CHAPTER 3

3. Results and Discussion

3.1 Dry matter production

3.1.1 Leaf DM yield (g/plot)

The results of the leaf DM yield of all the plant species are presented in Table 3.1.

Table 3.1 The leaf DM yield (g/plot) of five *Indigofera* species

Species	2003	2004	2004
	Autumn	Autumn	Spring
I. amorphoides	194.8^{a}_{1} (± 116.1)*	152.2^{a}_{1} (± 89.6)	120.8^{a}_{1} (± 47.0)
I. cryptantha	99.4^{ab}_{1} (± 29.0)	86.3^{ab}_{1} (± 33.9)	89.3^{a}_{1} (± 29.2)
I. costata	24.5^{b}_{1} (± 9.8)	23.3^{b}_{1} (± 4.0)	37.0^{a}_{1} (± 11.6)
I. viciodes	7.1^{b}_{1} (± 3.8)	27.2^{b}_{1} (± 15.7)	31.7^{a}_{1} (± 7.5)
I. arrecta	114.4^{ab}_{1} (± 27.7)	89.3^{ab}_{1} (± 35.0)	85.7^{a}_{1} (± 40.5)

^{a,b,c}Column means with common superscripts do not differ significantly ($P>0.05$)
^{1,2}Row means with common subscript do not differ significantly ($P> 0.05$)
*Standard deviation (SD)

There were significant differences during the autumn of 2003 in terms of available leaf dry matter yield between *I. amorphoides* and *I. costata* as well as *I. viciodes.* However, there were no significant differences found between *I. amorphoides*, *I. cryptantha* and *I. arrecta* as well as between *I. costata* and *I. viciodes*. During the autumn of 2004, significant differences were detected between *I. amorphoides* and *I. costata* as well as *I. viciodes*. However, no significant differences were found between *I. amorphoides*, *I. cryptantha* and *I. arrecta* as well as between *I. cryptantha*, *I. costata*, *I. viciodes* and *I. arrecta*. There were no significant differences during spring between the species. The leaf

DM yields in this study appeared to decrease with advancing maturity, environmental factors and cutting intervals, although not significant between the years (see Table 3.1). This was supported by Smith *et al*. (1992) who reported that the DM yield would increase due to the effect of environmental factors (temperature, rainfall), longer grazing or cutting intervals and advancing maturity. The proportion of inedible plant material will, however, also increase leading to a decline in forage quality.

3.1.2 Stem DM yield (g/plot)

The results of the stem DM yield of all the plant species are presented in Table 3.2.

Table 3.2 The stem DM yield (g/plot) of five *Indigofera* species

Species	2003	2004	2004
	Autumn	Autumn	Spring
I. amorphoides	127.5$^{a}_{1,2}$ (± 79.9)*	206.9$^{a}_{1}$ (± 124.6)	58.2$^{a}_{2}$ (± 33.7)
I. cryptantha	45.6$^{ab}_{1}$ (± 18.2)	108.7$^{ab}_{1}$ (± 24.4)	29.7$^{a}_{1}$ (± 11.2)
I. costata	14.8$^{b}_{1}$ (± 7.5)	79.0$^{b}_{1}$ (± 11.4)	13.0$^{a}_{1}$ (± 2.6)
I. viciodes	2.0$^{b}_{1}$ (± 1.6)	43.7$^{b}_{1}$ (± 12.0)	10.0$^{a}_{1}$ (± 2.2)
I. arrecta	84.8$^{ab}_{1,2}$ (± 30.2)	143.9$^{ab}_{1}$ (± 44.3)	50.9$^{a}_{2}$ (± 27.6)

^{a,b,c}Column means with common superscripts do not differ significantly ($P>0.05$)
^{1,2}Row means with common subscript do not differ significantly ($P> 0.05$)
*Standard deviation (SD)

During the autumn of 2003, there were significant differences found between *I. amorphoides* and *I. costata* as well as *I. viciodes*. There were, however, no significant differences between *I. amorphoides*, *I. cryptantha* and *I. arrecta* as well as between *I. costata and I. viciodes.* There were significant differences detected during the autumn of 2004 between *I. amorphoides* and *I. costata* as well as *I. viciodes*. However, there were no significance differences between *I. cryptantha*, *I. costata*, *I. viciodes* and *I. arrecta*.

During spring of 2004, there were no significant differences found between the species. There were significant differences detected between autumn and spring of 2004 for *I. amorphoides* and *I. arrecta.* Evans and Rotar (1987) reported that climate, soil types, maturity and management practices (such as fertilizer use, height and cutting interval as well as intercropping) may affect the DM yield.

3.1.3 Total DM yield (g/plot)

The results of the total DM yield of all the plant species are presented in Table 3.3

Table 3.3 The total DM yield (g/plot) of five *Indigofera* species

Species	2003	2004	2004
	Autumn	Autumn	Spring
I. amorphoides	322.3 $^{a}_{1,2}$ (± 194.4)*	359.1 $^{a}_{1}$ (± 213.3)	179.0 $^{a}_{2}$ (± 80.0)
I. cryptantha	145.0 $^{ab}_{1}$ (± 47.1)	195.1 $^{ab}_{1}$ (± 58.1)	119.0 $^{a}_{1}$ (± 40.4)
I. costata	39.3 $^{b}_{1}$ (± 17.3)	102.2 $^{b}_{1}$ (± 10.1)	50.0 $^{a}_{1}$ (± 10.0)
I. viciodes	9.1 $^{b}_{1}$ (± 5.4)	70.9 $^{b}_{1}$ (± 19.7)	41.3 $^{a}_{1}$ (± 9.6)
I. arrecta	199.2 $^{ab}_{1}$ (± 57.9)	230.9 $^{ab}_{1}$ (± 79.1)	136.7 $^{a}_{1}$ (± 68.0)

^{a,b,c}Column means with common superscripts do not differ significantly ($P>0.05$)
^{1,2}Row means with common subscript do not differ significantly ($P> 0.05$)
*Standard deviation (SD)

In autumn of 2003, there were significant differences found in terms of total dry matter yield between *I. amorphoides* and *I. costata* as well as *I. viciodes*. There were, however, no significant differences between *I. amorphoides*, *I. cryptantha* and *I. arrecta* as well as between *I. cryptantha, I. costata, I. viciodes and I. arrecta.* There was a significant difference during autumn 2004 between *I. amorphoides* and *I. costata* as well as *I. viciodes*. However, no significant differences were detected between *I. amorphoides*, *I. cryptantha* and *I. arrecta* as well as between *I. cryptantha*, *I. costata*, *I. viciodes* and *I. arrecta*.

There were no significant differences found during the spring of 2004 in terms of the total dry matter yield between all the species. There was, however, a significant difference between the autumn and spring of 2004 for *I. amorphoides*. Van Soest (1982) reported that as the forage matures there is an increase in dry matter yield leading to a decline in digestible dry matter.

