Selection for tillering rate in annual ryegrass and its influence on potential forage production under irrigated conditions*

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ABSTRACT

No information exists regarding the productivity of annual ryegrass and the influence of morphological yield components on yield under Libyan conditions. Therefore, the performance of two contrasting populations of annual ryegrass, and the correlated responses to selection for high (HTR) and low (LTR) tillering rate, and original population (Co) were evaluated over a period of two years. Micro swards of the populations were grown in the field under supplemental irrigation. Two harvests were taken from the plants during each growing season. In general, populations selected for differing tillering density under space planting had corresponding tiller density when grown in replicated plots, but an inverse yield/ tiller. Total dry yield was 8.16, 8.01 and 7.84 tons/ ha for the HTR, LTR and Co population, respectively. Difference in forage yield from the first harvest between populations was probably related to the greater light interception in early growth stages by the HTR population. In the first harvest, a close relationship existed between forage yield and tiller density. However, in the second harvest, yield/tiller was the most critical yield determinant. Selection of annual ryegrass for high tillering may be beneficial for grazing management system. Annual ryegrass can be used in conjunction with some other crops to substitute for the deficiency in the availability of forage during the winter and early spring.

INTRODUCTION

Herbage production by grass swards is associated with tiller density in the sward and yield/tiller (5, 11, 19). Earlier, it was reported that leaf elongation rate and yield/tiller were highly correlated with forage yield in annual ryegrass (*Lolium rigidum* L.) (5). Moreover, it was showed that leaf elongation rate was negatively correlated with tillering (5).

Several researchers have evaluated the influence of tiller density on yield/plant. However, in most cases the studies were conducted on space planting (9, 16, 17) and the conclusion was that tiller density had the most influence on yield. However, in studies with developed swards, when tiller density was high (14, 19) or when plant be-

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came reproductive (13), yield/ tiller became the most important. During early stages of regrowth when tiller density usually did not increase, yield/ tiller was linear with time and was the dominant yield factor (21). Therefore, rapid tiller production may be less important than yield/ tiller for dry matter production when tiller density is high.

Rhodes (11) found that with infrequent cutting, a longleafed population of perennial ryegrass (*Lolium perenne* L.) was superior in yield to short-leafed population. However, the short-leafed population was superior with a 14-day cutting frequency. He explained that the higher production of the long leafed over the short-leafed population may have been the result of the available radiant energy being spread over a greater LAI, and to a higher optimum LAI. The superior performance of the short-leafed population under frequent cutting may have been due to the greater residual LAI remaining after cutting. Similar results were reported on tall fescue (19, 21).

Studies on orchardgrass (*Dactylus glomerata* L.), suggested that rate of regrowth after cutting was dependent on both stored carbohydrate in the stubbles and remaining leaf area (18). Similar results have been reported on perennial ryegrass (3), and on tall fescue (21). Regrowth after cutting caused a rapid decrease in stored energy in tall fescue genotype selected for high yield/ tiller that had little residual leaf area, whereas a small decrease in stored energy occurred in a genotype selected for low yield/ tiller that had considerable leaf area remaining after cutting (21). Therefore, it might be suggested that cutting frequency can be optimized according to the morphology of the plant and its physiological development at the time of harvest, such that not only a high forage yield will be obtained but a rapid and prolonged growth will occur.

Evaluation of forage grasses and legumes by cutting is open to criticism since plant responses may not be the same as those after animal grazing. Advantages and disadvantages of using cutting studies to stimulate grazing have been reviewed by Matches (10) who listed the following limitations of cutting: (a) livestock pull and break off forages at random heights, (b) animal selection of particular parts, rather than the non specific cut that is usual with cutting, (c) litter accumulation and return of nutrients through animal excreta which may influence growth, is not considered, and (d) there is no trampling effect. In spite of these limitations, it was concluded that cutting studies can be used to gain much information. Moreover, Matches (10) suggested that herbage yields obtained in cutting studies were reliable for predicting yield performance of forage under grazing trials. The final assessment, however, must be in terms of animal performance. The present objectives were 1) to determine if there was a direct assiociation between rate of tillering and dry matter production in sward of annual ryegrass and 2) to determine the seasonal productivity of this crop.

MATERIALS AND METHODS

Based on selection made by Dr. K. Sgaier, seeds of two contrasting populations of annual ryegrass (*Lolium rigidum* L.) were used. Selected populations had been characterized as having (a) high tillering rate and low yield/ tiller (HTR); and (b) low tillering rate and high yield/ tiller (LTR).

