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YIELD RESPONSE OF FORAGE OATS (*AVENA SATIVA* L.) TO NITROGEN FERTILIZATION HARVESTED AT SUCCESSIVE STAGES OF MATURITY

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ABSTRACT

Oats, *Avena sativa* L. has recently gained importance as a winter forage crop. However, few information exists on management practices of the crop in Saudi Arabia. A field study was conducted to evaluate yield response of forage oats, c.v. Cayuse, to nitrogen fertilization when harvested at different stages of maturity. The experiment was conducted at the Agricultural Research and Experiment Station. King Saud University, College of Agriculture, Dirab, located about 50 km south west Riyadh. Fresh yield. plant height number of leaves and leaf area per plant were measured at time of harvest. Percentage dry matter and leaf-stem ratio were also determined.

Plant height, percentage dry matter and dry matter production increased significantly as time of harvest was delayed. Number of leaves per plant. leaf area per plant and leaf stem ratio decreased significantly as time of harvest was delayed. Increased in rate of nitrogen fertilization from nil to 150 kg/ha significantly decreased percentage dry matter. Dry matter production increased significantly at a rate of 75 kg N/ha but decreased significantly as the rate was doubled. Plant height, number of leaves per plant, leaf area per plant and leaf-stem ratio increased significantly in response to nitrogen fert1lization. Differences due to time of harvest × nitrogen fertilization interaction were significant in all measured parameters except percentage of dry matter and number of leaves per plant. The results indicated that the best dry matter production could be achieved when harvested at the early soft dough stage and a rate of 75 kg/ha nitrogen fert1lization. However. management factors, i.e. planting date, variety selection and irrigation requirement need to be considered in making recommendations to farmers in order to obtain maximum forage production.

INTRODUCTION

The productivity of native rangelands is inherently low in Saudi Arabia. Moreover, great seasonal variation occurs between the high productive spring season, and the low productive fall season (Tag El-Din, 1983). One of the strategies to cope up with low productivity of rangelands is to encourage production of forage crops to ease the pressure on rangelands and to complement their low productivity.

Currently, alfalfa, *Medicago sativa* is by far the most extensively cultivated forage crop in Saudi Arabia and accounts for about 30% of the crop production (El-Hag et al. 1989, Farnworth and Robinson, 1972). With scarcity of water for irrigation, emphasis should be given to "annual" winter crops to avoid greater demands for irrigation during summer months.

Recently, oats *Avena sativa* L. has gained some popularity among farmers as a winter forage crop. Extensive work has been done on oats management practices in temperate regions. Management practices such as time of harvest (Connell and Jobson, 1968, Lawes and Jones, 1971, Ciha, 1983), fertilization (Burton and Prine, 1958) and planting date (Stephens et al., 1977, and Ciha, 1983) were found to influence yield and forage quality of oats. However, there is little information existing on cultural practices of oats under the conditions of the central region of Saudi Arabia. The objective of this study was to investigate the yield response of forage oats to nitrogen fertilization when harvested at different stages of maturity.

MATERIALS AND METHODS

The experiment was conducted for two winter seasons (1989 and 1991) at the Agricultural Research and Experiment Station of King Saud University near Riyadh (Dirab, 24 42 N, 44 46 E, 600 Alt.). Forage oat (*Avena sativa* L.) variety Cayuse was used in the experiment. Treatments included harvesting at four phenological stages, namely: flag leaf (FL), heading (HS), milk (MS) and early soft dough (SD) stages, and three rates of nitrogen fertilization (0, 75 and 150 kg/ha) as urea 46% N. The whole amount of fertilizer was added three weeks after sowing in the first year. At the second year, one third of the total amount was added at sowing and the rest was added one month later. The experiment was arranged in a split plot design with four replicates. Harvesting time was assigned to the main plots while N rates were assigned to the sub-plots. The area of the experimental unit (sub-plot) was 7.5 m^2 and consisted of 10 rows, 3 m long and 25 cm apart. Seeds were sown at a rate of 140 kg/ha on 21 and 11 September in 1989 and 1991, respectively. Plots were fertilized with phosphorus (as super-phosphate) at a rate of 150 kg/ha at the time of sowing. Weeding was done manually and the crop was irrigated as needed.

Harvesting was done manually at a height of 5cm above soil surface when 50% of plants reached the desired stage of maturity. An area of 3 m^2 (inner 6 rows × 2 m long) was used to determine fresh forage yield. A sub-sample weighing about 300 gm was oven dried at 70°C for 72 hours to determine percentage dry matter and calculate dry matter production. At time of harvest the following parameters were recorded: plant height from soil surface to flag leaf, average number of leaves per plant, and average leaf area per plant for 10 plants. Leaf to stem ratio by weight was also determined using 20 plants. Two cuts were possible from the two early stages of maturity while only one cut was available from the late stages. Data were subjected to analysis of variance (Little and Hills, 1978) and the means were compared using least significant difference (LSD) test at 5% level.