3.2 Leaf to stem ratio

The results of the leaf to stem ratio of all the species are presented in Table 3.4

Table 3.4 Leaf:stem ratio of leaves and stems of five *Indigofera* species

Species	2004 Autumn	2004 Spring
I. amorphoides	47:53 $^{a}_{1}$	59:41 $^{a}_{2}$
I. cryptantha	41:59 $^{a}_{1}$	59:41 $^{a}_{2}$
I. costata	41:59 $^{a}_{1}$	57:43 $^{a}_{2}$
I. viciodes	43:57 $^{a}_{1}$	57:43 $^{a}_{2}$
I. arrecta	52:48 $^{a}_{1}$	52:48 $^{a}_{1}$

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P> 0.05)

There were no significant differences found within the seasons for all the plant species. However, there was a significant difference between the seasons for all species except for *I. arrecta*, which showed no significant difference. There were lower leaf:stem ratios during the autumn of 2004, which resulted in a decrease in CP content, IVDOM and an increase in NDF concentrations (see Tables 3.7; 3.12 and 3.10). Therefore, a leaf to stem ratio is a good indicator of forage quality. Crowder and Chheda (1982) reported that the decline in forage quality with maturity is primarily due to the increasing lignification of the stem and an increasing proportion of the stem compared to leaf. Legume quality is affected by leaf:stem ratio. Shehu *et a*l.(2001) reported that the leaf: stem ratio in legumes is valuable because the leaves are metabolic organs and the quality of stems are largely affected by their structural function. It is important to note that both maturation and ambient temperature will affect various parts of the same plant differently (Buxton *et al*., 1995).

3.3 Chemical composition

Samples from the five species (*Indigofera arrecta, I. cryptantha, I. costata, I. viciodes, and I. amorphoides*) were collected in autumn and spring. The results of the chemical composition are presented below.

3.3.1 Ash concentration

Table 3.5 The ash concentration (%) of leaves and edible components (leaves & fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves & fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	13.4^{a}_{1}(± 0.27)*	5.8^{a}_{2}(± 0.26)	5.1^{a}_{2} (± 0.38)	6.6^{ab}_{1} (± 0.06)
I. cryptantha	9.1^{b}_{1}(± 0.38)	5.5^{a}_{2}(± 0.24)	4.5^{a}_{2} (± 0.18)	8.2^{a}_{1} (± 1.11)
I costata	13.4^{a}_{1}(± 3.81)	5.0^{a}_{2}(± 0.19)	4.1^{a}_{2}(± 0.10)	6.8^{ab}_{1} (± 0.35)
I. viciodes	9.6^{b}_{1}(± 0.11)	7.0^{a}_{2}(± 0.13)	4.5^{a}_{2}(± 1.45)	6.2^{b}_{1} (± 0.66)
I. arrecta	12.2^{ab}_{1}(± 1.23)	5.9^{a}_{2}(± 1.19)	4.5^{a}_{2}(± 0.65)	7.5^{ab}_{1} (± 0.31)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P> 0.05)
*Standard deviation (SD)

3.3.1.1 Leaves

There were significant differences in the ash concentration of leaves during the autumn of 2003 between *I. amorphoides* and *I. cryptantha* as well as *I. viciodes*, and between *I. costata* and *I. cryptantha* as well as *I. viciodes*. However, there were no significant differences found between *I. arrecta* and all the other species as well as between *I.*

amorphoides and *I. costata*. In the autumn of 2004, no significant differences were found between the different species. There were significant differences between years in all species. There was a dramatic decrease in ash concentration during the autumn of 2004 in all the species. Thomas and Thomas (1985) as well as McDonald *et al*. (2002) reported that as the plant grows, the ash concentrations decrease (see Table 3.6). This is probably the reason for a lower ash concentration in 2004 as compared to 2003. The ash concentrations reported in this study during 2003 are in close agreement with those reported by Haafat and Hassani (1966) for lucerne (12.6%) and Van Rensburg (1968) and Everist (1969) of 9.86% for *L. leucocephala* and 11.78% for *I. arrecta*. Ahn *et al*. (1989) and Goodchild (1990) reported ash concentrations of 4.8% for *Acacia aneura* and 5.7% for *L. leucocephala* (which are also representative of fodder trees in the tropics and subtropics) compares well with the results obtained during 2004 in this study.

Table.3.6 Variations in ash concentration with forage age (years) in lucerne (Thomas and Thomas 1985; McDonald *et al*., 2002)

Legume	Forage age	Ash %
Medicago sativa	1	12.6
	2	11.6
	3	10.8

3.3.1.2 Edible components (leaves and fine stems)

The ash concentration in the edible components of all the species in the autumn of 2004 showed no significant differences. There was, however, a significant difference in the spring of 2004 between *I. cryptantha* and *I. viciodes*. However, there were no significant differences found between *I. amorphoides* and all other species as well as between *I. cryptantha, I. costata* and *I. arrecta*. There were significant differences between the two seasons in the edible component of all species. The lower ash concentration in autumn compared to spring is probably due to a decrease in leaf/stem ratio (Table 3.4). Shehu *et* *al*. (2001) reported that the quality of legume forage is negatively affected by an increase in the proportion of stems.

3.3.2 Crude protein concentration

Table 3.7 The crude protein concentration (%) of leaves and edible components (leaves and fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves & fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	26.6^{ab}_{1}(± 3.03)*	22.3^{b}_{2}(± 2.37)	13.7^{a}_{2}(± 2.37)	22.8^{a}_{1} (± 0.96)
I. cryptantha	29.7^{a}_{1}(± 0.67)	24.4^{b}_{2}(± 1.19)	8.10^{a}_{2}(± 1.19)	28.7^{a}_{1} (± 0.84)
I costata	22.6^{b}_{2}(± 0.31	31.1^{a}_{1}(± 3.51)	12.7^{a}_{2}(± 3.51)	26.2^{a}_{1} (± 7.76)
I. viciodes	25.5^{ab}_{2}(± 3.71)	29.1^{ab}_{1}(± 4.26)	12.9^{a}_{2}(± 4.26)	23.6^{a}_{1} (± 5.68)
I. arrecta	25.3^{ab}_{1}(± 3.78)	24.6^{b}_{1} (± 8.91)	18.2^{a}_{1}(± 8.91)	26.1^{a}_{1}(± 3.25)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P> 0.05
*Standard deviation (SD)

3.3.2.1 Leaves

There were significant differences found in the CP of leaves during the autumn of 2003 between *I. cryptantha* with the highest CP and *I. costata.* However, no significant differences were detected between *I. amorphoides* and all other species. During autumn of 2004, there were significant differences between *I. costata* and *I. amorphoides*; however, there were no significant differences between *I. amorphoides*, *I. cryptantha*, *I. viciodes* and *I. arrecta*. There were, however, significant differences between the two years for all the species, except *I. arrecta*. The CP concentrations of all species in this study obtained during 2003 compares well with the CP concentrations reported by

Robertson (1988) and Ahn *et al*. (1989) of 26.7% for *L. leucocephala* and 22.5% for *Acacia angustissima*.

Jones (1969), reported that lucerne plants may have 18% CP, but if the leaves and the stems were separated and analyzed, the leaves will have 26% CP, while the stems might have 11% CP. Van Soest (1982) stated that as plants mature, crude protein decreases, fibre increases and digestibility declines (see Table 3.8). This is in close agreement with the CP concentration obtained during 2003 in this study. As forages mature, there is a point at which the accumulation of digestible DM declines despite increasing forage DM yields.

