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GROWTH RATE AND YIELD OF *BRASSICA NAPUS* IN RESPONSE TO *ACACIA ANGUSTISSIMA* LEAF BIOMASS APPLICATION

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ABSTRACT

Acacia angustissima is an important agroforestry tree species and its biomass can be used for soil improvement in vegetable production. The study was conducted to investigate the productivity of *Brassica napus* (rape) in response to different *A. angustissima* biomass application rates and placement methods at Bindura University of Science Education, Zimbabwe during the 2010/2011 summer season. The experiment was laid out in a randomised complete block design (RCBD) as a 2×5 factorial treatment structure, replicated thrice. Placement method (spot and broadcasting) and biomass application rate (0 t/ha, 0.5 t/ha, 1.0 t/ha, 1.5 t/ha and inorganic fertilizer) were the treatment factors with 2 and 5 levels respectively. Fresh mass yield of *B. napus* harvested from the experimental units was measured three weeks after transplanting and at subsequent ten-day intervals till the end of the experiment. Data on yield and vegetative parameters were subjected to analysis of variance (ANOVA) using GenStat Version 16.1 statistical package and the least significant difference (LSD) was used in separating treatment means. In both the fresh and dry yield, the results were as follows: inorganic fertilisers > *A. angustissima* > untreated control. Treatments showed variation ($p<0.05$) in the number of leaves, leaf length and leaf width. There was significant interaction ($p<0.05$) between the application rate and placement method which was expressed in leaf length and width. The results showed that rape yield is most closely correlated with the nutrient content of biomass, together with the quantity of biomass applied. In comparison to non-amended treatments, it was concluded that *A. angustissima* biomass significantly increases growth rate and yield of *B. napus*.

Key words: *Acacia angustissima*, application rate, *Brassica napus*, placement method.

INTRODUCTION

Rape (*Brassica napus*) is a vegetable crop that is known for its fast growth (Oldham, 1999) and early maturity. In Zimbabwe, it can be grown all year round in the low-veld but generally sowing to reaping should be February to July and April to September, respectively (Jacobus, 1993) and both fresh and dried leaves are utilized as relish (Oldham, 1999). The production of rape and other leaf vegetables for local and export markets is one such profitable agricultural enterprise, and in Zimbabwe, smallholder vegetable production is a fast expanding enterprise due to the increasingdemand from the rapidly increasing urban populations (Kuntashula *et al*., 2004). Since vegetables are rich in vitamins, minerals and roughage which are essentials of a balanced diet, they provide household nutritional security (Nyakudya *et al*., 2010).

Application of organic matter is accepted as a good soil management practice to sustain crop production because it enhances soil fertility through the modification of soil physical, chemical and biological properties (Haering and Evanylo, 2005). Application of organic materials such as animal manure, green manure, plant residue and composted organic matter has been reported to produce high yield and quality food crops (Ikemura and Shukla, 2009). Some workers have also reported positive response in vegetables grown under both organic and inorganic fertilizer management (Akinfasoye and Akanbi, 2005; Taiwo *et al*., 2007). Nyakudya *et al*. (2010) reported that some important plant species useful for green leaf manure are *Neem*, *Acacia*, *Sesbania*, *Leucaena* as well as *Gliricidia*. Legumes' leafy biomass plays an essential role in the improvement of soil fertility (Bekunda *et al*., 1997) and mulches from tree foliage improve soil fertility as well as water holding capacity (Chanyowedza and Chivinge, 2002).

Given the central importance that fertilizers play in intensive vegetable systems, it becomes imperative to identify least cost fertilizer options for the farmer. Therefore, research on low-cost and locally available organic fertiliser is fundamental. One such potential alternative is the use of multipurpose *Acacia angustissima* tree. Amongst other heavy biomass yielders, *A. angustissima* has high nitrogen content of about 33.2 to 40.8 g/kg dry matter and has many other growth characteristics such as thornless, drought tolerance, rapid growth and good response to regular cutting (ICRAF, 2006). The ability of rapid growth of *A. angustissima* suits well for biomass transfer. The multipurpose trees have proved to be a potential nitrogen sources due to its high nitrogen fixing ability and content (Matarirano, 2003). However, since many organic materials contain low nutrient concentration, very large amounts of organic materials are required to obtain rational increases in crop yields. Organic resources play a critical role in both short-term nutrient availability and longer-term maintenance of soil organic matter in smallholder farming systems in the tropics (Hartz *et al.*, 2000). Despite these critical services that organic inputs provide to agricultural productivity, the use of organic materials for soil fertility is based primarily on trial and error (Parnes**,** 1990). However, crop fertility efficiencies can be gained through appropriate fertilizer placement method and application rates. Despite the high nutritive value and high fodder production of multipurpose trees, there is little information on the performance of *A. angustissima* biomass as a source of fertiliser for brassicas particularly rape crop.