RESULTS AND DISCUSSIONS

A summary of the analysis of variance (Table 1) indicated significant differences between the 1989 and 1991 seasons in all measured parameters, except for leaf-stem ratio with the first season being the least productive (Table 2). Both time of harvest and N fertilizer affected all measured traits and there was significant interaction between the two treatments except for percentage dry matter and number of leaves per plant (Table 1). The means over the two seasons and harvest time and fertilization treatments are shown in Table 2, while those of time of harvest × N-fertilization interaction are given in Table 3.

Table (1): Summary of the analysis of variance of the effect of time of harvest and nitrogen fertilization of fresh forage yield (FY), percentage dry matter (DM%), dry matter production (DMY), plant height (PH), number of leaves per plant (NL), leaf area per plant (LA) and leaf-stem ratio (LSR) of forage oats.

SOV	df	FY	DM%	DMY	PH	NL	LA	LSR
Rep's	3	NS	NS	NS	NS	NS	NS	NS
Season(S)	1	**	**	**	**	**	**	NS
Error (a)	3							
Harvest time (H)	3	**	**	**	**	**	**	**
S×H	3	*	NS	NS	NS	••	NS	NS
Error (b)	18							
Fertilization (F)	2	**	**	**	**	**	**	**
S×F	2	NS	NS	NS	**	**	NS	NS
H×F	6	**	**	NS	**	NS	**	**
S×H×F	6	NS	NS	*	NS	*	NS	NS
Error (c)	48							
Total	95							

* Significant at $P < 0.05$ ** Significant at $P < 0.01$ and NS is not significant.

Fresh forage yield decreased as stage of maturity at cutting progressed (Table 2). This decrease in yield was probably due to the single cut available from the last two stages of maturity. Fresh forage yield increased about 27% with the addition of 75 kg/ha nitrogen. Forage yield leveled off at 75 kg/ha N and was not increased as the rate of N-fertilizer was doubled (Table 2). Fresh forage yield responded positively to increase in the rate of N-fertilization when the crop was harvested at early stages of growth. However, this response diminished as harvest was delayed to more mature stages (Table 3).

Table (2): Effect of season, harvest time and nitrogen fertilization on fresh forage yield (FY), percentage dry matter (DM%), dry matter production (DMY), plant height (PH), number of leaves per plant (NL), leaf area per plant (LA) and leaf-stem ratio (LSR) of forage oats.

	FY(t/ha)	DM%	DMY (t/h)	PH (cm)	NL	LA (cm2)	LSR
				Seasons			
1989-90	69.113	22.463	14.803	107.84	3.983	175.29	0.314
1991-92	75.850	23.433	16.590	117.02	4.139	190.60	0.305
$LSD_{(0.05)}$	2.618	0.651	0.625	2.222	0.121	9.846	0.019
				Harvest time			
FL	87748	15.658	13.505	92.13	5.200	224.27	0.411
HS	84.369	19.292	16.139	112.15	4.400	192.45	0.313
MS	63.538	24.271	15.400	121.62	3.742	180.10	0.278
SD	54.272	32.571	17.743	123.83	2.904	134.97	0.236
$LSD_{(0.05)}$	3.703	0.920	0.885	3.14	0.172	13.925	0.027
				N-Fertilization			
0	61.639	24.359	14.654	96.00	3.706	130.55	0.264
75	78.369	22.534	16.687	118.12	4.178	194.01	0.327
150	77.337	21.950	15.758	123.21	4.300	224.29	0.337
$LSD_{(0.05)}$	3.002	0.798	0.766	2.72	0.149	12.06	0.023

Percentage dry matter increased as the time of harvesting was delayed(Table 2). This was expected as hemicellulose, cellulose and lignin contents increase with maturity (Miller, 1984). Addition of N-fertilizer, however, decreased percentage dry matter as foliage growth was encouraged. Percentage dry matter averaged about 33% at the early soft dough. This was above 21% as reported by Klebesadel (1969) for the same stage of maturity. However, the present results are at the lower limits if crop is intended for silage (Gardner and Wiggans, 1961).

