U. of K.J. Agric. Sci. 18(2), 153-165, 2010

Effect of Cutting System and Time of Nitrogen Application on Forage Yield of Barley

Moataz Ali Mohamed and Mohammed A. M. Khair [1]

Hudeiba Research Station, River Nile State, Sudan

Abstract: An experiment was conducted at Hudeiba Research Station Farm during the winter seasons of 2004/05, 2005/06 and 2006/07 to study the effect of cutting system and time of nitrogen application on forage yield of barley. The experiment was executed in split plot design with three replications; the times of nitrogen application were assigned to the main plots and the cutting systems to the subplots. Four nitrogen applications: at sowing, 15, 30 and 45 days from sowing (DAS) and four cutting systems: a single cut of the primary crop (SC) and three double cuts referred to as DC1, DC2 and DC3 were studied. The primary crops of the SC were cut at the milk stage, while those of the double cuts were cut at the age of 30, 45 and 60 DAS for DC1, DC2 and DC3, respectively, and the secondary cut in each double cut was at the milk stage. Compared with the SC system, the three DC systems prolonged the growing season but significantly reduced the dry matter yields even in the cumulative of both cuts. The DC systems increased the tiller densities, but reduced the plant densities and the total culm densities of the secondary crops. In terms of the cumulative yields of the DC systems, DC1outyielded the other DC systems. The time of nitrogen application did not affect the forage yield.

Key words: Barley; forage yield; cutting system; nitrogen; Sudan

INTRODUCTION

Tolerance to multiple cuttings is a desirable character for successful production of forage crops (Khair 1999). Such an attribute could reduce the cost of forage production through savings in the cost of seed and land preparation. Cost of irrigation can also be reduced as the regrowth rate

[1]Agricultural Research Corporation, Wad Medani, Gezira State, Sudan

from the residual sward (part of the plant remaining after cutting) is faster than from the seed. In fact, while the first cut of alfalfa in Wad Medani had taken about 60 days from seeding (Khair 1997) subsequent regrowths from the crown were usually cut by farmers at 21 – 28 days.

Forage crops in Sudan vary in their tolerance to multiple cuttings. For instance, alfalfa (*Medicago sativa*) is extremely tolerant to multiple cuttings that it could produce about 10 – 13 cuts annually in Khartoum (Nayel and Khidir 1995) and Gezira (Khair 1997). Along the River Nile banks, "lubia" (*Lablab purpureus)* survives frequent but lenient defoliation for about 9 months extending from October to July of the following year. Phillipesara, (*Vigna trilobata)* and clitoria (*Clitoria ternatea)* are moderately tolerant to multiple cuttings (Khair 1999).

In the Gezira (Sudan), barley (*Hordeum vulgare* L.) produces high yields of good quality forage under single cut system (Khair *et al*. 2001; Salih *et al*. 2006). In countries with long cold winter season, such as Jordan, more than one cut of barley is possible as the dry matter yields of the regrowth (Elshatnawi *et al*. 1999) increase as a result of clipping the primary crop. The growth stage of the primary crop may affect both tillering capacity and the plant height of the regrowth (Elshatnawi *et al*. 1999). Winter in the northern states of Sudan (Northern and River Nile States) is relatively cooler and longer than in other parts of the country. Hence, the question of whether multiple cuttings of barley there might increase forage yield is worth raising. The objectives of this study, therefore, were to evaluate the performance and dry matter yield of barley in response to a single cut versus 3 double cut systems and four times of nitrogen application.

MATERIALS AND METHODS

This study was conducted for three consecutive winter seasons *viz* 2004/05, 2005/06 and 2006/07 at Hudeiba Research Farm (latitude $17^{\circ}34'$ N, longitude $33^{\circ}56'$E and altitude 351 m above sea level), River Nile State, Sudan. The local climate is semi-arid with relatively cool short winter (November to February) (Adam 1996). The soil is a clay loam with pH varying from 8 to 8.5, and the organic carbon and total nitrogen are 0.37% and 0.03%, respectively.