Plots were located at the farm of the Faculty of Agriculture, Tripoli, on sandy loam soil. On 30th Oct. 1982, seeds of the two contrasting populations of annual ryegrass and the original population (Co) were planted in the field in 50 × 75 cm plot. Planting distance was 10 by 7.5 cm. between seeds. The experimental design was a randomized complete block design with six replications. The six replicates were separated by 1 m border. A top dressing of fertilizer at an equivalent rate of 12, 24, and 12 kg/ ha of N, P and K, respectively, was applied to the experimental area on 4 Dec., 1982. Moreover, N was applied as ammonium sulphate to all plots at the rate of 100 kg/ha on 2nd Feb. 1983, and on 20th March, 1983, making a total of 212 kg/ha of N applied during the weeding periodically. Plots were sprinkler irrigated as needed. The experiment was repeated during the growing season 1983-1984, with the planting date being 13 Oct., 1983.

At each harvest, plots were cut with hand clippers at a height of about 10 cm above ground level. During each growing season two harvests were taken, the first being vegetative, and the second harvest was reproductive. During the first growing season, the dates of harvesting were 14 March and 19 April. However, in the second growing season, harvests were taken on 22nd March and 24th April.

Area of leaf blades of a sub-sample from each plot was determined with leaf area meter (Canadian blower & Forage Co. Ltd.). The area-weight relationship of the subsamples was used to calculate the harvested leaf area index of the whole plot. Harvested forage was bagged and dried in a forced air oven at 70°C. Following each harvest in situ counts of live vegetative tillers were made in a random 10 × 30 cm quadrat in each plot.

For each harvest of 1982-1983 growing season, subsamples of dried herbage were ground and analyzed for forage quality using approximate analysis procedure and nitrogen content following the procedures of A. O. A. C. (1). Data for each cut was analyzed separately. Moreover, herbage yield for each growing season was summed over successive cuts to give total seasonal yield. Cumulated herbage yield of the two growing seasons was analyzed as split plot design as illustrated by Steel and Torrie (15). This allowed direct comparison of populations for each growing season.

RESULTS AND DISCUSSION

The interaction between populations and years for all the measured characteristics of the first and second harvest was not significant. Therefore, to facilitate presentation of the data, data for each population are presented as the average over the experimental years. The mean productivity of populations selected for differing tillering capacity is presented in Table 1. No significant difference was observed between the LTR and Co populations for forage yield in the vegetative growth harvest (Table 1). The vegetative forage yield of the HTR population was about 12 and 14% greater ($P < 0.05$) than the LTR and Co populations, respectively, (Table 1). However, while the HTR population was more productive than the LTR and Co populations in the vegetative growth harvest, the LTR and Co populations were most productive in the reproductive growth harvest (Table 1). In this harvest, the LTR population gave about 9 and 3% more reproductive forage yield as compared with the HTR and Co populations, respectively, with no significant difference occurring between the LTR and Co poplation. This probably occurred due to the rapid tillering of the HTR popoulation, and was consistent with previous data on tall fescue where a genotype characterized by rapid tillering rate and low yield/ tiller was superior in yield during sward development (19, 20), but as the sward developed and death of smaller tillers began to offset the continued production of new tillers and number of tillers per land area tended to stabilize, a genotype characterized by slow tillering rate, and high yield/ tiller became superior. Total forage yield for the season was 8.16, 8.01, and 7.84 ton/ha for the HTR, LTR and Co populations, respectively, with no significant difference between the HTR and LTR population. Cocks (2) reported an average total yield of dry matter over three planting densities, four defoliation regimes, and with a growing season of 4 months long for an annual ryegrass cultivar (*Lolium rigidum* CV. Wimmera) of 12.1 tons/ ha. This suggests that annual ryegrass can be used with some other crops to substitute for the deficiency of forage production during the winter and early spring months as suggested by Sgaier (12).

The HTR population produced the greatest tiller density and lowest yield/ tiller in both cuts (Table 1). Conversely, the LTR population produced the lowest tiller density and the highest yield/ tiller. These results indicated that selection for tillering rate under spaced planting and low competition at the seedling stage resulted in populations that had consistent tillering rate differences under sward conditions. Moreover, these results indicated that the major yield component changing during reproductive growth was yield/ tiller and not tiller density.

Table 1 — Herbage dry weight, yield/ tiller and tiller density of two contrasting populations of annual ryegrass and the original population (Co). Populations were selected for high (HTR) and low (LTR) tillering rate.