Dry matter production increased as the time of harvesting was delayed (Table 2). Schmidt (1962) reported that highest yield was obtained when crop was harvested at complete maturity as grain and straw. Little increase in dry matter accumulation was observed as crop passed the heading stage. This was in contrast to Hodgson (1956) who reported rapid increase in dry matter production until milk stage of maturity. Highest dry matter production was achieved at a rate of 75 kg/ha nitrogen fertilizer. Similar results were reported by Burton and Prine (1958) as high rates of N-fertilizer was applied. The significant decline in dry matter production as the rate of N-fertilizer was doubled was probably the result of yield loss due to lodging. Knapp and Harms (1989) reported increased lodging in wheat as N-rates were increased over 90 kg/ha. Harvesting time × N-fertilization interaction indicated that crop response to N-fertilization in terms of dry matter production may be slow as the as the crop matures. In fact, there were about 4% and 8% decrease in yield when 75 and 150 kg/ha N were applied and harvesting was delayed until early soft stage compared to the unfertilized crop, respectively. On the other hand, yield increased by 33 and 36% when the same rates were applied and harvesting took place at the flag leaf stage (Table 3).

Plant height increased in response to both delay in harvesting time and increase in N-fertilization (Table 2). This result was expected. The natural increase in plant height as the crop matures was substantiated by the increase in N-fertilization (Table 3). The increase in plant height had a negative impact on crop yield as taller plants were more susceptible to lodging.

Table 3. Effect of rate of nitrogen fertilization on yield of forage oats and other measured parameters when harvested at different stages of maturity

	N rate (kg/ha)		
Time of harvest	**0**	**75**	**150**
		Fresh forage yield (t/ha)	
FL	65.208	95.306	101.831
HS	68.026	90.419	94.661
MS	58.998	72.284	99.331
SD	54.324	55.869	53.523
$LSD^1_{(0.05)}$	= 9.257		
$LSD^2_{(0.05)}$	=11.096		
		Dry yield (t/ha)	
FL	10.984	14.569	14.963
HS	14.208	17.125	17.084
MS	14.935	17.280	13.986
SD	18.454	17.775	16.999
$LSD^1_{(0.05)}$	= 2.139		
$LSD^2_{(0.05)}$	= 2.618		
		% Dry matter	
FL	16.975	15.338	14.663
HS	21.075	19.800	17.800
MS	25.338	23.925	23.550
SD	34.050	31.875	31.787
$LSD^1_{(0.05)}$	= NS		
$LSD^2_{(0.05)}$	= NS		
		Plant height (cm)	
FL	74.0	97.2	105.1
HS	90.7	121.6	124.2
MS	107.7	124.7	132.6
SD	111.8	128.8	130.9
$LSD^1_{(0.05)}$	= 9.1		
$LSD^2_{(0.05)}$	= 11.2		
		Number of leaves	
FL	4.9	5.2	5.5
HS	4.2	4.4	4.6
MS	3.2	3.9	4.1
SD	2.5	3.1	3.1
$LSD^1_{(0.05)}$	= NS		
$LSD^2_{(0.05)}$	= NS		
		Leaf area (cm^2)	
FL	157.2	238.9	276.7
HS	135.0	210.0	232.4
MS	123.9	186.6	229.8
SD	106.1	140.5	158.3
$LSD^1_{(0.05)}$	31.4		
$LSD^2_{(0.05)}$	38.8		
		Leaf-stem ratio	
FL	0.324	0.437	0.472
HS	0.273	0.348	0.317
MS	0.218	0.281	0.335
SD	0.241	0.242	0.224
$LSD^1_{(0.05)}$	= 0.073		
$LSD^2_{(0.05)}$	= 0.960		

$LSD^1_{(0.05)}$ for nitrogen differences at the same harvest time, $LSD^2_{(0.05)}$ for differences of harvest time the same nitrogen level

Number of leaves per plant decreased significantly as the time of harvest was delayed due to leaf senescence. Nitrogen fertilization enhanced production of leaves. However, no differences could be detected between the two higher rates of N-application. No significant interaction was found between time of harvest and nitrogen fertilization for this trait.

Leaf area per plant decreased significantly as time of harvest was delayed (Table 2). Leaf area decreased 40% between flag leaf and early soft dough stages of maturity due to leaf senescence. Nitrogen fertilization, however, increased leaf area significantly. The increase was about 72% higher in the 150 kg/ha N over the unfertilized plants. Significant interaction was also observed between the time of harvest and N-fertilization treatments (Table 3). Leaf area response to increase in N-fertilization decreased as time of harvest was delayed. When crop was harvested at the flag leaf stage, leaf area increased by 52% and 76% as 75 kg/ha and 150 kg/ha nitrogen were applied, respectively. However, when harvesting was delayed until early soft dough stage of maturity the corresponding increases with N-fertilization were only 32% and 49%, respectively.

