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RESEARCH ARTICLE

Optimizing the clipping frequency and nitrogen topdressing in a dual-purpose oat used for fodder and cover cropping

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Summary
Management strategies such as nitrogen (N) topdressing and clipping can be used to optimize a cover crop for the dual purpose of soil cover and forage. The present study tested oat (*Avena sativa*) for a holistic provision of soil cover and forage under various levels of clipping frequency and N topdressing. Effects on root and above-ground biomass, acid detergent fiber, neutral detergent fiber, and crude protein (CP) were evaluated. Clipping frequency had four levels, namely clipped only at termination (C1), clipped at 28 days after emergence (DAE) and termination (C2), clipped at 28, 42 DAE, and termination (C3), and clipped at 28, 42, 56 DAE, and termination (C4). Nitrogen topdressing had two levels, namely with (N1) and without (N0) the recommended N topdressing. Increasing clipping frequency reduced the root and aerial biomass and did not affect the forage quality harvested before termination. However, N topdressing increased biomass and CP content across the clipping frequencies. Results suggest clipping thrice combined with N topdressing (C4 + N1) provides the best option to satisfy both soil cover and livestock demands. The treatment (C4 + N1) gave > 2 t ha^{-1} of biomass during the growing period and 6 t ha^{-1} at termination which can be used for livestock forage and soil cover, respectively. Clipping thrice without N topdressing (C4 + N0) was the best option for resource-constrained farmers.

Keywords: Cover cropping; Livestock forage; Oat; Smallholder farming systems; Residue biomass

Introduction

Crop production and livestock rearing are an integral part of smallholder (SH) farmers' livelihoods in the central Eastern Cape (EC) of South Africa (Muzangwa *et al.*, 2017; Rusere *et al.*, 2019). Maize (*Zea mays* L.) is the common crop of choice for the SH farmers. The grain is used for human consumption, while the residues and part of the grain are used for livestock feed, supplementing natural forages (Rusere *et al.*, 2019). Despite the high reliance on maize production by the SH farmers, maize yields obtained are low (Rusere *et al.*, 2019). The low maize production is linked to the inherently low fertility status of the soils (Mandiringana *et al.*, 2005), low fertilizer input system practised by the SH farmers, low rainfall reliability, high soil erosion rates, and inability to fight weeds (Manyevere *et al.*, 2014). A study by Mandiringana *et al.* (2005) reported that 60% of the EC soils have low pH (<5.0), organic carbon (<10 g kg^{-1}), K (<80 mg kg^{-1}), Ca

(<800 mg kg^{-1}), and P (<5 mg kg^{-1}). In addition, soils are normally left bare during the winter seasons, further exposing the soils to nutrient loss through wind and water-related erosion.

In view of this, it can be suggested that strategies that address both soil degradation and forage shortages are key for the SH systems. Cover cropping is a practice that can reduce soil erosion, promotes weed suppression, and increases rainfall infiltration and water conservation in the short term (Hontoria *et al.*, 2019; MacLaren *et al.*, 2019). In the long term, cover cropping benefits include increased soil organic carbon (SOC) (Turmel *et al.*, 2015). However, the adoption of cover cropping under the SH systems has failed due to insufficient residue biomass provided to the soil resulting in insignificant benefits from the practice (Muzangwa *et al.*, 2017). Available crop residues are prioritized for livestock feed rather than soil cover purposes (Tittonell *et al.*, 2015). To that end, it can be proposed that introducing high biomass yielding cover crops adapted to the central EC winter climate, such as oat, can alleviate maize production. Furthermore, if sufficient biomass residue is applied to the soil, livestock forage demands are met. The ability of oat to regrow when clipped further makes it a good candidate cover crop to use under the SH farming systems.

Limited studies have proposed management strategies for using oat for the function of providing residue for both soil cover and livestock forage. However, research suggests that biomass residue of 2 t ha^{-1} is the lowest benchmark to realize cover cropping benefits (Choudhary *et al.*, 2018; Ranaivoson *et al.*, 2017). On the other hand, the research evidence on the use of oat for livestock feed purposes provides discrepancies on the recommended clipping frequencies to obtain high and quality biomass. For instance, Kumar *et al.* (2017) suggested that higher cumulative biomass is obtained when oat is clipped once at 50% flowering as compared to when it is clipped twice at 60 days after sowing (DAS) and at 50% flowering. Contrary to these findings, Alipatra *et al.* (2012) reported the highest cumulative biomass from oat clipped twice, at 60 and 105 DAS, and lowest in oat clipped once, at 80 DAS. A plausible explanation for the discrepancies could be in the differences in the management of the N and environmental related factors in the reported experiments. Therefore, optimizing the clipping frequency for oat may be difficult without considering the N management and the climatic conditions of the EC province.