Harvest No.	Population	Herbage weight	Yield/ tiller	Tiller density
1st		metric tons/ha	mg	no./ dm^2
	HTR	4.46	156.9	52.4
	LTR	3.97	175.2	43.7
	Co	3.91	178.7	39.7
	L.S.D. (0.05)	0.30	18.4	3.2
2nd				
	HTR	3.70	197.9	45.0
	LTR	4.04	229.1	32.5
	Co	3.93	211.2	34.2
	L.S.D. (0.05)	0.32	12.3	2.3

Although LAI and SLW of populations did not show significant differences (Table 2), the HTR population gave about 12% greater LAI than the LTR population, and was consistent with its ability to tiller rapidly. Zarrough *et al.* (19) reported that a genotype of tall fescue selected for low tillering rate and high yield/ tiller showed progressively higher LAI at each harvest with 75% higher LAI, in the final harvest compared with the first. Therefore, it appeared that the main advantage of the HTR population occured during sward associated with production of sufficient leaf area for a high percentage of radiation interception. This is in agreement with the concept suggested earlier by Simmons *et al.* (14).

As the sward shifted from vegetative to reproductive growth, a transition from yield dependency on tiller density to that of yield/ tiller occurred (Table 3). During the vegetative harvest when competition between plants was lowest, and tillering density was increasing, a highly significant correlation was observed between forage yield and tiller density ($h = 0.91$, $p < 0.01$), due to the high forage yield and the tiller density of the HTR population (Table 1). However, at the reproductive growth harvest, the correlation between forage yield from this growth and tiller density was negative (Table 3), because tiller capacity was reduced and any additional yield increase would occur via increased tiller weight. At this harvest, forage yield was associated positively with yield/ tiller (Table 3).

Table 2 — Specific leaf weight (SLW) and leaf area index (LAI) at the first harvest of two contrasting population of annual ryegrass and the original population (Co). Populations were selected for high (HTR) and low (LTR) tillering rate.

Population	SLW	LAI
	mg/cm^2	
HTR	4.18	4.17
LTR	4.83	3.73
Co	4.57	3.81
LSD (0.05)	ns	ns

Table 3 — Correlation coefficient between some agronomic characters and forage yield at different harvests.

	Character	
Harvest No.	Yield/ tiller	Tiller density
1st	−0.89**	0.91**
2nd	0.92**	−0.83**

** Significant at $p < 0.01$

This supports the earlier suggestion that yield/ tiller is not the most important yield determinant until equilibrium tiller density is reached or during reproductive growth (3, 7, 13, 19). Overall, a negative correlation was observed between tiller density and yield/ tiller ($r = -0.93$, $p < 0.01$). This result suggested that the LTR population directed the majority of its photosynthate to the growth of the existing tillers rather than for the production of new tillers. In contrast, the population with the high tillering capacity had an average tiller density of about 49 tillers/dm^2 during the experimental period. The HTR population may have exhibited this character because the major portion of photosynthate was being utilized for the production of new tillers in lieu of the growth of the existing ones. Similar results were reported by Edwards and Cooper (4) for perennial ryegrass, Zarrough *et al.* for tall fescue (20) and those reported for this crop under spaced planting (5). Moreover, these results are similar to those reported by Ishida (6) and Rhodes (11) and show the importance of canopy characters in establishing optimal management systems. Zarrough *et al.* (19) reported that under frequent cutting and at low tiller density before the sward was complete and was achieving full light interception, tiller formation was more important yield determinant than was yield/ tiller. However, with infrequent cutting yield/ tiller was most critical in governing forage yield response.

After the evaluation of canopy structure of forage grasses (6, 11, 19) and the physiological factors related to their regrowth (18, 19) the results of this experiment suggest that using these selected populations of annual ryegrass for grazing may result in more yield by the HTR population. However, the LTR population may be more adapted for hay making. Further experiments should be conducted to evaluate the effect of mangement system on the porductivity of these populations.