Considering the economic importance of the *B. napus* as well as the potential use of *A. angustissima* as a key agroforestry tree species in Zimbabwe, the present study was undertaken with the main objective of assessing the productivity of *B. napus* (rape) in response to different *A. angustissima* biomass application rates and placement methods.

MATERIALS AND METHODS

Site description and experimental design: The experiment was carried out at Bindura University nursery (altitude 1100 m a.s.l) in Bindura town (17°8' S, 31°19' E) about 88 km north-east of Harare during the 2010-2011 rainy season. The site lies in Natural Region IIa of Zimbabwe’s Agro-ecological Zones, characterized by mean annual rainfall of 750-1000 mm and mean annual temperature of between 15 and 20ºC. The soil at the site has an average pH of 6.7 (Table 1) and it is dominated by 2:1 expanding clays. The soils at nursery site comprise of sandy clays and loam; moderately deep-to-deep well drained red and black clays with low organic carbon and low soil fertility. The site is located in a vlei, typical of *dambos* in Southern Africa.

The experiment was laid out as a 2×5 factorial treatment structure in a randomized complete block design (RCBD) replicated thrice to give 30 experimental units, with antecedent soil fertility being the blocking variable. The two factors were application rate and placement method. The application rate factor had four levels (inorganic fertilizer, control, as well as 0.5 t/ha, 1.0 t/ha and 1.5 t/ha of *A. angustissima* leaf biomass) whilst the placement method factor had two levels (broadcasting and spot application). The spacing between blocks and plots were 1 m and 30 cm respectively. The experimental units (plots) measured 2 m by 1 m each, with intra-and inter-row spacings of 20 cm and 30 cm respectively to give a plant population of 166 666 plants/ha. The treatments were randomly assigned to the plots using random number tables.

Table 1. Means of selected soil chemical characteristics at research site

Parameter		Status		
	Unit	**Block 1**	**Block 2**	**Block 3**
pH		7.1	6.7	6.3
Total N	Ppm	0.44	0.36	0.42
Available P	Ppm	188	128	162
Exchangeable K	me/100 g	2.18	2.02	2.29

Soil analysis: Nine soil samples were collected from the area covering all the experimental plots where rape seedlings were to be transplanted. The soil was collected using a soil auger and the soil samples were mixed. The samples were analysed using a precalibrated “Corning pH meter 220”. The 15 g of air dried soil of each sample was weighed into nine 100 ml beakers and 75 ml of 0.01M $CaCl_2$ solution was added to each sample. The samples were left for half an hour, of which swirling was done at 10 minute intervals before measuring the pH of the suspension using a pH meter standardized at pH 4.0 and pH 7.0 (Okalebo *et al.,* 2002).

Total Nitrogen was determined colourimetrically using the Kjeldahl method (Okalebo *et al.,* 2002).The available P was removed using an extracting solution of 0.5 M $NaHCO_3$ and the P was determined colourimetrically using a phosphomolybdate complex. Exchangeable base (K^+) was determined through complete oxidation and extraction with 1M NH_4OAc (pH =7) followed by spectrometric analysis (Okalebo *et al.,* 2002).

Field management, treatment acquisition and application: The cultivar Hobson (English Giant rape) seedlings were raised in a 2 m^2 standard nursery bed. Sowing was done on 15 November 2010 at a rate of 0.5

kg/ha. Mulching was done to reduce water loss and weeds were removed while they were still young. Prior to transplanting, the seedlings were hardened for 5 days and transplanting was done late afternoon to reduce transplanting shock. After scouting aphids were controlled using Malathion 50% E.C and Cabaryl 85WP at recommended rates. The crops were watered twice a week to field capacity. The total rainfall received during the cropping season was 430 mm. Pruning of yellowing leaves was done after leaf length measurements were taken.

