha. At 7 weeks after planting, it had 64.6 plants. This was followed by the treatment that was planted at 80 kg/ha with 98 plants. The treatment that was planted at the highest density of 120 kg/ha was significantly (P < 0.05) higher with 119 plants (Figure 2).

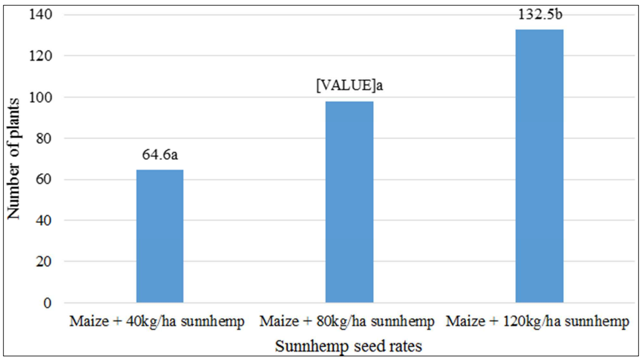

Figure 2. *Number of sunnhemp plants per m^2 at placement (7 WAP).*

3.1.3. Sunnhemp Fresh and Dry Biomass

Sunnhemp fresh and dry biomass was the highest in the treatment that was planted at the highest density of 120 kg/ha. At 7 weeks after planting, it had a fresh and dry mass of 2741.9 and 643.3 kg/ha, respectively. As anticipated, the treatment with a density of 40 kg/ha had the least biomass with 612.2 and 445.5 kg/ha on fresh and dry mass, respectively (Figure 3).

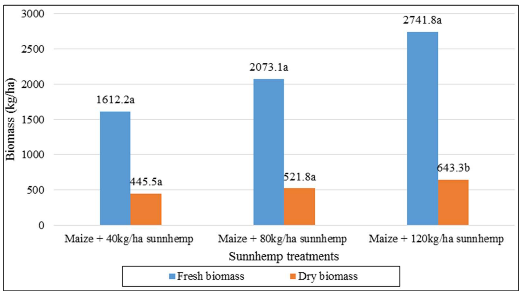

Figure 3. *Sunnhemp fresh and dry biomass (kg/ha) at placement (7 WAP).*

3.1.4. Labour Cost of Placement

More labour was required to place sunnhemp planted at the highest density of 120 kg/ha than at other seed rates. It required 26 man-days/ha to place as compared to sunnhemp planted at 40 kg/ha which required only 22 man-days/ha. When the two methods of placement were compared, incorporation was significantly ($P < 0.01$) higher than mulching. The man-days/ha that were required to incorporate sunnhemp into the soil was 29.8 while only 18.6 man-days/ha were required when mulching with sunnhemp (Figure 4).

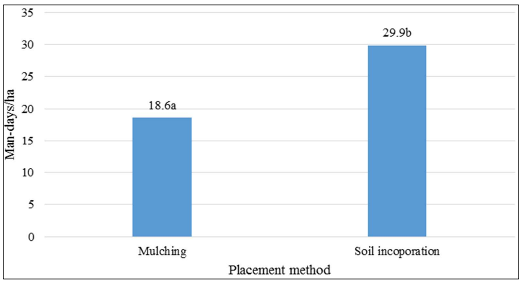

Figure 4. *Labour cost (man-days/ha) of placing sunnhemp.*

3.1.5. Rate of Nitrogen Release from Sunnhemp

Nitrogen released from sunnhemp increased with time starting from six days after placement. The lowest amount of nitrogen was recorded on sunnhemp planted at 120 kg/ha later incorporated into the soil, it had 0.036% 13 days after placement while at the same period sunnhemp grown at 80 kg/ha later incorporated had the highest nitrogen content of 0.778%. At 8 days after placement, sunnhemp planted at 40 kg/ha later incorporated into the soil had the highest nitrogen content of 0.653% at 20 days after placement (Figures 5 and 6).