The experimental area was divided into subplots, each 4.2 x 6.0 m with 7 ridges spaced 60 cm apart. Seeds of a local variety of barley were drilled to about 5 cm deep on the top of the ridges at the rate of 96 kg/ha. The sowing date in the three seasons was on 11^{th} Nov. Irrigation was applied every 11-12 days, and the plots were hand weeded twice.
The experiment was executed by split plot design with three replications. Four nitrogen treatments; namely, 184 kg/ha of urea (46%N) at sowing, 15, 30 and 45 days after sowing (DAS) were assigned to the main plots and the time of cutting to the subplots. The four cutting systems involved one single cut (SC) and three double cuts (DC) referred to as DC1, DC2, and DC3. The SC was taken when the primary crop was at the milk stage, whereas the first cut in the DC treatments was taken by cutting the primary crop at 30, 45 and 60 DAS for DC1, DC2 and DC3, respectively, and the secondary crops at the milk stage.

In each subplot, the two outer most ridges were considered margins. Two adjacent ridges, next to one of the margin ridges, were randomly allotted to yield (yield area), whereas the two ridges adjacent to the other margin ridge were allotted to sampling (sampling area). The central ridge was a margin to separate the yield area from the sampling area. In each subplot, the whole area, i.e. yield, sampling area and the margins were cut according to the treatments described earlier. Destructive samples were taken in 2004/05 and 2005/06 seasons to compare the growth attributes of the primary crop of the SC with those of the secondary crop of the DCs. Hence, they started at 15 DAS in the SC and 15 days after cutting the primary crop in the DC systems (initial sample) and continued every two weeks up to the harvest of each treatment (final sample). Samples (each from an area of 0.6x0.5 m) were randomly distributed in the sampling area. In each sample, data were collected on phenology, plant density, tiller density and culm density (No./m^2), and plant height (cm) was calculated as a mean of the height of the main shoot of five plants. The forage yield was taken from an area of 7.2 m^2 once for the single cut and twice for each DC system as described earlier. The fresh matter was weighed in the field immediately after cutting and sub sample of known fresh weight was oven dried to constant weight at 80° C for dry matter determination. The cumulative yield for each DC system was the sum of the yield of the first cut (primary crop) and the secondary crop.

Data on the plant, tiller and culm densities and plant height in each of the initial and the final samples as well as the dry matter yields of the primary crop, secondary crop and the cumulative yields of the DCs were analyzed using the procedure for the split plot design. Duncan's multiple range test was used to separate the means of the dry matter yield.

RESULTS

The time of nitrogen application did not show significant effect on barley performance or yield. Hence, the results of the effect of the cutting systems only will be described.

Phenology and growth durations: Delaying the first cut, according to the DC treatments, resulted in advanced phenological stage of the primary crop but shortened the duration of the secondary crop (Table 1). For instance, the phenology of the primary crop in the DC treatments were tillering, stem elongation and 75% heading when the first cut was at the age of 30, 45 and 60 days after sowing, respectively.

Table 1. Ages of cutting of the primary crop (I), secondary crop (II) and cumulative growth durations (CGD) of the single cut and 3 double cut systems of barley at harvest

Cutting system	Age at cutting (days)									
	2004/05			2005/06			2006/07			Mean
	I	II	CGD	I	II	CGD	I	II	CGD	
Single cut	69	-	-	65	-	-	70	-	-	68
Double cut 1	30	50	80	30	38	68	30	48	78	75
Double cut 2	45	45	90	45	34	79	45	44	89	86
Double cut 3	60	37	97	60	21	81	60	32	92	90

The growth durations of the secondary crops in all DC treatments were shorter than those of the SCs in all seasons. For instance, while the mean growth period of the primary crop of the SCs (over 3 years) was 68 days, the mean growth durations of the secondary crops (over 3 years) were 50, 45 and 37 days for DC1, DC2 and DC3, respectively. Within the regrowth of the DCs, however, prolonging the ages of the first cuts resulted in progressive shortening of the growth duration of the secondary crop. Despite the shorter growing period of the secondary crops, the DC treatments resulted in prolonged cumulative growth periods (CGP) compared to those of the SC treatments. The CGPs of 2005/06 were considerably shorter than those of the other years. The mean CGPs of the DC treatments were 75, 86 and 90 days for DC1, DC2 and DC3, respectively.