Inorganic fertilizers: Compound D (7%N: 14%P_2O_5: 7%K_2O) was applied in the experimental plots either by spot or broadcasting at a rate of 250 kg/ha on the day of transplanting (14 December 2010). Ammonium Nitrate (34.5% N) was applied to experimental plots either by spot or broadcasting at the rate of 100kg/ha, only at 2 weeks after transplanting. Ammonium Nitrate was incorporated into the soil immediately after application and plots were watered to minimise N losses through volatilization (Cooke, 1982; Troeh and Thompson, 1993; Agritex, 1993).

Acacia angustissima: Fresh leaf biomass of *A. angustissima var.angustissima* OFI 37/88 was obtained at mid maturity stage from four year old trees at SADC-ICRAF plot in Domboshawa, 25 km NE of Harare. The biomass was sun dried for two weeks in the shade, to minimize nutrient loss. *A. angustissima* dry leaf biomass was analysed for nutrient elements before incorporation (0.82%N, 284 ppm P and 15.22 ppm K), and was applied at 0.5 t/ha, 1.0 t/ha and 1.5 t/ha at seedling transplanting time. The biomass was incorporated into the experimental plots with respect to placement method (spot or broadcasting). Spot application of biomass was done at a depth of 9cm, to reduce leaching of nutrients. Watering was done to field capacity on each experimental plot, which measured 2 m by 1 m (2 m^2), at the time of application of *A. angustissima* leaf litter to enhance mineralization.

Data collection and analysis: Classic growth analysis (Gardner, 1985) was conducted based on five measurements: fresh mass yield, dry matter, number of leaves per plant, leaf length and leaf width. Data collection started 20 days after transplanting (DAT). A total of five harvests were done at an interval of 10 days from the first harvest. The harvesting intervals represent number of DAT with the first interval representing 20 DAT whilst the 5^{th} interval was 60 DAT. The number of leaves on each plant (excluding the primordia and 2 youngest leaves) was counted prior to each harvest. All side shoots were removed at each harvest time and were part of the measured fresh weight mass. Both the leaf length and width were measured using a 30 cm rule. The vegetable fresh yield mass was determined using a GP-3100 g top pan loading balance immediately after harvesting. The dry matter yield was obtained by drying the fresh leaves at 100°C (Kirk and Sawyer, 1997) and the mass was measured using 0.01 precision electronic top-pan balance.

Data were subjected to one way analysis of variance (ANOVA) using GenStat package Version 15.1. Least significant difference (LSD) at 5% significant level was used to separate means where treatment effects were significant.

RESULTS

Yield responses of *B. napus*

Dry matter yield: At all the five harvests, there were significant differences ($p<0.05$) in dry matter rape yield among treatment means, with the inorganic treatment having the highest yield followed by 1.5 t/ha, 1.0 t/ha, 0.5 t/ha and lastly 0 t/ha at 60 days after transplanting (DAT) (Table 2). However, inorganic fertiliser and 1.5 t/ha *A. angustissima* biomass treatments had the same performance especially at 41, 51 and 60 DAT (Table 2). Placement methods had no significant difference ($p>0.05$) in yield at all harvesting intervals (Table 2).

Fresh yield: The application rate had significant effect ($p<0.05$) on the fresh yield in all harvest though there was a marked decline from 51 DAT up to the last harvest. The fresh yield of rape crop was generally high in inorganic treatments as compared to *A. angustissima* biomass treatments (Table 3). Of all the treatments 1.0 t/ha *A. angustissima* treatments had the lowest yield at 22 DAT and 32 DAT and the control had the lowest fresh yields from the 41 DAT to the last. At 41 DAT, higher mean fresh yield were observed (). Generally all treatments' yield dropped at 51 days after transplanting (Figure 1) but despite the decrease the inorganic treatments outperformed the rest (Table 3).

The inorganic treatments in all placement methods outperformed all other treatments with the highest mean yield. However, the placement methods had no significant effect ($p>0.05$) on the fresh yield from 22 DAT up to 51 DAT. At 60 DAT (last harvest) there was significant effect ($p<0.05$) on fresh yield Table 3).

