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Nitrogen Use Efficiency of Perennial Cool Season Grasses Under Irrigation for Hay Production

With rising energy costs and high fertilizer prices it is imperative that irrigated cool season grass hay fields be managed for optimum forage production. Cool season grasses require nitrogen (N) fertilization to produce comparable yields to alfalfa, and to maintain stand health and longevity. Thus N fertilizer management is imperative for stewardship and sustainability of grass hay fields. Fertilizer recommendations based on a soil test for cool season perennial forage grasses are the same regardless of species. However, some of these grasses may be more nutrient use efficient with respect to N and produce more forage on less N fertilizer. If some cool season grasses are more N use efficient Ag producers could possibly lower their N fertilizer use and resultant costs without sacrificing hay yields and possibly stand longevity.

A project funded by the Western Sustainable Agricultural Research and Education program of USDA (Ag Professional/Producer grant) was conducted in 2010 and 2011 to determine if cool season perennial grasses harvested for hay had similar yields over a range of nitrogen fertilizer rates.

Methods

In April 2008 ‘Paiute’ orchardgrass (OG), ‘Paddock’ meadow bromegrass (MBG), ‘Manchar’ smooth bromegrass (SBG), ‘Luna’ intermediate (pubescent type) wheatgrass (IWG), ‘Oahe’ (non-pubescent type) IWG, ‘NewHy’ hybrid wheatgrass (HWG), ‘Hycrest’ crested wheatgrass (CWG), and ‘Bozoisky’ Russian wildrye (RWR) were each seeded into three 20’ x 200’ plots in an cultivated field at Gerry Miller’s five miles northwest of Buffalo, Wyoming.

In April 2010 each replicated block was divided into ten 20' wide strips across the grass plots and five of the strips were randomly assigned one of the following five N rates: 0, 50, 100, 150, and 200 lb actual N per acre resulting in 40 subplots per block. Nitrogen fertilizer in the form of ammonium-nitrate (NO_3-NH_4) was applied to the plots on 26 April.

In April 2011 four of the five 20' wide strips not used in 2010 were randomly assigned one of the following four N rates: 62.5, 125, 187.5, and 250 lb/ac. The same strips used in 2010 for the 0 lb N/ac rate were used again in 2011. The reason for the higher rates in 2011 was because it appeared that some of the grasses may not have reached their full yield potential at the 200 lb N/ac rate in 2010. On 2 May NO_3-NH_4 was applied to the plots.

Hay yield estimates

On 22 June 2010 herbage of each grass within each N rate subplot was harvested from a single 2.7 ft^2 hoop to a two to three inch stubble height and weighed. A sub-sample was collected, weighed, dried and weighed again to determine percent dry matter and pounds of dry matter forage per acre. Hay (12% moisture) in tons per acre for each grass by N rate was then estimated from the pounds of dry matter forage per acre, e.g. 1936 lb/0.88/2000 = 1.1 T/ac.

Herbage of each grass within each N rate subplot was harvested on 2 July 2011 in the same manner as was done in 2010. The ten day later harvest in 2011 was due to the grasses not being at the same stage of maturity on 22 June as they were in 2010, especially 'Luna' and 'Oahe' IWG.

Nitrogen response curves for each grass were estimated using their hay yields from each year and from the two years combined with a second order polynomial regression equation.

Results and Discussion

Estimated Hay Yields

Although the N response curve of 'Paiute' OG in 2010 would indicate it was as efficient in its use of the applied N for growth as the other grasses (Figure 1) its estimated hay yields were the least among the grasses (Table 1). The estimated hay yield of 'Hycrest' CWG was the highest with applied N up to 150 lb/ac and 'Oahe' IWG the highest with applied rates of from 150 to 200 lb/ac. Besides 'Oahe', 'Paddock' MBG and 'Bozoisky' RWR appeared to not have reached their peak hay yields at 200 lb N/ac and thus the reason that the maximum applied N rate in 2011 was 250 lb/ac.