Population change: Figure 1 shows two years mean plant, tiller and culm densities as affected by the cutting system. In general, the plant densities of the secondary crops of the three DC systems at harvest were significantly lower than those of the primary crop of the SC (Fig. 1). Within the DC systems, the delay in cutting the primary crop negatively affected the initial plant densities as well as its sustainability through the harvest time. Within the initial plant density of the DC systems, those of DC1 and DC2 were comparably more than that of DC3. Regarding the sustainability, while the initial plant density of the SC and DC1 were perpetuated through harvest, those of DC2 and DC3 were drastically reduced.

Cutting the primary crop in the three DC systems induced substantial number of tillers in the secondary crops (Fig. 1). The DC systems affected both the tiller densities as well as their sustainability through the harvest. The initial tiller density of DC2 was considerably higher than those of the other two DC systems. Regarding the sustainability, however, compared with that of DC1, the initial tiller densities of the DC2 and DC3 were reduced through the harvest. In fact, the final tiller densities of DC1, DC2 and DC3 were, respectively, about 69%, 21% and 13% of their initials. The SC crop showed no tillers at its initial sample but showed considerable tiller density at harvest.

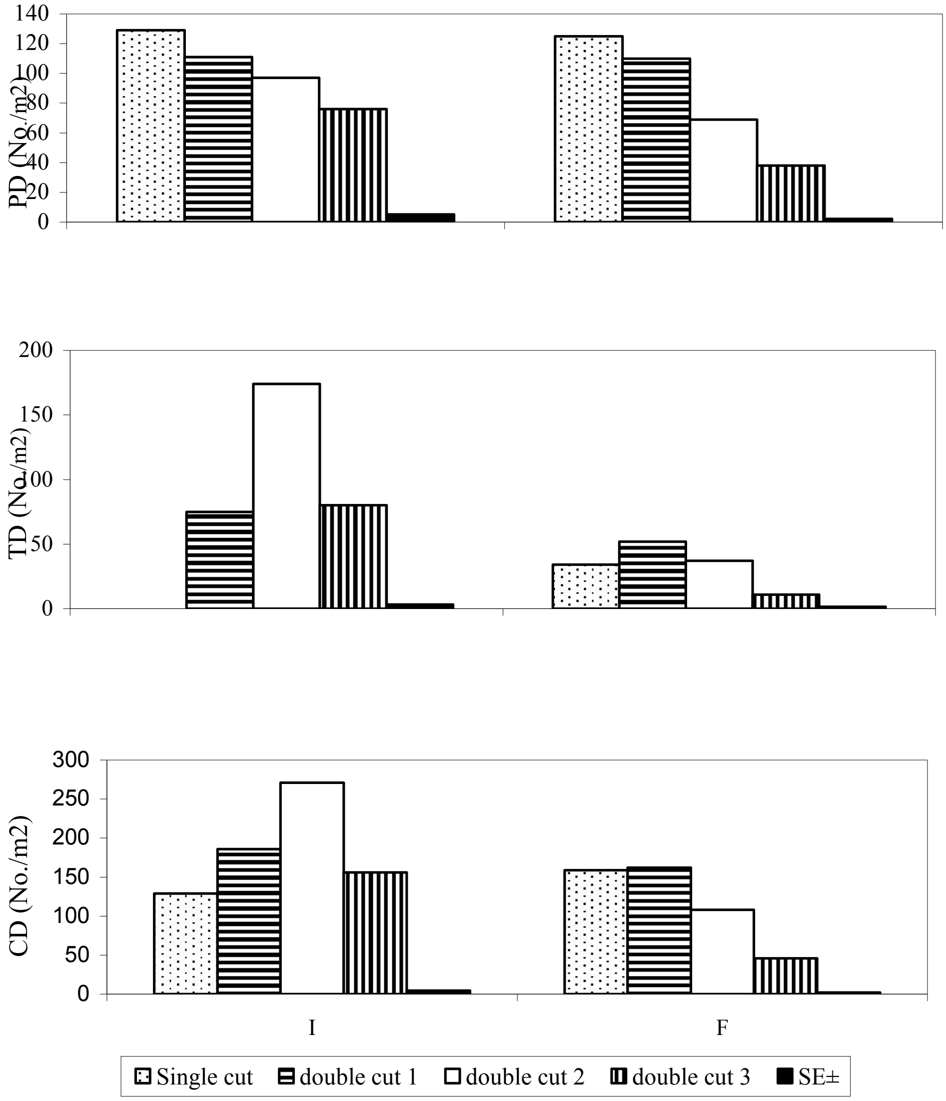

Fig. 1. Two years mean plant density (PD), tiller density (TD) and culm density (CD) of the primary crop (single cut) and secondary crop of the double cut of barley at the age of 15 days (I) and at harvest (F)

The initial total culm densities of the secondary crop of the three DC systems were by far higher than the initial culm density of the primary crop of the SC (Fig. 1). The culm densities among the secondary crop of the three DC systems were in a descending order of DC2, DC1 and DC3. The final culm densities of the primary crop of the SC and the secondary crop of DC1 were comparably higher than those of the secondary crops of either DC2 or DC3. Compared with their initial values, the final culm densities of the secondary crops of the DC systems were low. In fact, while the final culm density of the SC was even more than its initial value, the final culm density of DC1, DC2 and DC3 were, respectively, 87%, 40% and 30% of their initials.