Leaf-stem ratio decreased significantly as the time of harvest was delayed. Nitrogen fertilization increased leaf-stem ratio significantly although no differences could be detected between the two rates of application (Table 2). The significant interaction between time of harvest and N-fertilization suggested that the effect of nitrogen fertilization was not enough to mitigate the effect of delayed harvesting on leaf-stem ratio caused by leaf senescence. Leaf-stem ratio for 150 kg/ha N-fertilization was 111% higher when crop was harvested at the flag leaf than when harvesting was delayed until soft dough stage of maturity. Moreover, there was a 7% decrease in leaf-stem ratio when 150 kg/ha N-fertilizer was applied to a crop harvested at the soft stage of maturity.

To summarize the above results, forage oats responded to delayed time of harvest by an increase in plant height, a decrease in number of potentially photosynthesizing leaves and leaf area per plant. All above three parameters responded positively to increase in rate of nitrogen fertilization. These responses were reflected in an increase in percentage dry matter as harvesting time was delayed although suppressed by the increase in rate of nitrogen fertilization. Consequently, dry matter production increased as time of harvest was delayed and maximum dry matter production in response to nitrogen fertilization was attained at a rate of 75 kg/ha nitrogen. Leaf-stem ratio, an indicator of how digestible the forage is decreased as harvesting was delayed but was improved (*i.e.* increased) in response to increase in rate of N-fertilization.

While additional information *e.g.* nutritional value, planting date, suitable varieties and management practices for maximizing forage production are needed, it may suffice here to conclude that under the conditions of the present study, maximum forage production could be attained when the crop is fertilized at a rate of 75 kg/ha and harvested at the early soft dough stage of maturity. In a subsequent paper we shall present the nutritional value of forage oat produced under the imposed treatments.

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استجابة محصول علف الشوفان للتسميد الآزوتي عند الحصاد في مراحل مختلفة من النضج

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الملخص

ازداد الاهتمام مؤخراً بالشوفان كمحصول علف شتوي في منطقة الرياض بالمملكة العربية السعودية. وحيث لا توجد معلومات كافية عن السبل المثلى لزراعته في المنطقة فقد تم القيام بدراسة حقلية للتعرف على استجابة الشوفان من حيث الإنتاجية لثلاثة مستويات من التسميد الآزوتي عند الحصاد في مراحل مختلفة من نضج المحصول. أقيمت التجربة في محطة الأبحاث والتجارب الزراعية التابعة لكلية الزراعة، جامعة الملك سعود في ديراب على بعد ٥٠ كيلومتراً جنوب غربي مدينة الرياض. عند الحصاد تم قياس طول النبات وعدد الأوراق لكل نبات والمساحة الورقية للنبات الواحد ومحصول العلف الأخضر، كما تم تقدير النسبة المئوية للمادة الجافة في العلف وإنتاج المادة الجافة ونسبة

وزن الأوراق إلى السوق.

ازداد طول النبات والنسبة المئوية للمادة الجافة في العلف وغلة العلف الجاف ازدياداً معنوياً بتأخير الحصاد. أما عدد الأوراق لكل نبات والمساحة الورقية للنبات الواحد ونسبة الأوراق إلى السوق فقد انخفضت معنوياً بتأخير الحصاد. وقد أدت زيادة معدل التسميد العالية (١٥٠ كجم/هـ نيتروجين) إلى انخفاض النسبة المئوية للمادة الجافة في العلف انخفاضاً معنوياً. ازداد إنتاج المادة الجافة معنوياً عند معدل ٧٥ كجم/هـ من السماد الآزوتي ولكنه انخفض معنوياً عند مضاعفة معدل التسميد. ازداد طول النبات وعدد الأوراق للنبات الواحد وكذلك المساحة الورقية لكل نبات ازدياداً معنوياً بزيادة معدل التسميد. وقد كانت الاختلافات الناشئة بسبب تداخل عاملي موعد الحصاد والتسميد معنوية في جميع الصفات التي تم دراستها عدا النسبة المئوية للمادة الجافة في العلف وعدد الأوراق للنبات الواحد. تشير النتائج إلى أن أفضل غلة علف يمكن الحصول عليها بالتسميد بمعدل ٧٥ كجم /هـ نيتروجين على أن يتم الحصاد في مرحلة النضج المبكر لحبوب الشوفان. ولكن يجب مراعاة عدد من العوامل المتعلقة بالإنتاج كموعد الزراعة واختيار الأصناف المناسبة واحتياجات المحصول عند اقتراح التوصيات للمزارعين من أجل الحصول على أقصى قدر من الإنتاج. وهذا يتطلب دراسة إضافية على هذا المحصول.