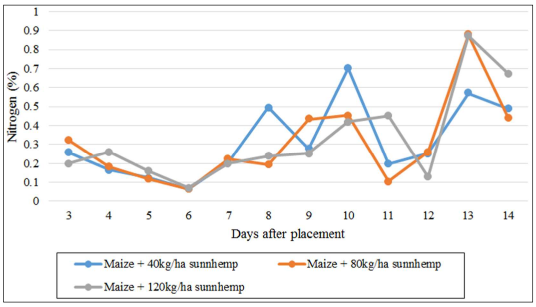

Figure 5. *Nitrogen (%) released from three sunnhemp seed rates from 3 to 12 days after placement.*

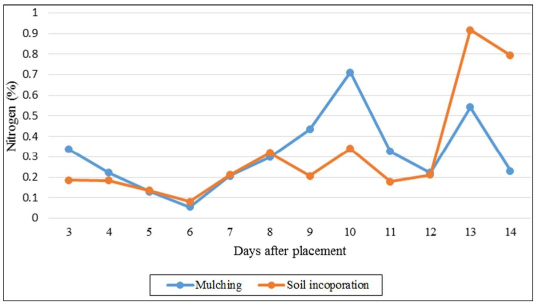

Figure 6. *Nitrogen (%) released from two sunnhemp placement methods from 3 to 12 days after placement.*

3.2. Maize Growth Parameters

3.2.1. Chlorophyll Content

Maize that received the recommended rate of synthetic fertilisers had the highest chlorophyll content throughout the experiment. At 9 weeks after planting it recorded 59.4 while the treatment where maize was grown in association with 80 kg/ha of sunnhemp later used as mulch had the lowest with 31.7. The lowest readings were recorded 6 weeks after planting where the readings ranged from 12.5 (Maize with sunnhemp later incorporated) to 19.1 (maize with the recommended rate of synthetic fertilisers). This was the narrowest range recorded in the five weeks (Table 1).

Table 1. *Chlorophyll content for all maize treatments at 5, 6, 7, 8 and 9 weeks after planting.*

Treatments	**Weeks after planting**				
	5	**6**	**7**	**8**	**9**
Maize with 40kg/ha sunnhemp-Mulched	17.5a	13.8a	27.1a	35.9a	41.8a
Maize with 40kg/ha sunnhemp-Incorporated	20.6a	13.8a	28.0a	30.7a	31.7a
Maize with 80kg/ha sunnhemp-Mulched	16.5a	12.6a	24.6a	23.7a	32.5a
Maize with 80kg/ha sunnhemp-Incorporated	18.6a	14.0a	27.2a	26.0a	36.1a
Maize with 120kg/ha sunnhemp-Mulched	17.4a	12.5a	28.0a	32.1a	42.2a
Maize with 120kg/ha sunnhemp-Incorporated	21.2a	14.0a	29.2a	36.5a	48.8b
Maize with no fertilisers	28.6b	15.7a	29.8a	43.4b	45.9b
Maize with half rates of 2:3:2 (22) and LAN	31.2b	14.8a	40.9b	45.7b	52.6b
Maize with recommended rates of 2:3:2 (22) and LAN	43.8c	19.1a	44.2b	54.7b	59.4c
Significance	**	NS	**	**	**
C. V. (%)	29.8	18.7	19.0	25.1	19.5

Mean values within the same column followed by the same letter are not significantly different at LSD $P < 0.05$.
NS = Not significant
** Significant at $P < 0.01$

3.2.2. Maize Leaf Area

At 8 weeks after planting, the highest leaf area was recorded in maize grown with 120 kg/ha of sunnhemp incorporated into the soil. It had a total leaf area of 19867.4 cm^2 while at the same period maize planted with 120 kg/ha of sunnhemp had the least with 13191.5 cm^2. However, at 12 weeks after planting, maize grown with the recommended rates of synthetic fertilisers had the highest leaf area while maize grown in association with 80 kg/ha of sunnhemp had the lowest (Table 2).