Apart from high biomass, forage quality is of importance in developing the management strategies for a dual-purpose oat. However, the effect of periodic herbage removal through clipping on forage quality is still unclear and requires further investigation. According to Blezinger (1999), good quality forage should have a crude protein (CP) of above 8%; crude fiber, measured as acid detergent fiber (ADF) content and neutral detergent fiber (NDF) content, should be below 45 and 65%, respectively. Alipatra *et al.* (2012) reported the highest CP in oat that was double clipped at 60 and 105 DAS compared to a single clipping at 80 DAS. Contrary to these findings, Kumar *et al.* (2017) reported higher CP in single-cut oat at 50% flowering than in double-cut oat at 60 DAS and 50% flowering. Research by Nirmal *et al.* (2016) and Tang *et al.* (2018) suggest that N fertilizer enhances CP and decreases NDF and ADF content in forages.

Nonetheless, N fertilizer effects on supporting herbage regrowth following clipping are not well documented. Studies seem to suggest that the regrowth of clipped plants is supported by the nonstructural carbohydrates (NSC) contained in plant reserves such as the roots and stolon (Liu *et al.*, 2018). However, the root's response to herbage removal varies from one grass species to another (Mapfumo *et al.*, 2002). This study was therefore done to investigate how oat responds to varying clipping frequencies and N topdressing and establish the feasibility of using oat for both livestock forage and soil cover. The specific objective was to evaluate the effects of clipping frequency and N fertilizer topdressing on oat root biomass, above-ground biomass, and forage quality.

Materials and Methods

The study employed a greenhouse pot experiment and a field trial. The greenhouse pot experiment studied the effects of clipping frequency and N fertilizer topdressing on oat root biomass, CP, and crude fiber (ADF and NDF). The field trial was carried out to investigate above-ground biomass build-up of oat as affected by the clipping frequency and N fertilizer topdressing.

Greenhouse Pot Experiment

Experimental site and design

The soil used in the greenhouse pot experiment was collected from the University of Fort Hare (UFH) Research Farm (32°46’15.8”S and 26°50’52.3”E) from a soil depth of 0–20 cm. The soil was air-dried for 72 hours, after which it was sieved through a 2 mm plate. To ensure homogeneity, the sieved soil was thoroughly mixed before any chemical analysis and experiment commencement. The soils are deep and of alluvial origin, classified as Haplic Cambisol (International Union of Soil Sciences (IUSS) Working Group, 2006) with 64.2% sand, 16.0% silt, and 19.8% clay (Mandiringana *et al.*, 2005). The soils were analyzed for pH in water using the pH meter (Crison Instruments, Alella, Spain) following procedures outlined in AgriLASA (2004). SOC was analyzed using the modified Walkley Black method following procedures outlined in the Agri-Laboratory Association of Southern Africa (AgriLASA, 2004) and total N was determined following the wet ashing procedure as outlined by Mnkeni and Gichangi (2008). The soils had a pH of 5.2, SOC of 0.63%, and total N was 0.041%.

The pot experiment was done in a semi-controlled greenhouse, at the UFH Research Farm. Plastic pots containing 8 kg soil with a diameter by height of 15 cm × 30 cm were used. Clipping frequency had four levels, namely clipped only at termination (C1), clipped at 28 days after emergence (DAE) and termination (C2), clipped at 28, 42 DAE, and termination (C3), and clipped at 28, 42, 56 DAE, and termination (C4). On the other hand, N topdressing had two levels, namely with (N1) (25 kg N ha^{-1}) and without (N0) (0 kg N ha^{-1}). The experiment was laid in a randomized complete block design (RCBD) with eight treatments per block, each replicated three times to give a total of 24 pots. All treatments designated to receive N (N1) were topdressed at 28 DAE; however, in treatments that had more than one clipping, N topdressing was split-applied in equal amounts after each clipping.