Table 3.8 Effect of stage of maturity on the nutrient content of lucerne (Van Soest, 1982)

Stage of maturity	**Crude protein (%DM)**	**Neutral detergent fibre (%DM)**
Vegetative	22	41
Bud	20	44
Early bloom	17	48
Mid bloom	16	50
Full bloom	15	52
Mature	13	55

The CP results in this study are similar to those reported by Karachi (1997) for *Lablab purpureus* (25%). Due to the high CP concentrations, farmers may use homegrown forages, such as *Indigofera,* lucerne and *L. leuecocephala*, to provide supplemental protein to grazing livestock (Phillips *et al*., 2002). The CP concentration of all the plant species recorded in both years will fulfill the CP requirements of cows and ewes for different functions (Table 3.9).

Table 3.9 The crude protein requirements of different classes of ruminants (NRC, 2001)

Classes of ruminants	**CP (%)**
Beef cows (maintenance)	9.2
Beef cows (early lactation)	9.6
Mature ewes (maintenance)	9.5
Mature ewes (lactating)	13.3

3.3.2.2 Edible components (leaves and fine stems)

There were no significant differences in the CP of edible components identified between the species during autumn and spring (Table 3.7). However, there was a significant difference between the two seasons for all species, except *I. arrecta*, which showed no significant differences. The CP concentration of all the plant species in both seasons fell within the general range of protein concentration of 12-30% in browse plants species (Gupta and Pradhan, 1975; McDonald and Ternouth, 1975; Bamualim, 1981; Minson, 1990; Rittner and Reed, 1992).

The decline in CP concentration during autumn is probably due to a decrease in leaf: stem ratio (Table 3.4). Shehu *et al*. (2001) reported that legume quality is affected by leaf:stem ratio. Evans (2002) reported a range 12.7 to 14.1% CP for the whole plant, which compares well with the CP concentration obtained during autumn in this study. Khamseekhiew *et al*. (2001) stated that the CP concentration of edible material (leaves & small stems) of *L. leucocephala* ranged from 14-30% CP, which is in close agreement with the CP concentration in this study during spring.

3.3.3 Neutral detergent fibre concentration

The results of NDF concentration determinations are presented in Table 3.10.

Table 3.10 The neutral detergent fibre (%) of leaves and edible components (leaves & fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves & fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	18.9^{a}_{2}(± 2.05)*	40.2^{b}_{1}(± 0.10)	62.5^{a}_{1}(± 3.52)	33.0^{a}_{2}(± 1.56)
I. cryptantha	22.2^{a}_{2}(± 0.40)	45.7^{ab}_{1}(± 0.40)	65.4^{a}_{1}(± 3.12)	35.1^{a}_{2}(± 1.90)
I costata	22.5^{a}_{2}(± 5.05)	50.4^{a}_{1}(± 0.72)	62.2^{a}_{1}(± 4.03)	34.7^{a}_{2}(± 6.60)
I. viciodes	25.5^{a}_{2}(± 6.30)	42.2^{b}_{1}(± 0.16)	60.7^{a}_{1}(± 7.45)	36.5^{a}_{2}(± 3.83)
I. arrecta	24.2^{a}_{2}(± 1.97)	46.5^{ab}_{1}(± 0.60)	59.5^{a}_{1}(± 6.32)	32.8^{a}_{2}(± 4.60)

^{a,b,c}Column means with common superscripts do not differ significantly ($P>0.05$)
^{1,2}Row means with common subscript do not differ significantly ($P> 0.05$)
*Standard deviation (SD)

3.3.3.1 Leaves

There were no significant differences in the NDF of leaves detected in the autumn of 2003 between all the plant species. However, in the autumn of 2004 there were significant differences found between *I. costata* and *I. amorphoides* as well as *I. viciodes*. No significant differences were detected between *I. amorphoides*, *I. cryptantha*, *I. viciodes* and *I. arrecta* as well as between *I. cryptantha*, *I. costata* and *I. arrecta*. There were significant differences between the two years for all the species. An increase in the NDF concentrations in 2004 was probably due to the ageing of the plants. Van Soest (1982) reported that the quality of foliage decreases with advancing maturity (Table 3.11). The decreased IVDOM in the autumn of 2004 (Table 3.12), as plants matured, is similar to that reporting an increase in NDF concentration being associated with a decrease in digestibility (Van Soest, 1982).

Tree foliage with low NDF concentrations (20-35%) is usually of high digestibility and species with high lignin are often of low digestibility (Bamualim *et al.*, 1980; NRC, 2001). Goodchild (1990) reported an NDF concentration of 30% for *L. leucocephala,* which is slightly higher than the NDF concentrations obtained during 2003 and lower than those in 2004. Fodder trees and shrubs have relatively high concentrations of crude protein, minerals and NDF (Wilson, 1977; Ibrahim, 1981). This is particularly in agreement with the results obtained in this study and emphasizes their value as dry season feeds for grazing livestock.

3.3.3.2 Edible components (leaves and fine stems)

The NDF concentrations of the edible components of all species investigated within the two seasons showed no significant differences. However, there were significant differences between the two seasons. The high NDF concentrations (59.50-65.43%) in autumn are probably due to a decrease in the leaf:stem ratio (Table 3.4). The stems have higher NDF concentrations than leaves, which is due to the higher concentrations of fibre and lignin (Karachi, 1997).

The quality of stems is largely determined by their structural function, which results in an increase in NDF concentrations (Shehu *et al.*, 2001). The average NDF of the whole plant for *L. leucocephala* is 34.5%, which is comparable to the NDF concentrations obtained during spring in this study (Murphy and Colucci, 1999). The NDF concentrations obtained during autumn in this study are in close agreement with 60.30% of *Albizia chinensis* reported by Robertson (1988). It is very important to note that total NDF concentration of forage is a dominant factor in determining forage quality. Forages that contain 40% NDF or less are generally of higher digestibility than forages that contains 60% NDF (Hoffman *et al.*, 2001). The results found during spring in this study agree fully with the results by NRC (2001), that a low NDF concentration (<35%) results in higher digestibility.

3.4 Digestibility

3.4.1 IVDOM

The results of IVDOM analyses are presented in Table 3.12

Table 3.12 The *In vitro* digestibility of organic matter (%) of leaves and edible components (leaves & fine stems) of five *Indigofera* species

	Leaves		**Edible (leaves & fine stems)**	
Species	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	71.7^{a}_{1}(± 4.00)*	59.8^{bc}_{2}(± 1.85)	56.8^{a}_{1} (± 3.94)	63.2^{a}_{1}(± 2.64)
I. cryptantha	70.7^{a}_{1}(± 2.88)	56.8^{bc}_{2}(± 2.31)	50.7^{a}_{2} (± 2.46)	72.2^{a}_{1} (± 2.60)
I. costata	65.5^{a}_{1}(± 1.21)	55.8^{c}_{2}(± 1.38)	52.1^{a}_{2} (± 7.92)	67.7^{a}_{1} (± 3.60)
I. viciodes	65.5^{a}_{1}(± 3.96)	66.6^{a}_{1}(± 1.85)	52.5^{a}_{2} (± 3.78)	67.1^{a}_{1} (± 7.22)
I. arrecta	70.2^{a}_{1}(± 3.05)	63.1^{ab}_{2}(± 1.21)	53.5^{a}_{2} (± 3.71)	65.5^{a}_{1} (± 8.23)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P> 0.05
*Standard deviation (SD)

3.4.1.1 Leaves

The *in vitro* digestibility of the organic matter of all species in the autumn of 2003 showed no significant differences. There were, however, significant differences in the autumn of 2004 between *I. costata* and *I. viciodes* as well as *I. costata* and *I. arrecta.* There were significant differences between the two years for all the species, except *I. viciodes*. As the plants mature, there is an increase in the proportion of fibre in the herbage, which has a strong influence on digestibility (McDonald *et al*., 2002). As plants mature, IVDOM declines. Similar results were obtained by Forwood *et al*. (1988) and Relling *et al*. (2001).