Plant height: Table 2 compares the plant height of the primary crop of the SC with those of the secondary crops of the DCs in 2004/05 and 2005/06. In all treatments, the plant heights in 2005/06 were shorter than in 2004/05. Regarding the treatment effects, the plant height of the primary crop in the SC was significantly taller than that of the secondary crops in the DCs in both years. The plant heights were significantly in a descending order of SC, DC1, DC2 and DC3.

Table 2**.** Plant height of barley (cm) at harvesting the primary crop (single cut) and the secondary crop (double cut) as affected by the cutting treatments

Treatment	Type of crop	2004/05	2005/06	Mean
Single cut	Primary	58	52.2	55.1
Double cut 1	Secondary	50	40.2	45.1
Double cut 2	Secondary	36	19.1	27.6
Double cut 3	Secondary	23	16.2	19.6
SE±		2.0	1.4	

Forage dry matter yield: The dry matter yields in 2005/06 were lower than in the other two seasons (Table 3). The dry matter yield of the primary crops was significantly affected by the cutting systems. The highest dry matter yield in the primary crop was exclusively scored by the SC system. The yielding pattern of the primary crop in the DC systems was in ascending order of DC1, DC2 and DC3. The dry matter yield of the primary crop in the SC system was actually higher even than the cumulative dry matter yield in all DC systems. The highest dry matter yield in the SC was 5.3 t/ha.

In all DC systems, the yielding pattern of the primary crop followed an opposite direction to their yields in the secondary crops. The mean dry matter yields of the primary crop of the DC systems were 0.5, 1.5 and 2.9 t/ha for DC1, DC2 and DC3, respectively; those of the secondary crop were 3.2, 1.1 and 0.5 t/ha for DC1, DC2 and DC3, respectively. The three years mean dry matter yield of the SC system compared with the cumulative dry matter yields of the DC systems were 4.8, 3.7, 2.6 and 3.1 t/ha for SC, DC1, DC2 and DC3, respectively.

Table 3. Dry matter yield (t/ha) of the primary crop, secondary crop and the cumulative yield of barley in 2004/05, 2005/06 and 2006/07 seasons as affected by the cutting systems.