Agronomic practices

Three oat seeds of an early maturing cultivar producing tall stems, Pallinup (McLean, 1995), were planted in each pot. Basal fertilizer 2:3:4 (30) was applied uniformly to all pots at a rate of 300 kg ha^{-1} at planting. The basal fertilizer supplied 20 kg N ha^{-1}, 30 kg P ha^{-1}, and 40 kg K ha^{-1}. These rates translated to 80 mg N, 120 mg P, and 160 mg K pot^{-1}, using the conversion factor of 1 ha equals 2 million kg of soil as stated by Mehlich (1972). Nitrogen topdressing was only applied after the first clipping, at 28 DAE. Treatments receiving N topdressing were supplied with LAN (28% N) to achieve a total N rate of 45 kg ha^{-1} (180 mg N pot^{-1}) recommended by DAFF (2010). The pots were irrigated to field capacity every 48 hours. The experiment was terminated at 90 DAE and had reached 50% flowering.

Data collection

Forage biomass for quality testing was collected from clippings done at 28, 42, 56 DAE, and the termination stage. A stubble of 10 cm high above the ground was left at each clipping. Root samples for dry weight determination were collected only at the termination stage after saturating the pots with water for 24 hours, carefully washing out the soil under low pressure running water. Both the vegetative and root biomass were oven-dried at 65 °C until constant mass before further lab analysis and calculation of dry weights, respectively. Quality tests done on the forage samples include CP, NDF, and ADF. CP was determined after wet ashing the samples and converting the total N to CP using the equation: CP (g kg^{-1}) = total N (g kg^{-1}) × 6.25 as outlined by Mnkeni and

Table 1. Rainfall and irrigation water (mm) received during the 2017 and 2018 oat growing period at the University of Fort Hare farm

	2017		2018	
Month	Rainfall (mm)	Irrigation (mm)	Rainfall (mm)	Irrigation (mm)
April	–	–	62.23	40.00
May	18.73	60.00	14.47	60.00
June	2.79	60.00	4.06	60.00
July	4.32	60.00	4.71	20.00
August	6.04	40.00	–	–

Gichangi (2008). NDF was determined after digestion of samples in a detergent solution, and the predominant residues analyzed were lignin, cellulose, and hemicellulose. ADF was determined after digesting of samples in sulfuric acid solution, and the predominant residues were lignin and cellulose. The procedure for NDF and ADF was performed using ANKOM^{200} fiber analyser with 65 rotations per minute agitation (ANKOM Technology).

Field Experiment

Experimental site and design

The field study was carried out at the UFH Research Farm with similar location and soil description as described for the greenhouse pot experiment. The farm lies at an average altitude of 508 m above the sea level and has a warm temperate climate with an average annual rainfall of about 575 mm and an annual mean temperature of 18°C. The field experiment had similar treatments as described for the greenhouse pot experiment. The experiments was laid out in a RCBD with eight treatments that were replicated three times. The net plot size measured 5 m × 5.25 m. The experiment was repeated over the 2017 and 2018 winter seasons.

Agronomic practices

The field was ploughed, disked, and rotovated before planting in the winter of both 2017 and 2018. Planting was done on the 11th of May and the 5th of April in 2017 and 2018, respectively. The oat seed was hand-drilled at a rate of 100 kg ha^{-1} into furrows 0.3 m apart, as recommended by DAFF (2010). At planting, basal fertilizer 2:3:4 (30) + Zn^{+} was applied uniformly to all plots as was adopted for the greenhouse pot trial. All plots received similar amounts of rainfall and supplementary overhead irrigation (Table 1). No chemical weed or pest control was done in the experiments. Weeds were manually removed by hand hoeing in all the plots. After C1 treatment reached 50% flowering, the experiments were terminated. The experiments were terminated on the 9th of August 2017 and on the 4th of July 2018, respectively.

Data collection

Data for vegetative biomass accumulation were taken at 28, 42, 56 DAE, and the termination stage of the experiment. Two quadrats measuring 1 m × 1 m were randomly thrown into the plot, and all vegetative biomass that fell within the quadrat was clipped to leave a stubble that was 10 cm above the ground. Vegetative dry matter was determined as described for the pot experiment. Cumulative biomass was determined for each treatment by adding the biomass at each clipping and the termination stage.