Vegetative growth responses of *B. napus*

Leaf number: *A. angustissima* application rate had significant effect ($p<0.05$) on the mean leaf number per plant in all the treatments at all the harvesting periods. There was a continual decline trend on the mean number of leaves for all treatments. The inorganic treatment had the highest mean leaf count of 17.92, at 29 DAT after the placement of ammonium nitrate. The control had marked increase in mean leaf number from 20 DAT up to 38 DAT compared to all *A. angustissima* biomass treatments. However all the treatments had a leaf number

Table 2. Effect of *A. angustissima* biomass application rate and placement method on *B. napus* dry matter yield (kg/ha)

	Days after transplanting				
Application rate	**22**	**32**	**41**	**51**	**60**
Inorganic fertiliser	1995^{a}	2365^{a}	2595^{a}	2080^{a}	1625^{a}
1.5 t/ha *Acacia*	445^{b}	855^{b}	2460^{ab}	2150^{ab}	1610^{a}
1.0 t/ha *Acacia*	375^{b}	590^{b}	1890^{b}	1535^{b}	1060^{b}
0.5 t/ha *Acacia*	570^{b}	935^{b}	1490^{b}	1210^{b}	795^{b}
0 t/ha (Control)	435^{b}	680^{b}	1195^{b}	915^{b}	635^{b}
Significance	*	*	*	*	*
	Days after transplanting				
Placement method	**22**	**32**	**41**	**51**	**60**
Broadcasting	875^{a}	1045^{a}	1985^{a}	1645^{a}	1205^{a}
Spot	815^{a}	1325^{a}	2230^{a}	1845^{a}	1340^{a}
Significance	**NS**	**NS**	**NS**	**NS**	**NS**

*denotes significant difference at p=0.05. NS=no significance. Means with different superscripts in the same column were significantly different at p=0.05.

Table 3. Effect of *A. angustissima* biomass application rate and placement method on *B. napus* fresh yield (kg/ha)

	Days after transplanting				
Application rate	**22**	**32**	**41**	**51**	**60**
Inorganic fertiliser	21500^{a}	33000^{a}	39000^{a}	16500^{a}	13500^{a}
1.5 t/ha *Acacia*	3250^{b}	8000^{b}	13000^{b}	1100^{b}	9000^{b}
1.0 t/ha *Acacia*	2500^{b}	4500^{b}	7150^{c}	6500^{c}	5500^{bc}
0.5 t/ha *Acacia*	3500^{b}	7500^{b}	1000^{b}	9500^{bc}	8250^{bc}
0 t/ha (Control)	4000^{b}	5500^{b}	7125^{bc}	5500^{c}	5000^{c}
Significance	*	*	*	*	*
	Days after transplanting				
Placement method	**22**	**32**	**41**	**51**	**60**
Broadcasting	8005^{a}	12520^{a}	16965^{a}	9665^{a}	9470^{a}
Spot	8195^{a}	13775^{a}	19030^{a}	12805^{a}	17605^{b}
Significance	**NS**	**NS**	**NS**	**NS**	**NS**

*denotes significant difference at p=0.05. NS=no significance. Means with different superscripts in the same column were significantly different at p=0.05.

Table 4. Effect of *A. angustissima* biomass application rate and placement method on mean *B. napus* leaf number per plant.

	Days after transplanting				
Application rate	**20**	**29**	**38**	**47**	**56**
Inorganic fertilizer	6.10±0.426^{a}	17.92±1.133^{a}	11.32±1.073^{a}	11.08±1.480^{a}	10.54±1.403^{a}
1.5 t/ha *Acacia*	4.40±0.426^{c}	8.41±1.133^{c}	8.17±1.073^{b}	8.05±1.480^{b}	9.40±1.403^{b}
1.0 t/ha *Acacia*	4.00±0.426^{c}	7.20±1.133^{c}	6.99±1.073^{b}	6.95±1.480^{b}	6.69±1.403^{bc}
0.5 t/ha *Acacia*	4.70±0.426^{c}	8.95±1.133^{c}	7.84±1.073^{b}	7.33±1.480^{b}	10.05±1.403^{ab}
0 t/ha (Control)	5.16±0.426^{b}	10.85±1.133^{b}	8.18±1.073^{b}	6.53±1.480^{b}	6.49±1.403^{bc}
Significance	*	*	*	*	*
	Days after transplanting				
Placement method	**20**	**29**	**38**	**47**	**56**
Broadcasting	4.92±0.301^{a}	10.90±0.801^{a}	8.64±0.759^{a}	8.98±1.047^{a}	8.85±0.992^{a}
Spot	4.68±0.301^{a}	10.34±0.801^{a}	8.51±0.759^{a}	7.73±1.047^{a}	9.49±0.992^{a}
Significance	**NS**	**NS**	**NS**	**NS**	**NS**