'Manchar' SBG, and 'Luna' and 'Oahe' IWG were the most efficient in their use of the applied N for growth in 2011 compared to the other grasses (Figure 2). 'Oahe' had the highest estimated hay yields with applied N at all rates compared to the other grasses followed by 'Luna' and 'Manchar' at rates higher than 62.5 lb N/ac (Table 1). Based on the N response curves of the grasses it would appear that they had not necessarily reached their maximum hay production level with 250 lb N/ac, although yields were leveling off.

Grass hay yields were generally greater in 2010 with less applied N compared to in 2011, except for 'Oahe' IWG in which its yields appeared to be comparable at similar N rates (Table 1). Differences in hay yields between 2010 and 2011 were greatest for 'Bozoisky' RWR followed by 'Hycrest' CWG and then 'Paddock' MBG. The greater hay yields of the grasses in 2010 compare to in 2011 may primarily be due to the greater yields with no applied N in 2010. These higher yields in 2010 with no applied N may have been due to the nitrate-N content of the soil averaging 6.4 ppm higher in mid-April 2010 compared to in early May 2011.

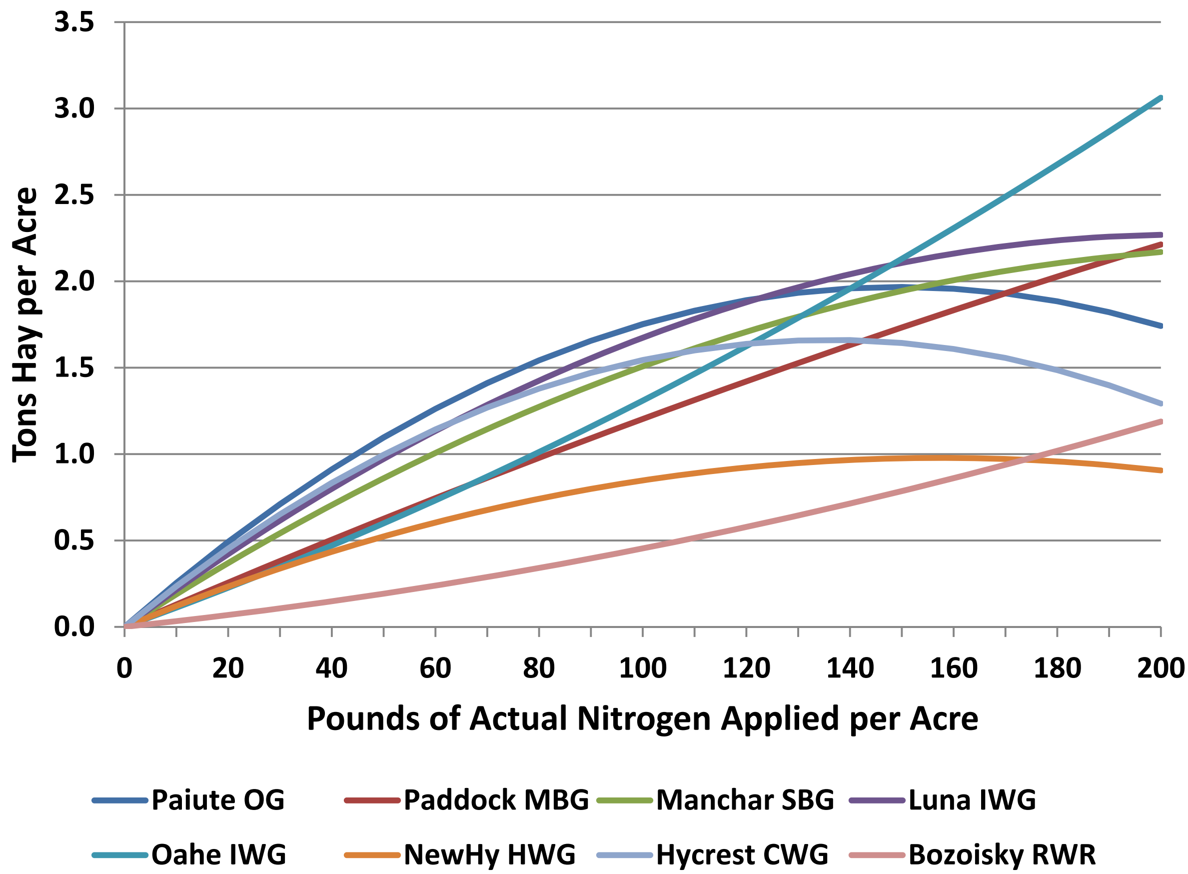

Figure 1: Estimated amount of additional grass hay due to nitrogen fertilizer at Gerry Miller's in northwest Johnson County on 22 June 2010.

Table 1: Estimated grass hay yields (T/ac) on 22 June 2010 and on 2 July 2011 for each applied N rate based on the nitrogen response curves from each year's actual yields.

	Nitrogen (lb/ac) in 2010						Nitrogen (lb/ac) in 2011				
Grass	**0**	**50**	**100**	**150**	**200**		**0**	**62.5**	**125**	**187.5**	**250**
Paiute OG	0.5	1.5	2.2	2.4	2.2		0.5	1.0	1.5	2.0	2.5
Paddock MBG	1.7	2.4	3.0	3.5	4.0		1.0	1.7	2.3	2.7	3.1
Manchar SBG	1.4	2.2	2.9	3.3	3.5		0.7	1.8	2.7	3.3	3.8
Luna IWG	1.3	2.3	3.0	3.4	3.6		1.0	2.1	3.0	3.7	4.2
Oahe IWG	1.7	2.3	3.0	3.8	4.7		1.4	2.6	3.5	4.1	4.3
NewHy HWG	1.9	2.4	2.8	2.9	2.8		1.2	1.8	2.3	2.7	3.1
Hycrest CWG	2.0	3.0	3.5	3.6	3.3		0.9	1.9	2.6	3.0	3.2
Bozoisky RWR	2.0	2.2	2.5	2.8	3.2		0.6	1.0	1.4	1.9	2.4