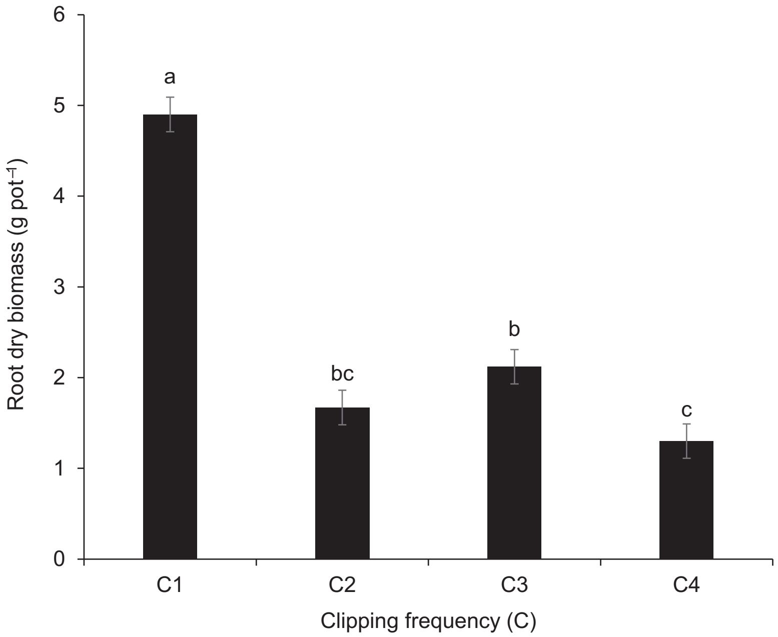

Figure 1. Effect of clipping frequency on oat root biomass from a greenhouse experiment at the University of Fort Hare. Different lowercase letters indicate significant differences at $p < 0.05$, LSD (0.05) 0.58. The standard error is 0.19. (C1 = clipped only at termination, C2 = clipped at 28 DAE [days after emergence] and termination, C3 = clipped at 28, 42 DAE, and termination, C4 = clipped at 28, 42, 56 DAE, and termination).

Data analysis

All the collected data from both pot and field experiments were subjected to a two-way analysis of variance (ANOVA) using JMP version 14.1 statistical package. The exception was the data on N topdressing effects on CP, ADF, and NDF collected before termination (C3 and C4) which was analyzed as a one-way ANOVA because of the N topdressing added after the first clipping (28 DAE). Cumulative biomass was calculated by summing up the yields from all the clippings. The seasonal data from the field experiment were first tested for homogeneity of variance using the F test, and the results showed that the variances were not homogeneous at $p < 0.05$. Therefore, the data for biomass accumulation for each season were analyzed separately. Mean separation was done using least significance difference (LSD) values from Tukey's honest significance difference (HSD) test.

Results

Greenhouse experiment

Root biomass

The root biomass data from the pot experiment showed no significant ($p > 0.05$) interaction of the clipping frequency and N topdressing factors. Of the two factors, only clipping frequency significantly affected ($p < 0.001$) the root biomass while N topdressing did not ($p > 0.05$). The root biomass was greatest in C1 pots while C4 had the least and followed the order C1 > C3 ≥ C2 ≥ C4 (Figure 1).

Forage quality during the growing period

In the first clipping (28 DAE), when treatment effects were not in place, the average CP, ADF, and NDF content was 3.16, 6.89, and 9.23 %, respectively. Data analysis on quality measurements done

Table 2. Clipping frequency × N fertilization effects on CP, ADF, and NDF content (%) of oat forage measured during the growing season (before termination) from a greenhouse experiment at the University of Fort Hare

	CP (%)		ADF (%)		NDF (%)	
	C3	C4	C3	C4	C3	C4
N1	8.4a	8.1a	27.6b	29.3a	35.9a	39.0a
N0	8.2b	7.8b	28.6a	29.8a	36.5a	38.3a
Significance	$p < 0.05$	$p < 0.05$	$p < 0.01$	ns	ns	ns
LSD	0.01	0.21	0.65	ns	ns	ns
SD	0.25	0.21	0.67	ns	ns	ns

Means in columns indicated by the same letter are not significantly different at $p = 0.05$. N1 = with topdressing, N0 = without topdressing, C3 = clipped at 28, 42 DAE, and termination, C4 = clipped at 28, 42, 56 DAE, and termination, DAE = days after emergence, SD = standard deviation.