The IVDOM of all the species, obtained in both years, falls within the general range of tropical browse plants of 36-69% (Milford and Minson, 1968). The results of IVDOM of leaves obtained in this study in the autumn of 2004 for *I. amorphoides*, *I. cryptantha* and *I. costata* are in close agreement with IVDOM reported by Lukhele and Van Ryssen (2002) of 55.9% for *Compretum molle.* Karachi (1997) reported that the IVDOM of the leaves of *L. purpureus* was 64.4%, which is in close agreement with the IVDOM reported in the autumn of 2003 in this study. Bulo *et al*. (1985) found that the IVDOM of leaves of shrubs and tree legumes varied from 36 to 63.4%.

3.4.1.2 Edible components (leaves and fine stems)

There were no significant differences found between all species for both seasons. However, there were significant differences between the two seasons for all species, with a higher IVDOM in spring compared to autumn, except for *I. amorphoides*, which showed no significant difference (56.80% and 63.15%). An increase in the IVDOM in spring was a result of a higher leaf:stem ratio (Table 3.4). The results obtained during autumn in this study compared well with the IVDOM reported by Lukhele and Van Ryssen (2002) of 52.6 to 54.3% for *Colophospermum mopane.* The decline in IVDOM in the autumn of 2004 is probably due to a decrease in leaf:stem ratio as a result of advancing maturity (Table 3.4).

3.5 Minerals

Livestock producers generally provide mineral supplements to meet the dietary requirements of their animals. As a matter of fact, it is known that deficiencies in certain minerals can cause health problems e.g. low Ca intake may, or will, cause thin and brittle bones. Therefore, it is important to understand the knowledge of mineral requirements of forage plants and grazing animals. A good nutrition programme not only meets the animal's needs, but also does so at minimal cost. This emphasis on cost is essential since cost/return analysis of livestock feed costs represent approximately 50-70% of the total cost, and feed costs are one of the few areas in which producers can make significant changes (Meissner *et al*., 1995).

3.5.1 Macro elements

3.5.1.1 Calcium concentration

The results of calcium concentration of all the species are presented in Table 3.13.

Table 3.13 The calcium concentrations (%) in leaves and edible components (leaves and fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves and fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	3.87^{ab}_{1}(± 0.45)*	1.79^{a}_{2}(± 0.02)	1.03^{a}_{2}(± 0.13)	2.12^{a}_{1}(± 0.13)
I. cryptantha	2.66^{b}_{1}(±0.07)	1.34^{a}_{2}(±0.05)	1.20^{a}_{2}(±0.25)	1.82^{a}_{1} (± 0.13)
I. costata	4.52^{a}_{1}(±1.52)	0.22^{a}_{2}(±0.03)	0.99^{a}_{2}(±0.06)	1.73^{a}_{1}(± 0.13)
I. viciodes	3.22^{ab}_{1}(±0.12)	1.44^{a}_{2}(±0.04)	1.38^{a}_{1}(±0.68)	1.61^{a}_{1}(± 0.13)
I. arrecta	3.79^{ab}_{1}(±0.63)	0.97^{a}_{2}(±0.03)	1.20^{a}_{2}(±0.32)	1.96^{a}_{1}(± 0.13)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P> 0.05)
*Standard deviation (SD)

3.5.1.1.1 Leaves

There was a significant difference in the Ca concentration in autumn of 2003 between *I. cryptantha* and *I. costata*, although no significant difference was detected among *I. amorphoides*, I. *cryptantha*, *I. viciodes* and *I. arrecta*. In the autumn of 2004, no significant differences were found between the different species. However, there were significant differences between the two years for all the species. The decrease in Ca concentrations during 2004 was probably due to an age effect, as reported by Ibrahim (1981) that Ca concentrations decrease with advancing maturity.

The Ca concentrations reported in this study in the autumn of 2004, are in close agreement with those reported by Dougall and Bogdan (1966), Van Rensburg (1968) and Everist (1969) of 1.88% for *I. hirsuta*, 2.52% for *I. arrecta* and 1.09% for *Acacia cana*. The concentrations of Ca of all the species included in this study will meet the Ca required by beef cows during lactation (0.18-0.27%), as recommended by NRC (1996). An inadequate intake of Ca may cause weakened bones, slow growth and low milk production. In a number of tropical countries (e.g. South Africa, Argentina, Brazil and Senegal) death from botulism as a result of bone chewing has been reported (McDowell, 1992). The Ca concentrations of the *Indigofera* species used in this study will satisfy the Ca requirements of ruminants (Table 3.14).

The nutrient requirements for various ruminant species are presented in Table 3.14.

Table 3.14 Nutrient requirements based on NRC and ARC for various ruminant species (McDowell, 1992 & 1997)

Elements	Requirements of ruminants (%)	Critical level based on ruminant needs (%)
Ca	0.18-0.82	0.3
Mg	0.1-0.2	0.2
P	0.18-0.48	0.25

3.3.1.1.2 Edible components (leaves and fine stems)

The Ca concentrations of the plant species investigated, within seasons, showed no significant differences. However, there was a significant difference between two seasons for all species, except *I. viciodes*. The higher Ca concentrations in spring were probably due to a higher leaf:stem ratio (Table 3.4). McMeniman and Little (1974) reported that forage tree leaves generally have higher Ca and P concentrations than stems.

3.5.1.2 Phosphorus concentration

The results of phosphorus analyses are presented in Table 3.15.

Table 3.15 The phosphorus concentrations (%) in leaves and edible components (leaves and fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves and fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	0.26^{ab}_{1}(± 0.08)*	0.26^{ab}_{1}(± 0.01)	0.11^{a}_{2}(± 0.03)	0.24^{a}_{1}(± 0.03)
I. cryptantha	0.33^{a}_{1}(± 0.01)	0.19^{b}_{2}(± 0.01)	0.10^{a}_{2}(± 0.04)	0.29^{a}_{1}(± 0.05)
I. costata	0.23^{b}_{1}(± 0.05)	0.25^{ab}_{1}(± 0.01)	0.10^{a}_{2}(± 0.01)	0.27^{a}_{1}(± 0.09)
I. viciodes	0.30^{ab}_{1}(± 0.02)	0.28^{a}_{1}(± 0.01)	0.13^{a}_{2}(± 0.01)	0.21^{a}_{1}(± 0.02)
I. arrecta	0.28^{ab}_{1}(± 0.02)	0.19^{b}_{2}(± 0.01)	0.15^{a}_{2}(± 0.07)	0.23^{a}_{1}(± 0.02)

^{a,b,c}Column means with common superscripts do not differ significantly ($P>0.05$)
^{1,2}Row means with common subscript do not differ significantly ($P> 0.05$)
*Standard deviation (SD)

3.5.1.2.1 Leaves

There was a significant difference in autumn of 2003 of P concentration in leaves between *I. cryptantha* and *I. costata* however, no significant differences were obtained between *I. amorphoides* and all other species. In the autumn of 2004, there was a slight decrease in P concentrations with significant differences between *I. viciodes* and *I. cryptantha* as well as *I. arrecta*. There were significant differences between the two years, except for *I. amorphoides, I. costata* and *I. viciodes*.