Table 2. *Leaf area (cm^2) for maize at 8, 10, 12, and 14 weeks after planting.*

Treatments	**Weeks after planting**			
	8	**10**	**12**	**14**
Maize with 40kg/ha sunnhemp-mulched	15853.5a	19086a	20262a	19993a
Maize with 80kg/ha sunnhemp-mulched	13191.5a	18277a	18531a	17036a
Maize with 120kg/ha sunnhemp-mulched	16968.5a	17715a	19731a	19079a
Maize with 40kg/ha sunnhemp-incorporated	15711.8a	17823a	17056a	17753a
Maize with 80kg/ha sunnhemp-incorporated	15065.4a	19236a	18401a	17743a
Maize with 120kg/ha sunnhemp-incorporated	19867.5b	20355a	18912a	18302a
Maize with no fertilisers	16024.6a	20624a	21350b	20304a
Maize with half rates of 2:3:2 (22) and LAN	18393.1b	21322a	22217b	20224a
Maize with recommended rates of 2:3:2 (22) and LAN	19191.2b	21858a	23591b	22443a
Significance	*	NS	*	NS
C. V. (%)	15.13	12.55	12.10	11.82

Mean values within the same column followed by the same letter are not significantly different at LSD P < 0.05. NS = Not significant
* Significant at P < 0.05

3.2.3. Leaf Area Index

Leaf area index was, throughout the experiment, highest in the treatment that was planted using the recommended rates of synthetic fertilisers. At 12 weeks after planting, it had a leaf area index of 2.1 while at the same period, maize grown with 80 kg/ha of sunnhemp later used as mulch had the lowest with 1.5. At 8 weeks after planting, maize grown with incorporated sunnhemp had a LAI of 1.5 while treatments with sunnhemp used as mulch had lower with 1.3 (Table 3).

Table 3. *Leaf area index for maize at 8, 10, 12, and 14 weeks after planting.*

Treatments	**Weeks after planting**			
	8	**10**	**12**	**14**
Maize with 40kg/ha sunnhemp-mulched	1.408a	1.700a	1.803a	1.778a
Maize with 80kg/ha sunnhemp-mulched	1.170a	1.625a	1.648a	1.518a
Maize with 120kg/ha sunnhemp-mulched	1.510a	1.578a	1.755a	1.695a
Maize with 40kg/ha sunnhemp-incorporated	1.400a	1.582a	1.515a	1.580a
Maize with 80kg/ha sunnhemp-incorporated	1.345a	1.710a	1.637a	1.578a
Maize with 120kg/ha sunnhemp- incorporated	1.765b	1.813a	1.680a	1.628a
Maize with no fertilisers	1.423a	1.833a	1.900b	1.805a
Maize with half rates of 2:3:2 (22) and LAN	1.635b	1.898a	1.975b	1.798a
Maize with recommended rates of 2:3:2 (22) and LAN	1.817b	1.942a	2.097b	1.995a
Significance	*	NS	*	NS
C. V. (%)	16.41	12.58	12.08	11.84

Mean values within the same column followed by the same letter are not significantly different at LSD P < 0.05. NS = Not significant

3.2.4. Number of Days to Beginning and Full Tasselling

Maize grown with the recommended and half the recommended rate of synthetic fertilisers both began tasseling earlier than the rest of the other treatments. They began tasseling 65.5 days after planting while maize grown with 80 kg/ha of sunnhemp later used as mulch began tasseling 67.3 days after planting. A similar trend was also observed with full tasseling. Maize grown with the recommended rates of synthetic fertilisers reached full tasselling stage 68.0 days after planting while maize grown with 80 kg/ha of sunnhemp later used as mulch, reached full flowering 72.0 days after planting (Figure 7).

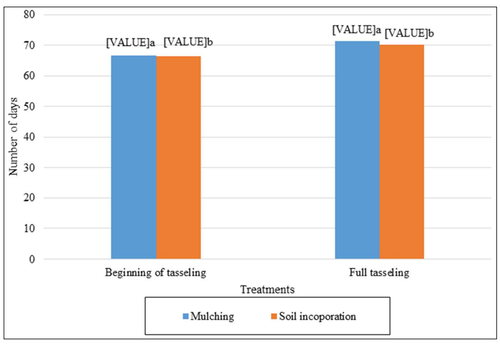

Figure 7. *Number of days to beginning and full tasseling at two sunnhemp placement methods.*

3.2.5. Crude Protein Content of Maize Stover

The results show that crude protein content of maize stover was high in maize grown with 80 kg/ha of sunnhemp later incorporated into the soil. At harvesting it had 7.5% crude protein content. This treatment was followed by that where maize was grown in association with 120 kg/ha of sunnhemp later used as mulch, it had 6.6%. The lowest amount of crude protein was found on stover from maize grown with 40 kg/ha of sunnhemp later incorporated into the soil (Table 4).