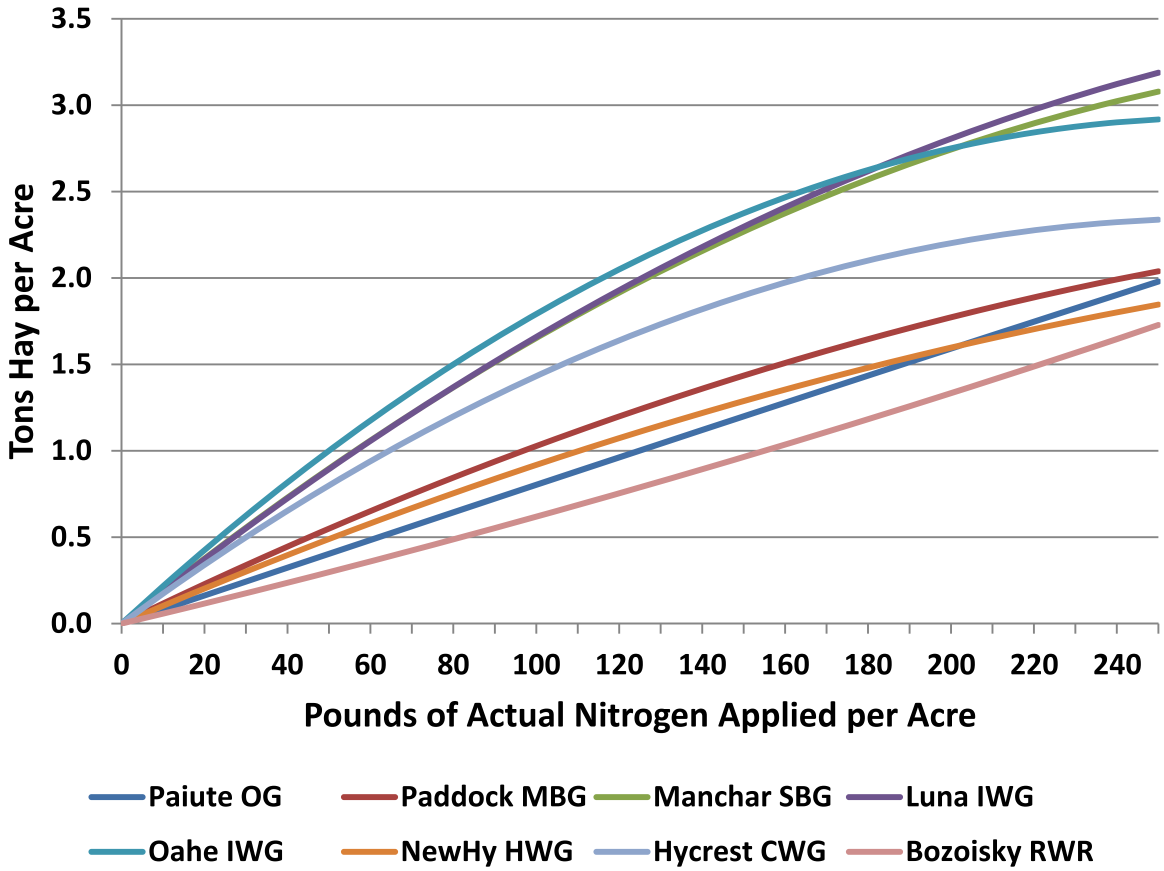

Figure 2: Estimated amount of additional grass hay due to nitrogen fertilizer at Gerry Miller's in northwest Johnson County on 2 July 2011.

Besides this difference in soil nitrate-N content between the two years the lower yields in 2011 may have also been due to May being cooler and mid- to late June drier than they were in 2010. Had the grasses been irrigated in early to mid-June 2011 they might have produced higher hay yields that year.

Estimated nitrogen response curves for the grasses using both 2010 and 2011 yield data indicated that 'Paiute' OG would yield the least amount of hay with no applied N followed by 'Manchar' SBG, whereas 'NewHy' HWG and 'Oahe' IWG would yield the most (Table 2). Although 'NewHy' and 'Oahe' yielded a similar amount of hay with no applied N 'NewHy' yielded an average of about half as much additional hay per pound of applied N as 'Oahe' (Figure 3).

'NewHy' HWG and 'Bozoisky' RWR were the least efficient among the grasses in their use of applied N for growth (Figure 3). If their hay yields at 0 lb N/ac had been similar to that of 'Paiute' OG they would have potentially yielded less hay than 'Paiute' with applied N as shown in Figure 3. However, due to hay yields of 'NewHy' and 'Bozoisky' with no applied N being three and two times as great as that for 'Paiute', respectively, they yielded more hay with applied N compared to 'Paiute'. This would indicate that looking at only NUE of a grass for selection would not be advisable.

Table 2: Estimated grass hay yields (T/ac) at each of the applied nitrogen rates in 2010 and 2011 based on nitrogen response curves from 2010 and 2011 actual yields.

	Nitrogen (lb/ac)								
Grass	**0**	**50**	**62.5**	**100**	**125**	**150**	**187.5**	**200**	**250**
Paiute OG	0.5	1.2	1.3	1.7	1.9	2.1	2.3	2.3	2.5
Paddock MBG	1.2	2.0	2.2	2.6	2.8	3.0	3.2	3.2	3.2
Manchar SBG	0.9	1.8	2.0	2.6	2.9	3.1	3.5	3.6	3.9
Luna IWG	1.1	2.0	2.2	2.8	3.1	3.3	3.7	3.8	4.1
Oahe IWG	1.5	2.4	2.6	3.2	3.5	3.8	4.2	4.3	4.6
NewHy HWG	1.4	2.0	2.1	2.4	2.6	2.7	2.9	2.9	3.0
Hycrest CWG	1.2	2.2	2.4	2.8	3.1	3.2	3.3	3.3	3.1
Bozoisky RWR	1.0	1.5	1.6	1.9	2.1	2.2	2.4	2.4	2.5