Table 3. Clipping frequency × N fertilization effects on CP, ADF, and NDF content (%) of oat forage measured at termination from a greenhouse experiment at the University of Fort Hare

			Clipping frequency				
			C1	C2	C3	C4	Mean
CP (%)	N fertilization	N1	12.4	12	13	12.1	12.4a
		N0	12.1	11.2	11.4	11.6	11.6b
		Mean	12.3	11.6	12.2	11.9	
		LSD N		0.43			
		SD		0.7			
ADF (%)	N fertilization	N1	27.2	28.5	29.5	30.1	28.8a
		N0	29.6	31.7	32.2	32.7	31.5b
		mean	28.4d	30.1c	30.8b	31.4a	
		LSD C		0.4			
		LSD N		0.21			
		SD		1.83			
NDF (%)	N fertilization	N1	32.4e	32.6de	33.0cde	35.1b	33.3b
		N0	33.1cde	33.7cd	34.0bc	37.5a	34.6a
		mean	32.8c	33.2bc	33.5b	36.3a	
		LSD C		0.46			
		LSD N		0.24			
		SD		1.62			

Means followed by different lowercase letters in the same main effect are statistically different at $p < 0.05$. N1 = with topdressing, N0 = without topdressing, C1 = clipped only at termination, C2 = clipped at 28 DAE and termination, C3 = clipped at 28, 42 DAE, and termination, C4 = Clipped at 28, 42, 56 DAE, and termination, DAE = days after emergence, SD = standard deviation.

on later clippings before termination showed significant N topdressing effects on CP content ($p < 0.05$). The CP content both in C3 and C4 biomass was increased by N topdressing. However, N topdressing had no significant ($p > 0.05$) effects on NDF content but significantly lowered ($p < 0.01$) ADF in C3 (Table 2).

Forage quality at termination

The forage quality data at termination showed significant clipping frequency and N topdressing interaction effects on NDF ($p < 0.05$) but not with CP and ADF ($p > 0.05$). CP was only significantly increased by N topdressing ($p < 0.05$) and the highest CP content was in C3 + N1 (13.0%) and the least was in C2 + N0 (11.2%) (Table 3). The clipping frequency effect was observed with the ADF ($p < 0.001$). The highest ADF content was in C4 and the lowest was in C1. Treatments that did not receive N topdressing had an 8.5% higher mean ADF content compared to the treatments that received N topdressing with a mean ADF content of 28.8% (Table 3). The NDF data showed that while the N topdressing significantly reduced NDF in C4 compared to the

Table 4. Clipping frequency × N fertilization effects on the biomass yield of oat harvested during the 2017 and 2018 growing periods from a field experiment at the University of Fort Hare farm

	2017 season (t ha^{-1})		2018 season (t ha^{-1})	
	Clipping frequency			
N fertilization	C3	C4	C3	C4
N1	0.7a	1.4a	0.6a	1.7a
N0	0.5a	0.6b	0.6a	0.9b
LSD	0.21	0.70	0.12	0.61
Significance	ns	$p < 0.05$	ns	$p < 0.05$
CV (%)	22	19	17	13
SD	0.15	0.53	0.084	0.49

Means followed by different lowercase letters in the same column are statistically different at $p < 0.05$. N1 = with topdressing, N0 = without topdressing, C3 = clipped at 28, 42 DAE, and termination, C4 = clipped at 28, 42, 56 DAE, and termination, DAE = days after emergence, SD = standard deviation.

non-application, it did not result in significant changes in C1, C2, and C3. The greatest NDF value was with the C4 + N0 while the least was with C1 + N1 (Table 3).

Field experiment

Biomass yield measured during the growing period

The ANOVA showed a significant improvement in biomass yield with N topdressing in C4 but not in C3. The results obtained are summarized in Table 4. Though C2 was not part of the ANOVA, as there were no N topdressing effects during the treatment clipping, the biomass yields were 0.63 t ha^{-1} and 0.60 t ha^{-1} for 2017 and 2018, respectively (results not presented).