The decrease in the autumn of 2004 was most probably due to maturity. Kabaija and Smith (1989) reported that P concentrations decline with maturity (Table 3.16). The P concentrations of all the plant species in this study during both years compared well with P concentrations reported by Van Rensburg (1968) of 0.29% for *I. arrecta*. The concentrations of mineral elements in the plants are dependant upon several factors e.g. stage of maturity and plant species (McDowell, 1992).

The variation in mineral composition with forage age in *Leucaena leucocephala* is presented in Table 3.16.

Table 3.16 Variation in mineral composition of forage with age (days) in *Leucaena leucocephala* (Kabaija and Smith, 1989)

Forage age (days)	P (%)	Mg (%)
21	0.12	0.42
42	0.13	0.25
63	0.10	0.25
84	0.10	0.24

3.5.1.2.2 Edible components (leaves and fine stems)

There were no significant differences in the P concentrations of edible components among all species for both seasons. However, there was a significant difference between the two seasons for all species, with an increase in P concentrations during spring, due mainly to a higher leaf:stem ratio (Table 3.4). The results obtained in the autumn of 2004 are in close agreement with the findings reported by Kabaija and Smith (1989) of 0.10%-0.13% for *L. leucocephala* while the P concentrations obtained in spring would fulfill the P requirements of ruminants (Table 3.14).

3.5.1.3 Magnesium concentrations

The results of magnesium concentrations are presented in Table 3.17.

Table 3.17 The magnesium concentrations (%) in leaves and edible components (leaves and fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves and fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	1.07^{a}_{1}(± 0.14)*	0.44^{b}_{2}(± 0.01)	0.50^{a}_{1}(± 0.08)	0.45^{a}_{1}(± 0.02)
I. cryptantha	0.39^{c}_{1}(± 0.08)	0.32^{bc}_{1}(± 0.02)	0.21^{b}_{2}(± 0.08)	0.61^{a}_{1}(± 0.06)
I. costata	0.46^{c}_{1}(± 0.05)	0.41^{b}_{1}(± 0.02)	0.19^{b}_{2}(± 0.04)	0.48^{a}_{1}(± 0.23)
I. viciodes	0.52^{bc}_{2}(± 0.03)	0.65^{a}_{1}(± 0.04)	0.29^{ab}_{2}(± 0.04)	0.47^{a}_{1}(± 0.08)
I. arrecta	0.65^{b}_{1}(± 0.01)	0.21^{c}_{2}(± 0.02)	0.24^{b}_{2}(± 0.03)	0.47^{a}_{1}(± 0.07)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P> 0.05)
*Standard deviation (SD)

3.5.1.3.1 Leaves

There were significant differences in the Mg concentration of leaves during the autumn of 2003 between *I. amorphoides* and all other species as well as between *I. arrecta* and *I. cryptantha* and *I. costata*. No significant differences were, however, detected between *I. cryptantha*, *I. costata* and *I. viciodes* as well as between *I. viciodes* and *I. arrecta*. In the autumn of 2004, there were significant differences between I. *viciodes* and all other species as well as between *I. arrecta* and *I. amorphoides* and *I. costata*. However, no significant differences were found between *I. amorphoides*, *I. cryptantha* and *I. costata* as well as between *I. cryptantha* and *I. arrecta.* There were also significant differences between two years for all species, except for *I. cryptantha* and *I. costata*. There was a decrease in Mg concentration in 2004 in *I. amorphoides*, *I. viciodes* and *I. arrecta*, most probably due to advancing maturity. Kabaija and Smith (1989) reported that Mg concentrations decreased with ageing (Table 3.16). The results reported by Kabaija and Smith (1989), of 0.24%- 0.42% for *L. leucocephala*, compare well with the Mg concentrations reported in this study. The Mg concentration of all the species found in this study will fulfill the Mg requirements of ruminants (Table 3.14).

3.5.1.3.2 Edible components (leaves and fine stems)

There were significant differences in the autumn of 2004 between *I. amorphoides* and *I. cryptantha*, *I. costata,* as well as *I. arrecta* however, no significant differences were found between *I. cryptantha*, *I. costata*, *I. viciodes* as well as *I. arrecta* and between *I. amorphoides* and *I. viciodes*. During the spring of 2004, no significant differences were found between all the species. There were significant differences between the two seasons for all the species, except for *I. amorphoides*. There was a marked increase for all species except for *I. amorphoides* in Mg concentration in the spring of 2004 due to an increase in leaf:stem ratio (Table 3.4). Marten *et al*. (1988) reported that leaves may have two to three times the Mg concentration of stems. The Mg concentrations of all the species in this study will satisfy the Mg required by beef cows during lactation of 0.17-0.20% (NRC, 1996).

3.5.2 Micro elements

McDowell (1997) stated that undernutrition is one of the most important limitations to grazing livestock production. Many classes of livestock are mostly dependent for all their nutrients on the quality of forage available to them, either in the form of grazing, or as conserved hay or silage.

3.5.2.1 Copper concentration

The results of copper analyses are presented in Table 3.18.

Table 3.18 The copper concentrations (mg/kg) in leaves and edible components (leaves and fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves and fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	11.8^{a}_{1}(± 1.76)*	8.8^{a}_{1}(± 1.36)	9.1^{a}_{1}(± 1.15)	10.4^{a}_{1}(± 1.59)
I. cryptantha	10.9^{a}_{1}(± 0.99)	10.8^{a}_{1}(± 0.56)	9.1^{a}_{1}(± 1.44)	10.1^{a}_{1}(± 1.11)
I. costata	13.3^{a}_{1}(±2.77)	9.5^{a}_{2}(± 0.80)	10.2^{a}_{1}(± 1.53)	11.1^{a}_{1}(± 2.27)
I. viciodes	15.3^{a}_{1}(± 3.40)	10.2^{a}_{2}(± 0.64)	9.2^{a}_{1}(± 5.83)	11.8^{a}_{1}(± 1.93)
I. arrecta	13.7^{a}_{1}(± 3.82)	9.0^{a}_{2}(± 0.62)	11.0^{a}_{1}(± 1.88)	9.6^{a}_{1}(± 1.15)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P>0.05)
*Standard deviation (SD)

3.5.2.1.1 Leaves

There was no significant difference in the Cu concentration of leaves between all the species for both years. However, there were significant differences between the two years for *I. costata*, *I. viciodes* and *I. arrecta*. The Cu concentrations of all the species found in this study were above the general requirements of 6.00mg/kg for grazing animals (MacPherson, 2000) (Table 3.19). McDonald and Wilson (1980) stated that maturity leads to a decrease in Cu content of forage because of a decline in the proportion of leaf present and a drop of the Cu content of the stem. The recommended Cu concentration for beef cattle is 10mg/kg and it is also important for normal red blood cell formation (NRC, 1996).