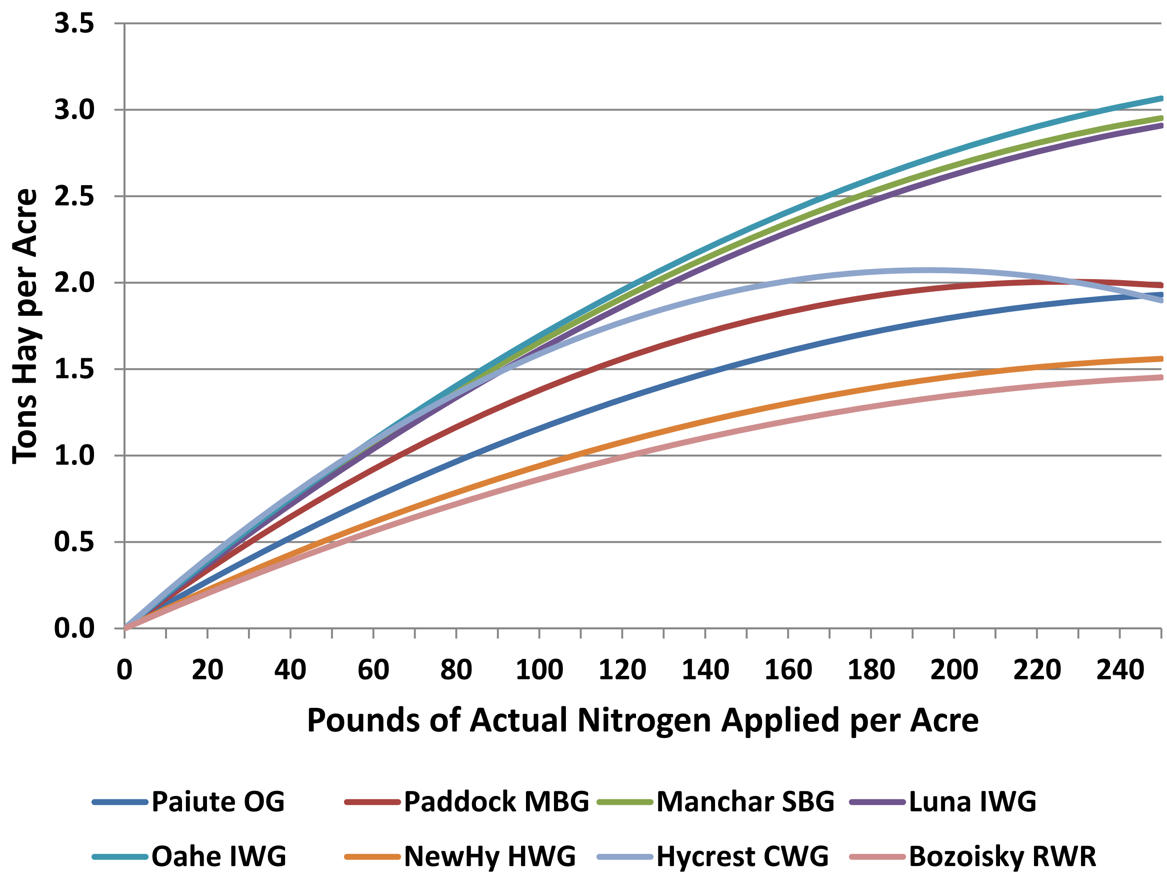

Figure 3: Estimated amount of additional grass hay due to nitrogen fertilizer at Gerry Miller's in northwest Johnson County.