For forage crops which are to be fed to livestock, the maximum production of dry matter is not the major criterion for the farmer. The nutritive value of the crop to be fed to the animal must also be considered. Moreover, knowledge of the mechanism of canopy development and their genetic control should allow breeders to be more efficient in yield improvement. At the same time using physiological information to improve only yield would appear simplistic when physiological factors associated with forage quality need to be considered. The results of the chemical analysis for crude fiber (C. F.), crude protein (C. P.), ash, ether extract (E.E.) and nitrogen free extract (N.F.E.), expressed in percentage basis showed that in the first harvest, the difference between populations for these variables was not significant. The overall mean crude fiber, crude protein, ash, ether extract and nitrogen free extract for the three populations was 23.5, 17.6, 9.3, 4.0 and 42.72%, respectively. Moreover, forage from the reproductive harvest, showed no significant difference among populations for crude fiber, ash, ether extract and nitrogen free extract (Table 4), with a mean overall population of 28.3, 7.5, 3.1 and 45.13% crude fiber, ash, ether extract, and nitrogen free extract, respectively. However, the Co population gave about 15 and 12% ($p < 0.05$) greater crude protein in comparison with LTR and HTR populations, respectively. Moreover the results in Table 4 showed that the quality of all populations tended to fall in the reporductive growth, even though the total forage yield was increasing (Table 1). The high content of crude fiber is an indication of a poor quality of fertile tillers. Poor quality is also probably due to the lower leaf/ stem ratio. In this harvest, the HTR, LTR and Co populations had about 93, 95 and 97% of the tillers that were reproductive. This trend in quality of dry matter is similar to that reported by Lawes and Jones (8) who reported that quality falls after ear emergence.

Collectively, these results emphasize that tiller density with differing combinations of yield/ tiller, selected from native ecotypes differ significantly in their productivity. In particular, while the population composed of plants with high tillering rate and low yield/ tiller gave higher forage yield from the vegetative growth, population with low tillering rate and high yield/ tiller was most productive at the reproductive growth. This suggests that annual ryegrass can be selected for morphological characters that allow adaptation to hay making or grazing. Moreover, it is particularly important that

Table 4 — Crude fiber, crude protein, ash, ether extract and nitrogen free extract of two contrasting poupulations selected for high (HTR) and low (LTR) tillering rate and the original population (Co) of annual ryegrass during the second harvest.

Population	C.F.	C.P.	Ash	E.E.	NFE
HTR	27.74	11.75	7.73	3.06	45.90
LTR	29.08	12.13	7.62	3.14	44.92
Co	27.92	13.56	7.02	3.09	44.56
L.S.D. (0.05)	n.s.	1.44	n.s.	n.s.	n.s.

the precise management systems which result in high yield and their productivity under rain-fed conditions should be precisely defined for each population. Finally, it is suggested that this crop can contribute in filling the gap in the seasonal distribution of forage crop caused by the low productivity of forage during the winter and early spring.

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معدل التفريع في الزيوان الحولي وأثره على القدرة الانتاجية للعلف تحت ظروف الزراعة المروية

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المستخلص

ليس هناك معلومات متوافرة حول انتاجية الزيوان الحولي وتأثير المكونات الظاهرية للانتاج على ذلك تحت الظروف البيئية. لذلك، فقد تمت دراسة أداء عشيرتين متباينتين من الزيوان الحولي والاستجابة للانتخاب لمعدل عالٍ ومنخفض من التفريع بالمقارنة مع العشيرة الأصلية لمدة سنتين في الحقل تحت نظام الري التكميلي.

لقد أخذت حصدتان من النباتات خلال موسم النمو. وبصفة عامة، فقد دلت النتائج على أن العشائر التي اختيرت لتباينها في معدل تفريعها تحت نظام زراعة النباتات على مسافة متباعدة حافظت على نفس كثافة تفريعها عند زراعتها على مسافات متقاربة في قطع متكررة بالحقل، ولكن وزن كل فرع كان عكس معدل التفريع في هذه العشائر. هذا كما كان وزن العلف الجاف المتحصل عليه خلال موسم النمو هو 8.16, 8.01, 7.84 طن/ هـ. لكل من العشيرة عالية التفريع ومنخفضة التفريع والعشيرة الأصلية على التوالي.

ومن المحتمل أن تعود الاختلافات بين هذه العشائر في وزن العلف الجاف خلال الحصدة الأولى الى تفوق العشيرة مرتفعة التفريع في استقبال الأشعة الضوئية

خلال المراحـل الأولى من النمو. وقـد كانت هنـاك علاقـة قويـة بين انتـاج العلف وكثافة التفريع خلال الحصدة الأولى، ولكن في الحصدة الثانية كان وزن الفـرع هو العامل الأكثر فاعلية في تحديد الانتاج من العلف.

إن انتخاب الزيوان الحولي الذي يمتاز بمعدل عالٍ للتفـريع قـد يكون مفيـداً تحت نـظام الرعي، هـذا كما أنـه يمكن استعـمال هـذا المحصـول الى جـانب بعض المحـاصيل الأخـرى لتعويض النقص في وفـرة العلف خلال فصـل الشتـاء وأوائـل الربيع.