Cutting system	Primary crop			Secondary crop			Secondary crop			Mean
	2004/05	2005/06	2006/07	2004/05	2005/06	2006/07	2004/05	2005/06	2006/07	
Single cut	5.2 A	3.9 A	5.3 A	NA	NA	NA	5.2 A	3.9 A	5.3 A	4.8 A
Double cut 1	0.6 D	0.4 D	0.5 D	3.5 A	2.1 A	4 A	4.1 B	2.5 B	4.4 B	3.7 B
Double cut 2	1.4 C	1.4 C	1.8 C	1.8 B	0.13 B	1.3 B	3.2 C	1.5 C	3 D	2.6 C
Double cut 3	2.7 B	2.2 B	3.8 B	0.4 C	NA	0.12 C	3.1 C	2.2 B	3.9 C	3.1 C
SE±	0.1	0.11	0.17	0.08	0.1	0.15	0.15	0.13	0.17	0.15

Values with different letters in the same column are significantly different at P< 0.05, according to Duncan's multiple range test.
NA ≡ Not Available.

DISCUSSION

In terms of dry matter yield and possibly the economics of production of barley in Sudan, the SC system seems to be more advantageous than the DC systems. In fact, the cumulative yield of each of the three DC systems was significantly lower than that of the SC system in the three seasons. Regarding the economics of production, the longer cumulative growth duration, associated with the three DC systems, imposes greater need for irrigation water, in terms of quantity and frequency. In addition, the cost of cutting twice in each of the DC systems is undoubtly higher than that of the single cut in the SC system.

Prevalence of suitable environmental condition, together with cutting the primary crop at the stage of tillering, seems as perquisite for successful secondary crop of barley (Elshatnawi *et al*. 1999). With respect to the growing condition of barley in Sudan, the lowest day/night temperatures occur normally during the 62 days of both December and January (Adam 1996). The secondary crop in the three DC systems in this study was subjected to varying numbers of these cold days. The reductions in yields of the secondary crops paralleled similar reductions in the number of those cold days to which they were exposed. This can explain the descending order of the dry matter yield of the secondary crops for DC1 through DC3.

The optimum sowing date for barley as forage in Hudeiba (Sudan) is still undetermined. In the Gezira, however, the 1st of December is the optimum (Salih *et al*. 2006), probably because it exposes the whole primary crop to the low temperature of both December and January. In 2005/06 season, the mean temperature of December was higher than in other seasons. This might explain the lower dry matter of 2005/06 than in either of the two other seasons. Likewise, the growth periods of the secondary crops of all DCs in 2005/06 were shorter than in 2004/05 and 2006/07. Hence, the variation in the duration of the growth periods among the DC system might have resulted in the inter-seasonal differences in the dry matter yields of the secondary crops among similar DC treatments, as well as among different DC treatments within each season.

Apparently, in DC1, the primary crop was cut when it was at the stage of tillering, whereas in DC2 and DC3 the primary crops were cut at stem elongation and 75% heading, respectively. The regrowth of barley in DC1 was resumed on 11th December. It is, therefore, logical to compare the second cut of DC1 with that obtained by Salih *et al*. (2006) from the single cut of barley sown on 15th December. Such comparison revealed that the dry matter yield of the second cut of DC1 of this study was even higher than that of the primary growth of barley sown on 15th December in Wad Medani (Salih *et al*. 2006). Hence, the possibility of increasing the dry matter yield of the second cut of DC1 by exposing the regrowth of barley to all days of December and January by growing barley on 1st Nov. and cutting on 1st Dec. is worth considering.

The plant density was systematically reduced as one moves from DC1 through DC3. This may explain, to some extent, the parallel reductions in the dry matter yields of the secondary crops. Tillering in the secondary crops, on the other hand, was very profuse especially in the DC2. The loss in plant density due to cutting of the primary crop was compensated for as both the initial tiller and culm densities of DC2 were even higher than those of SC and DC1. The loss of those tillers at harvest, on the other hand, probably due to the non conducive growing conditions of the secondary crops, might have resulted in the low DM yields of DC2.