Breakeven cost for N fertilizer

Although the grasses had their highest estimated hay yields at 200 lb N or more per acre are rates this high the most profitable? That depends on the cost of the N fertilizer and the value of a ton of hay. In order for fertilization to pay the price for the nutrient in the fertilizer and its application cost on a per acre basis needs to be less than the value of the additional pounds of hay per acre due to the fertilizer less harvesting costs.

As of late March 2012 the price for a ton of ammonium-nitrate was $575. Ammonium-nitrate contains 34% N so there is 680 lb of N in a ton (2000 * 0.34). Thus, a pound of N would cost $0.85 ($575 ÷ 680 lb). Cost for application has been around $5 per acre so to determine the cost per pound of nutrient applied the per acre application cost ($5) is divided by the pounds of nutrient applied.

For example: If 50 lb N/ac was applied the application cost would be $0.10/lb ($5.00 ÷ 50 lb); if 150 lb N/ac was applied the cost would be $0.0333/lb ($5.00 ÷ 150 lb). Thus, total cost for 50 lb N/ac would be $47.50 (50 lb * ($0.85/lb N + $0.10/lb for application) and for 150 lb N/ac it would be $132.50.

*Note: Urea another form of N fertilizer that contains 46% N was priced at $640 per ton in late March 2012 and thus a pound of N it would cost $0.70 (2000 lb * 46% = 920 lb N; $640 ÷ 920 lb = $0.70/lb). This would appear to be the better deal but there can be loss of some of the N through volatilization unless it is immediately incorporated into the soil with a tillage operation. Obviously for a grass hay field or pasture this is not possible. However, if either precipitation or irrigation occurs within a day or two after application, these losses can be minimized, especially if air temperatures are below 65° F (soil < 50° F). At air temperatures between 65° and 85° F volatilization of N from Urea can range between 10% and 30%. Thus, if urea is to be applied instead of ammonium- nitrate it would be best to apply 20% more. For example: If 100 lb N/ac is the desired rate to apply then 120 lb N/ac should probably be applied if urea is used. Thus cost per acre would be about the same: 100 lb N from ammonium-nitrate = $85 and 120 lb N from urea = $84.*

Grass hay in large round bales has sold for an average of $80 per ton over the past few years, thus it would be $0.04 per pound ($80 ÷ 2000 lb). However, harvest costs should be subtracted from the price of the hay to come up with its true value. From the 2008 Nebraska Custom Farm Rates – Part I publication EC823 (University Of Nebraska Extension) swathing/crimping cost in NW Nebraska have been $14/ac and cost for large round baling $9/ac for a total of $23/ac. These costs are probably in line for eastern Wyoming. Dividing $23/ac by the pounds of hay harvested per acre would provide the $/lb of hay for harvest costs. The above publication also indicated that lifting and hauling costs for large round bales averaging 1560 lb was $3/bale or about $0.002/lb of hay. Because these harvest cost calculations are cumbersome and there can be a wide variation among them it is easier to use a constant harvest cost of $0.01/lb of hay. This constant is based on hay yields of at least one ton per acre more due to N fertilizer than without N fertilizer. As a result the value of a pound of hay after harvest costs would be $0.03 ($0.04 - $0.01) or $60/T.

With the above information it can be determined how much additional hay per acre due to the fertilizer needs to be produced to pay for it. This is calculated by multiplying cost per pound of the applied nutrient, in this case N, by the amount applied per acre and then dividing by the value of the hay less harvest costs ($/lb). For example: 50 lb N/ac would cost $47.50/ac ($0.85/lb N + $0.10/lb to apply) based on spring 2012 costs and dividing this amount by $0.03/lb results in 1583 lb/ac or 0.8 T/ac of additional hay that would need to be produced by the grass. If 100 lb N/ac was applied the additional amount needed would be 1.5 T/ac ($90/ac ÷ $0.03/lb = 3000 lb); for 150, 200, and 250 lb N/ac the additional amount of hay would need to be 2.2, 2.9, and 3.6 T/ac, respectively.