Biomass yield at termination

The interaction of clipping frequency and N topdressing was not significant ($p > 0.05$) on the biomass yield harvested at the termination stage in both years, 2017 and 2018. However, there were significant differences in the biomass yield of oat due to the main effects of clipping frequency ($p < 0.001$) and N topdressing ($p < 0.001$) in both seasons. Increasing the clipping frequency significantly decreased the biomass yield that was obtained at the termination stage (Table 5). Generally, in both seasons, oat which had received N topdressing had higher biomass yield under all clipping frequencies. The highest oat yield at the termination stage was in C1 + N1. This was followed by C2 + N1 and C4 + N0 which had the least biomass yield in both seasons (Table 5).

Cumulative biomass

An interaction ($p < 0.001$) between clipping frequency and N topdressing on the cumulative biomass yield in both winter seasons was observed. Although all N topdressed treatments had significantly higher biomass yield than non-topdressed, N topdressing effect was more pronounced in C4 as compared to other clipping frequencies in both seasons. In addition, the main effects of clipping frequency and N topdressing had significant ($p < 0.001$) effects on the cumulative oat biomass harvested, the trend was as observed with the biomass data at termination. In the 2017 season, the highest cumulative oat biomass was obtained in C1 + N1 and was comparable to C4 + N1 and C2 + N1. In the 2018 season, the highest cumulative oat biomass was in C1 + N1 and was comparable with C4 + N1 (Table 6).

Table 5. Clipping frequency × N fertilization effects on the biomass yield of oat measured at termination in the 2017 and 2018 winter seasons from a field experiment at the University of Fort Hare farm

		Clipping frequency (C)				
		C1	C2	C3	C4	Mean
2017 season						
N fertilization	N1	8.5	7.5	6.5	6.1	7.2a
	N0	6.6	6.4	5.3	4.4	5.7b
	Mean	7.6a	7.0b	5.9c	5.3d	
	LSD C		0.31			
	LSD N		0.27			
	CV (%)		18			
	SD		1.26			
2018 season						
N fertilization	N1	8.7	7.8	6.8	5.8	7.3a
	N0	7.0	6.5	5.3	4.1	5.7b
	mean	7.9a	7.2b	6.0c	5.0d	
	LSD C		0.18			
	LSD N		0.24			
	CV (%)		15			
	SD		1.41			

Means followed by different lowercase letters in the same main effect are statistically different at $p < 0.05$. N1 = with topdressing, N0 = without topdressing, C1 = clipped only at termination, C2 = clipped at 28 DAE and termination, C3 = clipped at 28, 42 DAE, and termination, C4 = clipped at 28, 42, 56 DAE, and termination, DAE = days after emergence, SD = standard deviation.

Table 6. Clipping frequency × N fertilization effects on the cumulative biomass yield of oat harvested measured from a field experiment at the University of Fort Hare farm

Clipping frequency (C)	N fertilization	2017 Winter season (t ha^{-1})	2018 winter season (t ha^{-1})
C1	N1	8.5a	8.7a
	N0	6.6cd	7.0d
C2	N1	7.7ab	8.1b
	N0	6.6cd	6.8d
C3	N1	7.3bc	7.6c
	N0	6.0de	6.0e
C4	N1	8.4a	8.4ab
	N0	5.7e	5.9e
LSD		0.51	0.27
CV (%)		16	13
SD		1.08	1.06

Means followed by different lowercase letters in the same column are statistically different at $p < 0.05$. N1 = with topdressing, N0 = without topdressing, C1 = clipped only at termination, C2 = clipped at 28 DAE and termination, C3 = clipped at 28, 42 DAE, and termination, C4 = clipped at 28, 42, 56 DAE, and termination, DAE = days after emergence, SD = standard deviation.