The reduction in the yield of the secondary crop could not solely be attributed to loss of plant density, because SC and DC1 varied greatly in the dry matter yield while having almost similar final culm densities. The difference in the dry matter yield among SC and DC1, however, paralleled similar differences in the plants height. So, the lower dry matter yield of the DC1 compared with that of SC is likely to be due to their difference in plant height which in turn reflects the importance of the conducive growing conditions in stem elongation. In conclusion, for optimum forage harvesting of barley in Sudan, the crop should be cut in a single cut when the primary crop attains the milk stage.

REFERENCES

Adam, H.S. (1996). *Agricultural Climate*. Al Asala for Press, Publishing and Media Production. University of Gezira. Wad Medani, Sudan. (In Arabic).

Elshatnawi, M.K.J.; Ghosheh, H.Z.; Shannag, H.K. and Ereifej, K.I. (1999). Defoliation time and intensity of barley in the Mediterranean range land. *Journal of Range Management* 9, 258 – 262.

Khair, M.A.M. (1997). Effect of seed rate on plant population and forage yield of alfalfa on heavy clay soils in Sudan. *University of Khartoum Journal of Agricultural Sciences* 5 (2), 23 – 36.

Khair, M.A.M. (1999). *Principles of Forage Crop Production* (In Arabic). Training and Publication Administration. Agricultural Research Corporation. Wad Medani, Sudan.

Khair, M.A.M.; Krause, R.; Salih, S.A. and Babiker, S.A. (2001). Short note: Barley, Hordeum vulgare, a potential winter forage in the Sudan. *Sudan Journal of Agricultural Research* 3, 85 – 87.

Nayel, B.A. and Khidir, M.O. (1995). Effect of seed rate and fertilization on fodder and seed yield of lucerne (Medicago sativa L.). *University of Khartoum Journal of Agricultural Sciences* 3 (1), 24 – 46.

Salih, S.A.; Khair, M.A.M. and Gangi, A.S. (2006). Effect of seed rate and sowing date on growth and forage yield of barley in the Gezira (Sudan). *University of Khartoum Journal of Agricultural Sciences* 14 (2), 252 - 264.

تاثير نظم القطع ووقت إضافة النيتروجين على إنتاجيةعلف الشعير

معتز على محمد و محمد أحمد محمد خير[1]

محطة بحوث الحديبة، ولاية نهر النيل، الدامر- السودان

موجز البحث: أجريت تجربة في محطة بحوث الحديبة (ولاية نهر النيل) خلال فصل الشتاء لمواسم 05/2004 و06/2005 و 07/2006 بهدف دراسة تأثير وقت إضافة النيتروجين ونظام القطع علي إنتاجية العلف من الشعير. أضيف النيتروجين فى أربعة أوقات: عند الزراعة وعند 15و 30 و45 يوما من الزراعة وأستخدمت أربعة نظم قطع: القطع لمرة واحده عند طور اللبنة وثلاث قطعات ثنائية يشار اليها فيما بعد بثنائى القطع 1، وثنائى القطع 2 وثنائى القطع 3. أستخدم تصميم القطع المنشقة بثلاثة مكررات لتجربة، وأستخدمت القطع الرئيسية لأضافة النيتروجين والفرعية لوقت القطع. حصاد النمو الأول لنظام القطع الواحد كان عند مرحلة اللبنة ولنظم القطع الثنائى 1، 2 و3 بعد 30 و 45 و 60 يوما من الزراعة على التوالى بينما كان حصاد النمو الثانى عند بلوغ النمو الثانى لمرحلة اللبنة. أظهرت النتائج تفوق نظام القطع الواحد علي كل نظم القطع الثنائي في إنتاجية المادة الجافة للعلف فى كل من القطع الأول والأنتاجية التراكمية للقطعتين. تسببت كل نظم القطع الثنائي فى إطالة موسم النمو, وتقليل الكثافة النباتية, وزيادة أعداد الخلف، وتقليل العدد الكلي للسيقان. تفوق نظام القطع الثنائي 1 في الإنتاجية علي نظم القطع الثنائي الأخرى. لم يؤثر زمن إضافة النيتروجين على الأنتاجية من العلف.

---

[1]محطة بحوث الجزيرة- هيئة البحوث الزراعية، ولاية الجزيرة - ود مدنى، السودان