Between 20 and 120 lb N/ac 'Hycrest' CWG, 'Manchar' SBG, and 'Luna' and 'Oahe' IWG produced more hay than the minimum amount needed to pay for the fertilizer (Figure 3). 'Luna' produced enough additional hay up to 140 lb N/ac and 'Manchar' and 'Oahe' up to 170 lb N/ac. However, the most profitable N rates for 'Hycrest', 'Luna', 'Manchar', and 'Oahe' were at 70, 80, 90, and 90 lb N/ac, respectively, with 'Oahe' the most profitable overall (Figure 4), $12 per acre more net income than without any applied N.

Applicability to other hay fields

Would the regression equations for these grasses be applicable to other hay fields in northeast Wyoming? Substituting the 0 lb N/ac (intercept) hay values in the regression equations with the average 0 N/ac hay yields from Ray Daly's along lower Piney Creek in Sheridan County and Larry Vignaroli's along Clear Creek near Ucross the resultant yields at 100 lb N/ac were comparable to the actual yield amounts from these sites (Table 3).

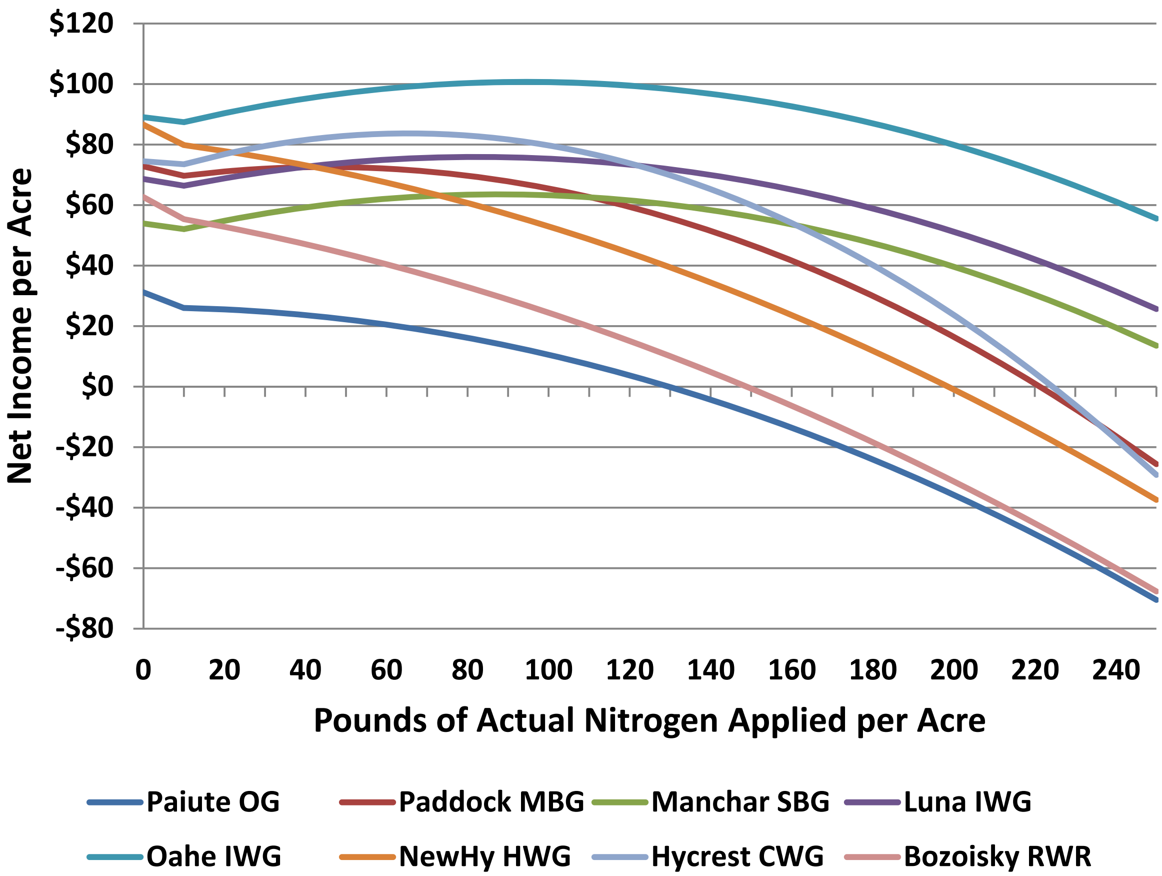

Figure 4: Net income on a per acre basis for hay of each grass after fertilizer and harvest costs have been accounted for.

Table 3: Regression coefficients for each of the eight grasses from Gerry Miller's hay field determined from hay yield amounts for each applied nitrogen rate in 2010 and 2011.
Regression equation: *Estimated hay yield = Intercept + a * N rate (lb/ac) + b * N rate*^{2}
Example for Paiute OG @ 50 lb N/ac: $1.2\ T/ac = 0.5199 + 0.01412 * 50 + -0.00002557 * 50^2$

$$1.2\ T/ac = 0.5199 + 0.706 - 0.00002557 * 2500$$
$$1.2\ T/ac = 1.2259 - 0.063925$$

And, average actual hay yield amounts at 0 and 100 lb N/ac from Ray Daly's and Larry Vignaroli's and the estimated amounts for 100 lb N/ac if the intercept value in the equation is substituted with the actual values for 0 lb N/ac.
Example for Paddock MBG: $4.3\ T/ac = 2.9 + 0.01767 * 100 - 0.00003895 * 100^2$

$$4.3\ T/ac = 2.9 + 1.767 - 0.00003895 * 10000$$
$$4.3\ T/ac = 4.7 - 0.4$$