*denotes significant difference at p=0.05. NS=no significance. Means with different superscripts in the same column were significantly different at p=0.05.

decline from 47 DAT up to 56 DAT (Table 4). In all the treatments, the placement methods had no significant effect ($p>0.05$) on mean leaf number. However, the broadcasting placement method had the higher mean leaf number from 29 DAT as compared to spot placement. Conversely at 56 DAT, the spot placement method had a mean leaf number of 9.49 cm which was higher than that of the broadcasting method (Table 4). There were no significant ($p>0.05$) interactions of placement methods and application rate on mean leaf number.

Leaf width (cm): Generally there were significant differences ($p<0.05$) in leaf width among and within treatments in all periods of leaf measurement. The application rate had a significant effect ($p<0.05$) on the leaf width except on the last harvest. The 1.5 t *A. angustissima* treatment had the highest mean leaf width (13.8 cm) per plant in the last harvest as compared to the inorganic treatments (11.1 cm). The 0 t/ha control treatment had the lowest mean leaf width at 47 DAT and 56 DAT (Figure 1).

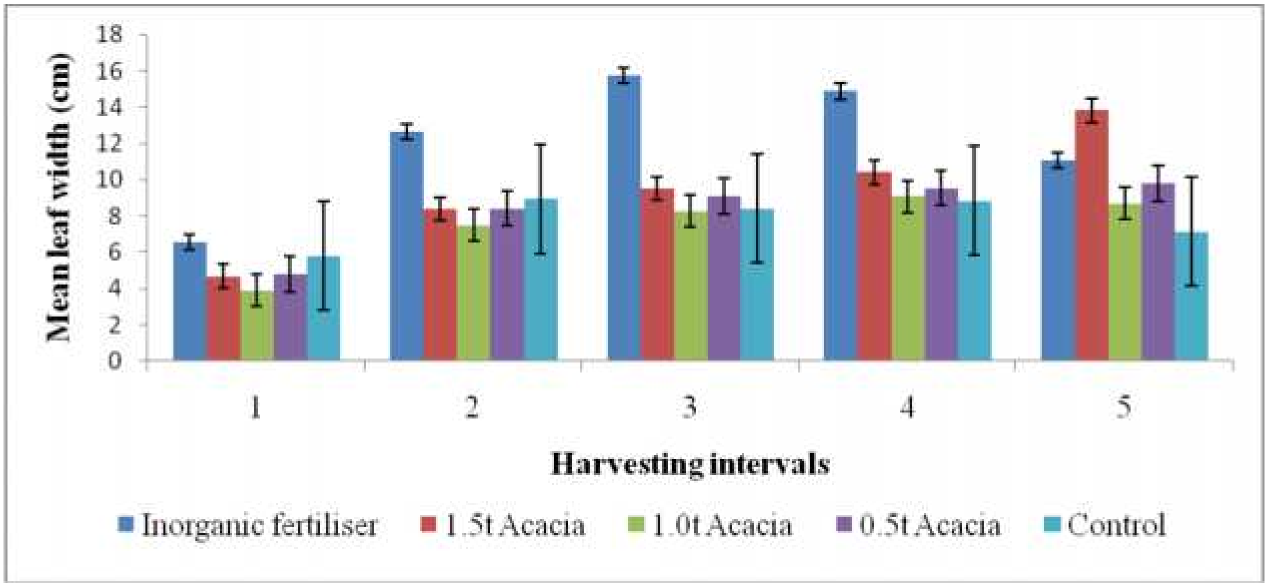

Figure 1: Effect of *A. angustissima* biomass application rate on mean *B. napus* leaf width

In all the measurements among the treatments, placement method had no significant ($p>0.05$) effect on leaf width, this implies that the growth of the leaves was not influenced by the placement method (Table 7).

Table 5. Effect of *A. angustissima* biomass placement method on mean *B. napus* leaf width

	Days after transplanting				
Placement method	**20**	**29**	**38**	**47**	**56**
Broadcasting	5.07±0.307[a]	9.51±0.470[a]	10.81±0.623[a]	11.05±0.693[a]	11.40±2.12[a]
Spot	4.90±0.307[a]	8.99±0.470[a]	10.52±0.623[a]	10.92±0.693[a]	10.30±2.12[a]
Significance	**NS**	**NS**	**NS**	**NS**	**NS**

NS=no significance; Means with same superscripts in the same column were not significantly different at p=0.05.