Discussion

The study investigated the practicability of multi-clipping oat, so it serves a dual purpose of soil cover and livestock forage. Quick regrowth of the clipped oat is key in determining the amount of biomass production and hence its ability for multi-purpose. In such cases, plant roots play an important role in water and nutrient uptake to support regrowth (Ryan *et al.*, 2016). In this study, measured root biomass decreased with increased clipping frequency indicating a gradual depletion of plant carbohydrate reserve present in the roots as suggested by Janhi *et al.* (2020). According to Liu *et al.* (2018), roots form part of the reserve containing NSC, which are responsible for the regrowth of aerial biomass. Furthermore, Bloom (1997) also stated that increasing clipping frequency disrupts the required C: N ratio that should be maintained, thereby inhibiting N uptake until the appropriate C: N ratio is restored. Therefore, the carbohydrates present in the plant reserve, such as in the roots, are channeled toward above-ground biomass regrowth, rather than toward root expansion.

The observed reduction in biomass with increased clipping frequencies was consistent with findings from a similar experiment with forage sorghum as a test crop (Janhi *et al.*, 2020). The reduction in biomass is linked to the increased period of recovery with increased clipping frequencies. According to Ferraro and Oesterheld (2002), the recovery period allows for the growth of vegetative structures such as leaves, as well as increasing plant height. In furtherance, the removal of aerial biomass puts a strain on the development and efficiency of the root system to absorb and take up nutrients and water to support active growth (Liu *et al.*, 2018). However, the results from the current study point to the importance of N topdressing in ensuring quick recovery after clippings. Nitrogen is involved in the development of vegetative structures, and this can explain the higher yields obtained under N topdressed treatments compared to the non-topdressed.

Besides increasing the biomass, N topdressing had far-reaching effects on the forage quality. This is largely due to the N being an integral part of protein synthesis, giving a plausible explanation for higher CP content in N topdressed oat compared to the non-topdressed. On the other hand, the decrease in CP content with increasing clipping frequency observed during the growing period can be attributed to a decrease in N uptake by the roots which occurs under limited carbon conditions. Similar findings were reported by Francia *et al.* (2006) who stated that higher CP values were observed in oat that was clipped once as compared to when it was clipped twice. However, these results differ from the findings of Alipatra *et al.* (2012) who reported significantly higher CP content in treatments that were clipped twice as compared to treatments that were clipped only once.

The resulting insignificant effects of supplementary N on crude fiber content during the growing period were also reported by Eltelib *et al.* (2006). The sharp rise in NDF by C4 + N0 suggests that increasing clipping frequency under limited N soils raises NDF content in oat. However, contrary to these findings, Kumar and Chaplot (2015) reported increased crude fiber with an increase in N application, while Ayub *et al.* (2009) reported that N did not affect forage crude fiber. The accepted ranges of crude fiber are ADF $> 45\%$ and NDF 65% (Blezinger, 1999). In this study, all the ADF and NDF values observed in both cover crops during the growing season and at termination fit within these ranges.

The biomass yields at termination obtained under all clipping frequencies were above the minimum threshold value (2 t ha^{-1}) for cover cropping benefits such as reduced water runoff, erosion, water infiltration, and retention (Choudhary *et al.*, 2018; Findeling *et al.*, 2003; Ranaivoson *et al.*, 2017; Scopel *et al.*, 2005). The difference between the cumulative biomass and the biomass yield at termination across the two seasons provided an indication of possible biomass levels that could be used for livestock feed purposes. The results suggest that treatment C4 + N1 can be considered for the dual purpose as it produced the highest biomass (2.4 t ha^{-1}) for forage purposes and also had a high biomass yield at the termination stage (6 t ha^{-1}). The greenhouse experiments showed that the forage quality of C4 + N1 fell within the recommended quality range for livestock forage. However, resource-constrained farmers can adopt C4 + N0, which gave 1.7 t ha^{-1} biomass yield for forage purposes during the growing period and 5.8 t ha^{-1} at the termination stage. Forage quality of C4 + N0 falls within the required range; therefore, a further 3.8 t ha^{-1} can be removed from the dry matter harvested at the termination stage and be fed to livestock.

Conclusions

The study showed that oat can be used for the dual purpose of soil cover and livestock forage purpose. The best treatment combination to achieve this win-win situation is when the oat is clipped thrice during the growing season, with N topdressing after each successive clipping (C4 + N1). This treatment combination supplies the minimum required biomass yield, 2 t ha^{-1}, for soil cover and a further 6.4 t ha^{-1} biomass yield can be directed to livestock forage. It can further be suggested that resource-poor farmers adopt C4 + N0 treatment combination and supplement it with locally available livestock manure.

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