The threshold concentration of micro-elements in forage for ruminants is presented in Table 3.19.

Table 3.19 Threshold concentration of micro-elements in forage for ruminants (MacPherson, 2000)

Minerals	Cattle	Sheep
Cu (mg/kg)		
Desirable	>10.0	>5.0
Marginal	>10.0	>5.0
Deficient	<10.0	<5.0
Zn (mg/kg)		
Desirable	50	50
Marginal	20-40	30-50
Deficient	<20.0	<30.0
Mn (mg/kg)		
Desirable	25	25

3.5.2.1.2 Edible components (leaves and fine stems)

The Cu concentrations of all the plant species, within and between the two seasons, showed no significant differences. The results obtained in this study during spring will satisfy the Cu requirements of sheep (Table 3.19).

3.5.2.2 Zinc concentrations

The results of Zinc analyses are presented in Table 3.20.

Table 3.20 The zinc concentrations (mg/kg) in leaves and edible components (leaves and fine stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves and fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	48.4^{a}_{1}(±15.54)*	$30.3\ ^{a}_{2}$(±0.85)	$31.1\ ^{a}_{2}$(±2.21)	$51.8\ ^{a}_{1}$(± 4.06)
I. cryptantha	50.2^{a}_{1}(±15.99)	$50.9\ ^{a}_{1}$(±6.93)	$51.8\ ^{a}_{1}$(±13.75)	$53.1\ ^{a}_{1}$(± 4.88)
I. costata	35.0^{a}_{1}(±8.32)	$27.1\ ^{a}_{1}$(±0.30)	$27.1\ ^{a}_{2}$(±9.88)	$51.4\ ^{a}_{1}$(± 9.05)
I. viciodes	47.4^{a}_{1}(±8.74)	$39.4\ ^{a}_{1}$(±0.06)	$49.2\ ^{a}_{1}$(±13.33)	$42.2\ ^{a}_{1}$(± 9.20)
I. arrecta	45.4^{a}_{1}(±4.87)	$48.6\ ^{a}_{1}$(±16.33)	$41.8\ ^{a}_{1}$(±21.02)	$47.4\ ^{a}_{1}$(± 4.48)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P>0.05)
*Standard deviation (SD)

3.5.2.2.1 Leaves

There were no significant differences in the Zn concentration of leaves between all the species for each year. There were, however, significant differences between two years for *I. amorphoides*. The Zn concentrations in all the species meet the requirement of ruminants and it is important for normal development and functioning of the immune system (MacPherson, 2000). The recommended Zn requirement in beef cattle is 30mg/kg, which is present in sufficient concentrations in all species for both years, except *I. costata* during 2004.

3.5.2.2.2 Edible components (leaves and fine stems)

In the autumn/spring of 2004, there were no significant differences among all species. However, the Zn concentration showed a significant difference between the two seasons for *I. amorphoides* and *I. costata*. The Zn concentration of all species, in both seasons, will fulfill the requirements of ruminants (Table 3.19).

3.5.2.3 Manganese concentrations

The results of manganese analyses are presented in Table 3.21.

Table 3.21 The manganese concentrations (mg/kg) in leaves and edible components (leaves and stems) of five *Indigofera* species

Species	**Leaves**		**Edible (leaves and fine stems)**	
	2003	2004	2004	2004
	Autumn	Autumn	Autumn	Spring
I. amorphoides	148.0^{b}_{2}(±9.90)*	281.3 $^{a}_{1}$(± 13.46)	143.8 $^{a}_{1}$(±29.53)	125.8^{b}_{1}(±10.7)
I. cryptantha	137.4^{b}_{2}(±11.52)	279.8 $^{a}_{1}$(± 2.51)	139.3 $^{a}_{1}$(±33.91)	169.6^{b}_{1}(±43.2)
I. costata	153.1^{b}_{2}(±28.54)	210.6 $^{b}_{1}$(± 3.76)	164.9 $^{a}_{1}$(±23.24)	214.8^{ab}_{1}(±107.2)
I. viciodes	142.5^{b}_{2}(±1.20)	213.2 $^{b}_{1}$(± 3.78)	117.1 $^{a}_{1}$(± 5.83)	218.9^{ab}_{1}(±66.5)
I. arrecta	186.0^{a}_{2}(±13.97)	227.3 $^{b}_{1}$(± 9.11)	165.4 $^{a}_{2}$(±24.58)	345.7^{a}_{1}(±144.0)

^{a,b,c}Column means with common superscripts do not differ significantly (P>0.05)
^{1,2}Row means with common subscript do not differ significantly (P>0.05)
*Standard deviation (SD)

3.5.2.3.1 Leaves

During the autumn of 2003, there were significant differences between *I. arrecta* and all other species in terms of Mn concentration in the leaves. In the autumn of 2004, *I. amorphoides* and *I. cryptantha* contained significantly more Mn concentrations than *I. costata*, *I. viciodes* and *I. arrecta*. However, there were no significant differences between *I. amorphoides* and *I. cryptantha* as well as between *I. costata*, *I. viciodes* and *I. arrecta*. Significant differences were found between the two years for all the species. The Mn concentration of leaves for these two years differs from the results reported by Beeson and MacDonald (1951) who stated that Mn concentrations were found not to change consistently with advancing maturity. The Mn concentration in forages is usually present in excess of the requirements of ruminants (Minson, 1990). This is in agreement with our results, with the highest Mn concentrations of 281mg/kg. Mn is important in cattle reproduction because it is required for normal oestrus and ovulation in cows and for normal libido and spermatogenesis in bulls. The Mn concentrations of all the plant species in both years will fulfill the Mn requirements of ruminants (Table 3.19).

3.5.2.3.2 Edible components (leaves and fine stems)

The Mn concentration of all species in the autumn of 2004 did not differ significantly. There were significant differences found in spring of 2004 between *I. arrecta* and *I. amorphoides* as well as *I. cryptantha*, however, no significant differences were detected between *I. amorphoides*, *I. cryptantha*, *I. costata* and *I. viciodes* as well as between *I. costata*, *I. viciodes* and *I. arrecta*. There was a significant difference between the two seasons for *I. arrecta*. The findings in this study agree with those reported by Minson (1990), that Mn concentration in forages is usually present in excess. MacPherson (2000) stated that the absorption of manganese by livestock appears to be poor and it is adversely affected by high concentrations of Ca and P. Wedekind and Baker (1990) reported, however, that an excess of P appears to be a greater inhibitor of dietery Mn than the Ca concentration. The Mn concentrations of edible components for all the species in this study will meet the requirements of ruminants (Table 3.19).

3.6 Voluntary feed intake and digestibility

The prediction of intake is important because feed costs may account for 70%, or more, of the total costs (Meissner *et al.*, 1995). Intake is more closely related to the rate of digestion of diets than the digestibility, although the two are generally related to one another. Feeds that are digested rapidly and are also of high digestibility, promote high intake. The feed intake of animals determines the amount of nutrients available for production above that required for maintenance (McDonald *et al*. 2002). Illius (1998) has suggested that intake is probably the most important variable determining animal performance and voluntary intake is generally correlated with the amount of nutrients that can be extracted from a feed i.e. digestibility. Intake of feed is related to feed quality, species of the animal, its status, energy demand and even its sex. A growing animal consumes relatively more feed than a mature one, and pregnant or lactating female consumes even more (Fox *et al*., 1990; Robbins, 1993).