Table 4. *Crude protein (%) content of stover for all maize treatments at harvesting.*

Treatments	Protein content
Maize with 40kg/ha sunnhemp-mulched	5.9b
Maize with 40kg/ha sunnhemp- incorporated	4.1a
Maize with 80kg/ha sunnhemp-mulched	6.6b
Maize with 80kg/ha sunnhemp- incorporated	3.2a
Maize with 120kg/ha sunnhemp-mulched	7.5c
Maize with 120kg/ha sunnhemp- incorporated	4.3a
Maize with no fertilisers	4.1a
Maize with half rates of 2:3:2 (22) and LAN	4.1a
Maize with recommended rates of 2:3:2 (22) and LAN	6.2b
Significance	**
C. V. (%)	20.79
LSD ($P < 0.01$)	1.839

**significant at $P < 0.01$

3.3. Maize Yield

Maize yield was highest in the treatment that received the recommended amount of inorganic fertilisers. It had 8405.7 kg/ha while maize grown with 40 kg/ha of sunnhemp later incorporated into the soil had the lowest yield with 6559.8 kg/ha. Soil incorporation of sunnhemp was beneficial as it yielded 7519.3 kg/ha while mulching was lower with 7325 kg/ha. Maize grown with the highest density of sunnhemp had a higher yield than the other densities (Table 5).

Table 5. *Yield (kg/ha) at harvest for all maize treatments.*

Treatments	Yield
Maize with 40kg/ha sunnhemp-mulched	7942.4a
Maize with 80kg/ha sunnhemp-mulched	6945.7a
Maize with 120kg/ha sunnhemp-mulched	7668.4a
Maize with 40kg/ha sunnhemp-incorporated	7037.2a
Maize with 80kg/ha sunnhemp- incorporated	6559.7a
Maize with 120kg/ha sunnhemp- incorporated	8329.9a
Maize with no fertilisers	7691.6a
Maize with half rates of 2:3:2 (22) and LAN	8059.8a
Maize with recommended rates of 2:3:2 (22) and LAN	8405.7a
Significance	NS
C. V. (%)	17.44
LSD ($P < 0.05$)	1941.46

NS = not significant

4. Discussion

4.1. Sunnhemp Data

There was no significant difference in sunnhemp canopy height at placement seven weeks after planting. However, as expected, sunnhemp planted at a lower density of 40 kg/ha also had the lowest plant height. In his study, Mabuza (2009) found similar results when sunnhemp was planted at 40 and 80 kg/ha, canopy height was 96 and 86 cm, respectively at 9 weeks after planting. However, Casey *et al*. (2011) found that the mean height of sunnhemp at 4, 8, and 13 weeks after planting was 20, 180, and 280 cm, respectively. The sunnhemp was planted at a density of 22, 45 and 67 kg/ha, respectively. This is higher than what was realised in this study.

There was a significant difference ($P < 0.05$) in the number of plants per m^2. Sunnhemp planted in at 120 kg/ha had the highest density when compared to the 40 and 80 kg/ha densities. In a similar study, Casey *et al.* (2011) found that two weeks after planting, the plant density was 19.6, 28.0, and 36.6 plants/m^2 for the 22.4, 44.8, and 67.2 kg/ha seeding rates, respectively.

There was a significant ($P < 0.01$) difference in the labour cost of placement for the two methods used. Mulching required less labour while more labour was required for soil incorporation. This was at 7 weeks after planting. Vakeesan et al. (2008) stated that large amounts of green manures are needed when using sunnhemp as a green manure, labour is intensive and the nutrients only become available after the decomposition process, which may mean a wait of 2-3 months. These challenges were also realised during this project and are responsible for the poor adoption of using sunnhemp as a green manure crop in Swaziland.