There was a significant interaction ($p<0.05$) of placement method and application rate on the mean leaf width during the first two measurements. This indicates that both the placement method and application rate influence the leaf width growth. However in the last measurement, all the treatment factors had no significant effect ($p>0.05$) on the leaf width.

Leaf length (cm): There was a significant effect ($p<0.05$) of application rate on the mean leaf length from the first up to the fourth measurement. In all Acacia treatments, the 1.5 t/ha rate gave the highest mean leaf length up to the last. The control had the lowest mean leaf length as compared to all other treatments, while the inorganic outperformed the rest (Figure 2).

Generally there was no significant ($p>0.05$) difference of application method to leaf length in the first (20 DAT) to the last measurement (56 DAT). However, for the placement methods spot outperformed the broadcasting method at 38 DAT till the last harvest (Table 7).

Table 6. Interaction effect of *A. angustissima* biomass application rate and placement method on mean *B. napus* leaf width

	Placement method			
	First harvest		Second harvest	
Application rate	Broadcasting	Spot	Broadcasting	Spot
Inorganic Fertiliser	7.46±0.615[a]	5.62±0.615[ab]	14.25±0.940[a]	11.04±0.940[a]
1.5 t/ha *Acacia*	5.00±0.615[b]	4.35±0.615[b]	8.80±0.940[b]	8.00±0.940[b]
1.0 t/ha *Acacia*	3.90±0.615[b]	3.91±0.615[bc]	7.82±0.940[b]	7.20±0.940[bc]
0.5 t/ha *Acacia*	3.91±0.615[b]	5.74±0.615[a]	7.16±0.940[b]	9.71±0.940[ab]
Significance	*	*	*	*

*denotes significant difference at p=0.05. Means with different superscripts in the same column were significantly different at p=0.05.

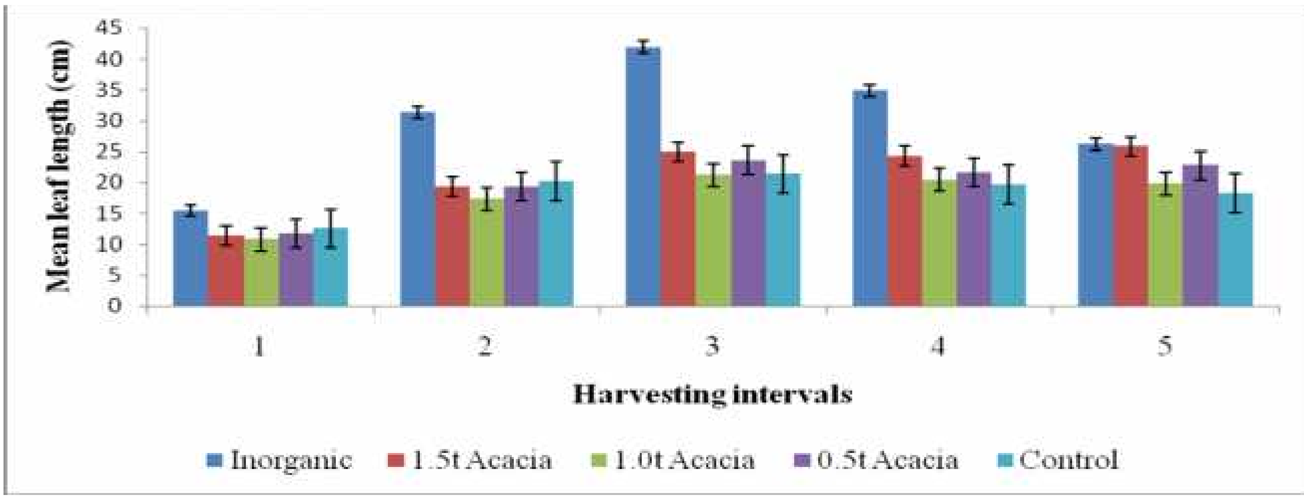

Figure 2. Effect of *A. angustissima* biomass application rate on mean *B. napus* leaf length

Table 9. Effect of *A. angustissima* biomass placement method on mean *B. napus* leaf length

Placement method	Days after transplanting				
	20	29	38	47	56
Broadcasting	12.53±0.665[a]	22.61±1.099[a]	27.67±1.334[a]	25.06±1.627[a]	24.2±2.22[a]
Spot	12.10±0.665[a]	21.05±1.099[a]	28.14±1.334[a]	25.56±1.627[a]	23.1±2.22[a]
Significance	**NS**	**NS**	**NS**	**NS**	**NS**

NS=no significance; Means with same superscripts in the same column were not significantly different at p=0.05.