Van Soest (1982) reported that there is a greater variation in intake amongst animals than variation in digestibility and intake is, therefore, a more important factor affecting production, than digestibility. The quantity of dry matter voluntarily eaten by an animal is the most important factor controlling the productive value of a feed. Therefore, if animals consume only a small quantity of a tropical legume, the production of meat, or milk, will be low, no matter how high the protein or mineral content of each unit of feed (Milford and Minson, 1968).

The physical regulation of intake in ruminants is thought to be the major factor influencing the intake of forages, by the mechanism of retention time in the rumen. Forages with a long retention time in the rumen have a lower intake than those with a shorter retention time (Thorton and Minson, 1973). This physical regulation of intake is often expressed as a relationship between intake and digestibility, but Laredo and Minson (1973) showed that forages of the same digestibility could have different intakes.

For forages, digestibility is determined by features of the plant, but potential digestibility and hence potential intake may not be achieved due to the interactions between feeds and the animal itself (Gill and Romney, 1994). A major factor, which could enhance intake of forages, is a lower cell wall content. This is a major reason for the advantages of legumes over grasses and immature forages over those of greater maturity (Buxton *et al.*, 1995).

Large quantities of forages can have an effect on DMI, because of the amount of fibre present and the digestibility of fibre. There are differences in the digestibility and rate of digestion for different forages species. However, intake is considered to be more important than digestibility in influencing DMI from forages (Mertens, 1992).

- Environmental effects on forage quality

The environmental conditions where the plant is grown have an effect on the quality of forage, but the effects are not as great as those of increasing maturity. Temperature is one of the factors, which has a great effect. A rise in temperature reduces the leaf: stem ratio, which generally reduces forage digestion because of the lower digestibility of the stems (Buxton *et al.*, 1995). Buxton *et al.* (1995) stated that for each 1°C increase in temperature the digestibility of forages would decrease by 3 to 7%. Therefore, forages grown in cooler regions are of a higher quality than forages grown in warm climates.

3.7 Chemical composition of forages

The results of the chemical composition of the feeds (hand cut samples) used in the intake trial are presented in Table. 3.22.

Table 3.22 Chemical composition of lucerne, *Indigofera* spp and *L. leucocephala*

Parameters	**Lucerne**	***Indigofera spp***	***L. leucocephala***
CP (%)	20.4 ^{a}(± 0.30)*	14.9 ^{b}(± 0.95)	21.4 ^{a}(± 1.03)
NDF (%)	43.8 ^{c}(± 1.27)	64.6 ^{a}(± 2.04)	47.9 ^{b}(± 2.25)
IVDOM (%)	67.7 ^{a}(± 1.35)	53.3 ^{b}(± 2.16)	46.3 ^{c}(± 1.60)

^{a,b}Row means with common superscripts do not differ significantly (P>0.05)
*Standard deviation (SD)

3.7.1 Crude protein concentrations

There was a significant difference in the CP concentration between lucerne and *Indigofera* species as well as between *L. leucocephala* and *Indigofera* species. There was, however, no significance difference between lucerne and *L. leucocephala*. Jones (1979) reported that leucaena is well known for its high nutritional value and for the similarity of its chemical composition with lucerne. This is evident from the CP concentrations in this study (Table 3.22).

The CP concentrations of the three feeds used in this study are sufficient for optimal livestock production. This is supported by Leng (1990) who stated that less than 8% CP cannot sustain optimal livestock production and recommended N supplementation of such forages to obtain an optimal level of animal production. Evans (2002) reported a wide range between 12.7-14.1% for *Lablab purpureus* for the whole plant, which compares well with the results obtained in this study for *Indigofera* species (14.92%). The CP concentrations of *L. leucocephala* obtained in this study were in close agreement with the value of 20.9% CP reported by Tudsri *et al.* (2002). Duke (1983) reported a CP concentration of 20.4% of lucerne, which is similar to the results for lucerne (20.4%) in this study.

3.7.2 Neutral detergent fibre concentrations

There are significant differences between lucerne*, Indigofera* species and *L. leucocephala* of NDF. Meissner *et al.* (1989) reported an NDF concentration of 50.9% for sainfoin, which is lower than the results for *Indigofera* species obtained in this study. The NDF concentration of 42.4% for *Lablab purpureus* (Aganga and Autlwetse, 2000) is similar to the results obtained with lucerne, but lower than *L. leucocephala* in this study. NRC (2001) reported NDF values of lucerne, which ranged from 35-45%. This compares well with the results for lucerne (43.8%) in this study. Meissner *et al.* (1991) stated that intake is generally limited where NDF levels exceed 55 to 60% of dry matter, as was the case with the *Indigofera* species.

3.7.3 *In vitro* digestibility of organic matter

There are significant differences between lucerne, *Indigofera* species and *L. leucocephala*. Wilman and Asiedu (1983) reported an *in vitro* digestibility of organic matter of 67.2% for lucerne, which correspond with the results for lucerne obtained in this study (Table 3.22). Kruger (1991) reported that IVDOM of *Leucaena leucocephala* ranged from 46 to 63%. This correlates with the recordings of IVDOM for leucaena and *Indigofera* species (Table 3.22).The IVDOM values for lucerne reported by Meissner *et al*. (1989), which ranged from 59.2% to 68.7%, also correspond well with the results (67.7%) in this study. The IVDOM figures of lucerne, *Indigofera* species and *L. leucocephala* obtained in this study fall within the general range of tropical browse plants of 36-69% reported by Milford and Minson (1968).

3.8 Intake and digestibility of lucerne, *Indigofera* spp and *L. leucocephala*

Organic matter intake (OMI), digestible organic matter (DOMI) and neutral detergent fibre intake (NDFI) of lucerne, *Indigofera* species and *L. leucocephala* are presented in Table 3.23.

Table 3.23 Intake by sheep of lucerne, *Indigofera* species and *L. leucocephala*

Parameters	**Lucerne**	***Indigofera* spp**	***L. leucocephala***
Initial Ave. Weight (kg)	61.0	70.5	56.5
OMI (g/d)	1414.5 ^{a}(± 45.4)*	1194.6 ^{b}(± 152.2)	1205.7 ^{b}(± 70.5)
DOMI (g/kg W $^{0.75}$)	44.9 ^{a}(± 9.5)	26.6 ^{b}(± 2.6)	28.6 ^{b}(± 5.8)
NDFI (g/d)	679.4 ^{b}(± 37.3)	803.8 ^{a}(± 94.9)	626.9 ^{b}(± 30.6)

^{a,b}Row means with common superscripts do not differ significantly (P>0.05)
*Standard deviation (SD)

3.8.1 Organic matter intake

There were significant differences between the OMI of lucerne and that of *Indigofera* species and *L. leucocephala.* No significant differences were, however, found between *Indigofera* spp and *L. leucocephala.* There is a general trend for voluntary intake in sheep to increase with an increasing digestibility of dry matter (Milford and Minson, 1968). This is most probably the reason for an increase in the organic matter intake for lucerne as compared to *Indigofera* species and *L. leucocephala.* A number of authors have shown that ruminants decrease their intake of feeds in response to ingestion of toxins (Provenza *et al*., 1990; Thompson and Stuedemann, 1993).