The rate of sunnhemp mineralisation was significantly ($P < 0.05$) higher in soil incorporation of sunnhemp than mulching. This was at 6, 11 and 14 days after placement. There was no significant difference in the amount of released nitrogen in the different densities. Warren et al. (2012) stated that the amount of plant-available N and the rate of its release from sunnhemp residues are dependent on soil moisture, temperature and microbial activity. This explains the slow release of nitrogen from sunnhemp used as mulch, it lacked adequate moisture and was low on microbial population since it was not covered. These results are also consistent with those of Ambrossano et al. (2003) who found that green manures incorporated to the soil were more intensively mineralised, preventing the soil native organic N to be mineralized.

4.2. Maize Growth Parameters

Though insignificant, maize chlorophyll content was higher in maize grown with soil incorporated sunnhemp than treatments where sunnhemp was used as mulch. Van den Berg & Perkings (2004) observed that changes in chlorophyll content can occur as a result of nutrient deficiencies, exposure to environmental stress, exposure to certain herbicides, and differences in light in the environment during growth (shading). This observation explains the lower chlorophyll content in sunnhemp treatments.

There was a significant ($P < 0.05$) difference in maize leaf area at 8 and 12 weeks after planting. The increase in the number of leaves per plant could possibly be ascribed to the fact that nitrogen often increases plant growth and plant height and this resulted in more nodes and internodes and subsequently more production of leaves. They stated that nitrogen significantly increased leaf area through effect on elongation of leaves.

There was a significant ($P < 0.01$) difference in days to full flowering between sunnhemp treatments. Maize grown with sunnhemp later incorporated into the soil reached full flowering earlier than maize grown with maize grown with sunnhemp later used as mulch. Nitrogen application accelerated the time to reach 50% tasseling as compared to control. These results are fully in line with the findings of Amin (2011) who reported that nitrogen decreased the interval from seeding to flowering.

There was a significant ($P < 0.05$) difference in days to full flowering between fertiliser treatments. Maize treatment that received the recommended rate of fertilisers reached full flowering earlier than all the treatments. The reason still lies with the availability of nitrogen which encouraged vegetative growth more vigorously than the other treatments which were low in nitrogen supply.

4.3. Maize Yield

Maize grown with 80 kg/ha of sunnhemp that was later incorporated into the soil was significantly ($P < 0.01$) higher in crude protein content than all the other sunnhemp treatments. Although insignificant, maize stover from incorporated sunnhemp was higher in crude protein than that from mulched treatments. This indicates that soil incorporation of sunnhemp was beneficial. This positive result from sunnhemp treatments suggest that farmers proceed grazing their crop residues in-situ while the incorporated sunnhemp will still be available for maize uptake the following season. Maize fields should be used immediately after harvest for 30 to 60 days to take maximum advantage of the feed value of the residue. This would allow the permanent pastures to "stockpile" additional days of fall growth that could be grazed after the animals come off the corn fields (Samples and McCutcheon, 2003). Grazing corn fields for an extended period, even all winter, is also an option if supplemental feed is provided.

There was no significant difference in maize yield across all treatments. However, maize grown using synthetic fertilisers yielded higher than the control and also maize grown using sunnhemp. In a similar study where maize was grown with alfalfa incorporated into the soil at 6 weeks after planting, Nxumalo *et al*. (2010) found that the yield of plants applied with fertiliser was not significantly higher than yield of plants incorporated with alfalfa at six weeks after planting. They concluded that this probably was an indication that alfalfa supplied as much nutrients as fertiliser. The results are also in line with those by Mthethwa (2009), who found that varying fertiliser rates did not significantly affect maize yield.

5. Conclusion

Maize planted using inorganic fertilisers accumulated higher dry biomass than maize planted using sunnhemp. Maize planted using inorganic fertilisers yielded higher than maize planted using sunnhemp. Maize planted with 120 kg/ha of sunnhemp yielded higher (7662 kg/ha) than the other seed rates (4.1 and 5.4% respectively). Maize yield from maize planted with sunnhemp that was later incorporated into the soil yielded higher (2.6%) than maize planted with sunnhemp later used as mulch. Labour cost of sunnhemp placement was significantly ($P < 0.01$) higher (37%) for soil incorporation than mulching.

References

[1] Ambrosano, E. J., Trivelin, P. C., Cantarella, H., Ambrosano, G. M. and Muraoka, T. (2003). Nitrogen mineralization in soils amended with sunnhemp, velvet bean and common bean residues. *Scientia Agricola*. 60.1.133-137.