There was a significant interaction ($p<0.05$) of placement method and application rate on the mean leaf length on the second harvest interval (29 DAT). However, there was no significant interaction ($p>0.05$) between placement method and application in leaf length on all the other harvest intervals (Table 10).

Table 8. Interaction effect of *A. angustissima* biomass application rate and placement method on mean *B. napus* leaf length at second harvest.

	Placement method	
Application rate	Broadcasting	Spot
Inorganic fertiliser	34.83±2.199[a]	27.71±2.199[a]
1.5 t *Acacia*	20.86±2.199[b]	17.85±2.199[c]
1.0 t *Acacia*	18.11±2.199[b]	16.59±2.199[c]
0.5 t *Acacia*	16.64±2.199[b]	22.07±2.199[b]
Significance	*	*

*denotes significant difference at p=0.05. Means with different superscripts in the same column were significantly different at p=0.05.

DISCUSSION

The inorganic fertiliser treatments gave the most superior results in both dry and fresh mass yields compared to other treatments in all the harvests. This can be attributed to the lower nutrient supply to *B. napus* in treatments with *A. angustissima* biomass compared to inorganic fertiliser treatments. The findings are similar to those by Nyakudya *et al*. (2010) who reported that the recommended treatment with inorganic fertilisers and poultry manure gave the highest yield as compared to biomass applications. Figueroa *et al*. (2010) reported that electron transport rate and biliprotein content were higher under high nutrient supply which all increased photosynthetic activity thereby increasing plant growth rate and yield. A similar trend was observed by Li *et al*. (2012) where nitrogen fertilization showed a significant effect on promoting the net photosynthetic rate in green corn leaves. The slow accumulation of nitrogen levels of *A. angustissima* treatments might have negatively affected the photosynthesis process leading to reduced growth rate and consequently yield. Moreover, *A. angustissima* biomass supplied an equivalent of 0.82% N of which these rates are much lower than the nitrogen supplied by inorganic fertilisers alone in the inorganic treatment of 34.5% N. Therefore, low rape yields obtained with low *A. angustissima* biomass application rate could be attributed to insufficient levels of nutrients supplied by the biomass to the plant for normal growth. These findings are in agreement with Shiralipour *et al*. (1998) who indicated that organic material of nutrient composition of 1 to 1.2% N tended to produce the lowest yield increases of vegetables because of high C: N ratios and low nitrogen availability.

The biomass application rates of 0.5 t/ha, 1.0 t/ha and 1.5 t/ha in spot placement method gave higher yields than the rates in broadcasting method. This could be attributed to a high nutrient level supplied by the treatment per unit volume of soil resulting in higher crop growth rate and vigour. The relatively high yields in spot placements could be due to a high nutrient concentration around the root zone of the plants. This improved nutrient uptake by plants especially phosphorus, which is immobile in the soil resulting in early vigour, high growth rate, and high nutrient use efficiency (Heal, 1997). The spot placement method can facilitate the use of less biomass per unit volume of soil as well as reducing leaching of nutrients (Sikora and Stott, 1996) and subsequently achieving sound yields compared to broadcasting. Hence, incorporating prunings in the soil at planting gave higher nitrogen recovery compared to surface application. The low *B. napus* yields obtained with broadcasting placement of biomass showed that broadcasting is an inefficient way of applying biomass. In broadcasting, biomass nitrates were exposed to a larger surface area and liable to rapid leaching and microbial activity leading to nitrogen immobilisation and hence low response to initial nitrogen supplied by biomass. The findings concur with Mafongoya *et al.* (1997a) who indicated that incorporation of prunings resulted in higher N uptake and recovery than surface application as mulch. When prunings were incorporated, *Cajanus cajan* and *Leucaena leucocephala* gave a higher grain yield of 5.6 tha^{-1}, compared with 1.1 tha^{-1} obtained from the control treatment.