The foliage of *L. leucocephala* contains the toxic amino acid mimosine, which may reach levels of up to 12%. In the rumen this is converted to DHP (3 hydroxy-4-(1H)-pyridone), which causes goitre, loss of appetite, hair loss and loss of weight (Lowry, 1987). This was, therefore, the probable reason for a decrease in intake (OMI) of *L. leucocephala.* The lower intake of leucaena was reported by Jones (1979) to be associated with the effects of mimosine when pure diets of *L. leucocephala* were fed. Van Soest (1982) reported that intake also declines with increasing ADF and NDF concentrations in the forage and digestibility declines with increasing lignin content of the forage. This statement agrees with the lower OMI of *Indigofera* species compared to lucerne and *L. leucocephala* due to it having the highest NDF concentration (64.6%) in this study.

The higher neutral detergent fibre and lower crude protein concentrations in these *Indigofera* species (Table 3.17), compared to that of lucerne and *L. leucocephala*, could have affected the organic matter intake of *Indigofera* species (Table 3.23). This is supported by Nocek and Russell (1988), who reported that excess neutral detergent fibre often limits intake because of physical fill in the rumen. Roux and Meissner (1984) stated that the feed intake of forages is controlled by physical constraints, primarily the rumen fill and the rate of removal of digesta from the rumen, while Milford and Minson (1966) reported that the minimum crude protein requirements of the microbial population in the rumen are 7% for animal grazing tropical pastures.

3.8.2 Digestible organic matter intake (DOMI)

The amount of feed consumed by animals during the intake trial in this study is expressed as organic matter intake per day. However, in this case it is also expressed as digestible organic matter intake (DOMI) per kg metabolic livemass of the animals DOMI g/kg $W^{0.75}$/day.

While there were significant differences in DOMI obtained between lucerne and the other two forages, there were no significant differences between *L. leucocephala* and the *Indigofera* species. Engels (1972) reported that the maintenance requirement for grazing sheep is 33.5 g DOMI/kg $W^{0.75}$/d. We have to account that animals in this study were fed in metabolic cages, which could have an influence on voluntary intake of animals. Nsahlai *et al*. (1997) reported that the DOMI requirements for stall fed animals are 28.2 g DOMI/kg $W^{0.75}$/d. The results obtained in this study, for *L. leucocephala* and lucerne, indicate that these forages will be able to supply the maintenance requirements of sheep (Table 3.23). Under this experimental circumstance *Indigofera* species did not fulfill the maintenance requirements of sheep. The lower DOMI for *Indigofera* species in this study is associated with higher NDF concentrations (Table 3.7). This was supported by Berg and Hill (1989), who reported that intake, declines with an increase in NDF concentration.

3.8.3 Neutral detergent fibre intake

There was a significant difference in NDF intake detected between lucerne and *Indigofera* species as well as between *Indigofera* species and *L. leucocephala*. No significant difference was, however, found between lucerne and *L. leucocephala*. Van Soest (1987) reported that the use of NDF intake within forages is an indicator of forage quality. Quality is closely linked to animal performance. However, great variation exists amongst forage types, which must be considered. Ruiz *et al*. (1995) stated that a measure of NDF digestibility would explain the differences in fibre quality. A measure of NDF intake could explain the indigestible and slowly digestible portion of the diet that occupies space in the digestive tract and thus lower intake.

The organic matter digestibility (OMD) and neutral detergent fibre digestibility (NDFD) are presented in Table 3.24.

Table 3.24 Digestibility of lucerne, *Indigofera* species and *L. leucocephala* utilized by sheep

Parameters	**Lucerne**	***Indigofera* spp.**	***L. leucocephala***
OMD (%)	67.1 ^{a}(± 3.4)*	63.7 ^{a}(± 2.3)	56.4 ^{b}(± 2.2)
NDFD (%)	44.4 ^{b}(± 6.8)	55.5 ^{a}(± 1.1)	41.0 ^{b}(± 3.4)

^{a,b}Row means with common superscripts do not differ significantly (P>0.05)
*Standard deviation (SD)

3.8.4 Organic matter digestibility

There were significant differences in organic matter digestibility (OMD) between lucerne and *L. leucocephala* as well as between *Indigofera* species and *L. leucocephala*. No significant difference was, however, found between lucerne and *Indigofera* species. McDonald *et al*. (2002) reported that feeds, that are digested rapidly and are of a high digestibility, promote high intakes. This corresponds with the OMI and OMD for lucerne in this study (Table 3.23 and Table 3.24). NRC (2001) reported a 60% OMD for lucerne forage, which is lower than the OMD of lucerne in this study.

Joyce *et al*. (1973) reported an OMD of 62.5% for lucerne, which is slightly lower than 67.1% obtained in this study (Table 3.24). Skerman (1970) reported an OMD for *L. leucocephala* of 65%, which is much higher than the OMD recorded in this study. Leucaena is well known for its nutritional value and for the similarity of its chemical composition to that of lucerne. Jones (1979) reported that the organic matter digestibility for *L. leucocephala* ranged from 50 to 71%. The OMD of lucerne, *Indigofera* species and *L. leucocephala* found in this study, falls within that range. McManus *et al*. (1985) stated that tannins in the leaves and especially in the stems of *L. leucocephala*, reduce digestibility. This is most probably true for the OMD of *L. leucocephala* reported in this study.

Tannins are secondary metabolites with a high capacity to form complexes with protein. These complexes are stable at a normal rumen pH and remain undegraded in the rumen resulting in a reduced protein availability and thus limiting animal production (McManus *et al*., 1985). McDonald *et al*. (2002) reported that the lower the NDF concentration, the higher the digestibility. The relatively lower NDF concentration obtained in this study for lucerne (43.8%) and *L. leucocephala* (47.9%) resulted in a higher organic matter intake than with the *Indigofera* species, which had a higher NDF concentration of 64.6% (Table 3.22).

3.8.5 Neutral detergent fibre digestibility

There were significant differences in neutral detergent fibre digestibility (NDFD) between lucerne and *Indigofera* species as well as between *Indigofera* species and *L. leucocephala*. There was, however, no significant difference between lucerne and *L. leucocephalala.* The NDF digestibility values of lucerne, *Indigofera* species and *L. leucocephala*, obtained in this study are lower than the NDF digestibility of 60% for lucerne reported by Oba and Allen (1999). The primary factor that influences NDF digestibility within a species is maturity, or the stage at which the forage was harvested.

When cell and stem diameter increases and heavily lignified xylem tissues develop, NDF digestibility decreases (Hoffman *et al*., 2001). This is probably the reason for the low NDF digestibility reported for *L. leucocephala* in this study. Hoffman *et al*. (2001) reported that lactating dairy cows would increase their dry matter intake and produce more milk when fed forages that have a higher NDF digestibility. The NDF digestibility is an important factor affecting feed intake and production. Oba and Allen (1999) reported that one unit increase of digestibility is associated with 0.17 kg increase in dry matter intake.