Grass	*Regression Coefficients (T/ac)*			Intercept @ 0 lb N/ac (T/ac)	@ 100 lb N/ac	
	Intercept (0 lb N/ac)	*a*	*b*		*Estimated T/ac*	Actual T/ac
Paiute OG	0.5199	0.01412	-0.00002557			
Paddock MBG	1.2137	0.01767	-0.00003895	2.9[1]	*4.3*	4.1[1]
Manchar SBG	0.8986	0.01972	-0.00003165	2.8	*4.5*	4.2
Luna IWG	1.1440	0.01911	-0.00002990	2.6	*4.2*	3.8
Oahe IWG	1.4848	0.02003	-0.00003107	2.3	*4.0*	3.4
NewHy HWG	1.4428	0.01151	-0.00002109	2.6	*3.5*	3.1
Hycrest CWG	1.2415	0.02140	-0.00005523	2.3	*3.9*	3.2
Bozoisky RWR	1.0447	0.01051	-0.00001880	2.0	*2.9*	2.7

[1]Values for Paddock MBG are actually from Regar MBG so possibly may be low.

Summary

Although it would appear from the data of this study that fertilizing with N may be borderline profitable at current fertilizer and hay costs and for some grasses an actual loss in net income could occur regardless of the rate used, the additional hay produced due to N may actually result in a savings of money. If the hay produced is to be fed to the producers own livestock the cost of the N fertilizer may be less than what it would cost to purchase more hay if enough had not been produced, especially if the price of hay exceeded $80/T.

As indicated in the methods section these grass stands were only in their second and third years of production and within a few years without N fertilization, whether a commercial product or livestock manure, it is probable that hay yields would decline due to a thinning of the stands. Thus, N fertilization may be needed every two or three years to maintain the stands, especially if not grazed by livestock.

Quality of the hay needs to be taken into account as well. Most grass hays if harvested at seed ripening (mature) are low in crude protein content ($\leq$ 6%) but if the field had been fertilized with N ($\approx$ 100 lb/ac) the crude protein content could be at least 10% the level required of a lactating beef cow. Forage quality data was collected from these grasses and will be presented in a future newsletter.

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