The inorganic treatments with ammonium nitrate two weeks after transplanting increased nitrogen concentrations in rape crop during the vegetative growth period. This has been evidenced by treatments with inorganic fertilisers where vegetative growth parameters and yields were high from 41 days after transplanting up to the last harvest as compared to *A. angustissima* biomass treatments. Similar trends have been observed by Fox (1995) who reported that high rate of nitrogen increased leaf area development and increased overall crop assimilation. Furthermore, Kumari (2011) reported that increased nitogen levels influence photosynthesis primarily by increasing leaf area through increase cell in cell number.

Low performance of treatments with *A. angustissima* biomass can also be attributed to the fact that the biomass transfers and other sequential systems like improved fallows do accumulate phosphorus in their biomass and return it to the soil via litter decomposition. The crop absorbed phosphorus as orthophosphate ions which are available at low pH values. However, the phosphorus content of biomass was relatively low compared with plant needs. Troeh and Thompson (1993) reported that the most essential function of phosphorus in plants is in energy storage and transfer and its deficiency in *B. napus* restricts both top and root growth. However, of all nutrients, nitrogen is required in the larger quantity for plant growth, and the capacity of soils to supply nitrogen to plants is inextricably linked to the amount and nature of the soil organic matter. Since other nutrients appear to have less effect than N on vegetative growth parameters and yield (Gardner *et al*., 1985), the results variations may be attributed to N supply. As plants mature, nitrogen concentration of the tissue decreases due to increase in structural carbohydrates hence the drop noted in the fourth and fifth (Table 2 and Figure 2) harvest may be due to ageing. Base *et al*. (2003) also stated that productivity was lowered with crop age and leaf number decline due to senescence. In control there was no fertiliser applied thus the steady growth and yield exhibited by *B. napus* might be due to the constant N amount in these soils with some growth increase from the second to the third harvest.

Leaf number showed significant variation and was highest at the second harvest (29 DAT) where the inorganic treatment had the best performance. These results are similar to those reported by Nyakudya *et al.*

(2010). This can be attributed to the fact that this harvest time coincided with the period when nutrient supply in the inorganic fertiliser treatment was at its peak (100 kg Nha^{-1}). The number of leaves per plant in the *A. angustissima* treatments was lower than the inorganic treatment probably due to suppression by low nutrient supply levels in the organic treatments. The general declining trend in leaf count in all treatments from the first to the last harvest could be due to changes in the *B. napus* developmental stages and declining nutrient supply (Nyakudya *et al*. (2010). Since rape crop is known for its fast growth (Oldham, 1999), probably there was no synchronisation between decomposition rate and uptake of nutrients from the soil or may be the N release was not sufficient to meet peak N demands of associated crops (Fox *et al*., 1990). The low yields in *A. angustissima* treatments could be due to nitrogen mineralisation from soil organic matter and incorporated biomass, they typically peaked before the crop reached its maximum rate of nitrogen utilization. The lower performance of *A. angustissima* especially on vegetative growth parameters may also be due to N losses that might have occurred during storage prior to use (Bekunda *et al*., 1997).

A. angustissima has a wide variation of polyphenols content; the most widely distributed class of plant secondary metabolites which have been shown to influence nitrogen use efficiency in the soil-crop-continuum. Prunings which have high concentration of lignin of polyphenols (Fox *et-al*, 1990, Palm *et al*., 2001), with high capacity to bind protection (Handayanto *et al*., 1994) might have little net nitrogen mineralization. Therefore, these polyphenols are known to be regulators of soil process where it has been shown that they inhibit nitrification (Kuiters, 1990). The rate of nitrogen mineralization decreased substantially with increasing protein complexing or binding capacity of polyphenols (Northup *et al.,* 1995Mafongoya *et al*., 1997b). The polyphenols are known to affect biomass quality, at times having a larger effect on decomposition rates than more frequently measured parameters such as nitrogen and lignin.

Conclusion: The higher *B. napus* yields expressed by *A. angustissima* application exhibited the potential of biomass as an alternative nutrient source than continuous cropping without fertilisers. The results showed that rape yield is most closely correlated with the nutrient content of biomass, together with the quantity of biomass applied. Therefore, with appropriate application rates and provision of adequate time for mineralization to occur, *A. angustissima* biomass has potential to improve rape yields to sustainable levels.

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