[2] Amin, M. E. (2011). Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). *Journal of the Saudi Society of Agricultural Sciences.* 10. 17-23.

[3] Anonymous, (2006). Soil fertility management for the maize cropping systems of small holders in Southern Africa. http://www.suelo.br/pdf/sa/v63n5/31405 pdf. 05-04-2008.

[4] Casey, A., Wynia, R. and Row, J. (2011). Evaluation and Use of Sunn Hemp (*Crotalaria juncea* L.) at the Manhattan Plant Materials Center, Manhattan, Kansas. Plant Materials Center. Manhattan. Kansas. USA.

[5] Daughtry, C. S., Walthall, C. L., Kim, M. S., Brown de Coulstoun, E. and McMurtrey, J. E. (2000). Estimating Corn Leaf Chlorophyll Concentration from Leaf and Canopy Reflectance. *Remote Sensing Environment*. 74: 229–239.

[6] Dlamini, M. (2007). Evaluation of soil and water conservation techniques on performance of maize at Luyengo. Unpublished B. Sc. Final year research report. University of Swaziland, Luyengo Campus, Luyengo, Swaziland.

[7] Food and Agricultural Organisation (2001). Soil fertility Management in support of food security in Sub-Saharan Africa. Publishing and Multimedia Service, Information Division, Food and Agriculture Organization of the United Nations, Rome. Italy.

[8] Mabuza, M. (2009). Evaluation of sunnhemp (*Crotalaria juncea* L.) alone or in association with maize (*Zea may* L.). Unpublished B. Sc. Final year research report. University of Swaziland, Luyengo Campus, Luyengo, Swaziland.

[9] Miracle, M. P. (2006). Maize in Tropical Africa. The University of Wisconsin Press, Madison, U.S.A.

[10] Mthethwa, C. M. (2009). Residual effect of sunnhemp (*Crotalaria juncea*) as a green manure crop on a succeeding maize (*Zea mays*) crop. Unpublished M. Sc. Final year research report. The University of Swaziland, Luyengo campus, Luyengo, Swaziland.

[11] Nxumalo, G., Ossom, E., Rhykerd, R. and Rhykerd, C. (2010). Alfalfa (*Medicago sativa* L.) Green Manuring and Ecological Properties under corn (*Zea mays* L.) culture in Swaziland Alfalfa (*Medicago sativa* L.) Green Manuring and Ecological Properties under corn (*Zea mays* L.) culture in Swaziland. *Advances in Environmental Biology*. 4 (3): 477-484.

[12] Palm, C. A. and Sanchez, P. A. (1999). Nitrogen release levels from the leaves of some tropical legumes as affected by their lignin and polyphenolic contents. *Soil Biology and Biochemistry*. 22: 31-36.

[13] Samples, D. and McCutcheon, J. (2003). Grazing Corn Residue. http://ohioline.osu.edu/anr-fact/0010.html. 29/03/2015.

[14] Vakeesan, A., Nishanthan, T. and Mikunthan, G. (2008). Green manures: Nature's gift to improve soil fertility. http://www.agriculturesnetwork.org/magazines/india/2-living-soils/green- manures-natures-gift-to-improve-soil/at_download/article_pdf. 25/03/2015.

[15] Van den Berg, A. K. and Perkings, T. D. (2004). Evaluation of a portable chlorophyll meter to estimate chlorophyll and nitrogen contents in sugar maple (Acer saccharum Marsh.) leaves. Forest *Ecology and Management*. 200: 113–117.

[16] Wang, K. H., McSorley, R. (2008). Management of Nematodes and Soil Fertility with Sunnhemp Cover Crop. http://edis.ifas.ufl.edu/NGO43. 12/04/2009.

[17] Warren, J., Wilson, T. and Edwards, J, (2012). Using sunnhemp as a cover crop in Oklahoma. http://osufacts.okstate.edu. 03/03/2015.

[18] United Nations. (2012). Swaziland Food Insecurity Intensified by Financial Crisis. http://www.futuredirections.org.au/publications/food-and-water-crises/28- global-food- and-water-crises-swa/450-swaziland-food-insecurity-intensified-by-financial-crisis.html. 02/06/2014.