QUALITY OF ALFALFA HAY AS INFLUENCED BY PHOSPHORUS AND POTASSIUM FERTILIZATION

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ABSTRACT

In two field and laboratory experiments, research was conducted to determine impacts of nutrient applications on alfalfa hay quality and nutrient value at Irrigated Research and Extension Center near Prosser, WA. The phosphorus (P) study P soil tests levels were 6.7 and 5.7 ppm at the beginning of 2019 and 2020, respectively (Olsen P test) in 2019 and 2020. The potassium (K) study was conducted on a soil test level of 85 and 78 ppm K in 2019 and 2020, respectively. Applying phosphorus increased protein, NDFD 48, and Net Energy for Lactation (NEL) concentration and decreased ash and lignin concentration. Over five seasonal alfalfa cuttings, phosphorous increased protein higher in the first and second cuttings. Applying 240 lb. P_2O_5 increased total nutrient value of hay by $25 and $42 ton^{-1} averaged over cuttings and first cutting, respectively. The total nutrient value increases over control was 382, 519, 930 and 1,004 dollars acre^{-1} year^{-1} when 30, 60, 120, 240 lbs. P_2O_5 acre $^{-1}$ was applied, respectively. Applying 320 lb K_2O acre^{-1} increased protein concentration 1% when averaged over cuttings. Although not statistically significant applying 320 lb K2O acre^{-1} increased nutrient value of hay by $12 ton^{-1}. Total nutrient value in $ acre^{-1} year^{-1} increase over the control was 121, 372, 407, 534, 722 when 40, 80, 160, 240, 320 lbs. K_2O acre^{-1} was applied, respectively. Nutrient values responded more to phosphorus at 8 ppm than potassium at 82 ppm in second- and third-year alfalfa. Relative Feed Value (RFV) is a poor indicator of alfalfa nutrient value because RFV failed to detect value increases of protein and NDFD 48. Both protein and NDFD 48 directly impacts dairy animal digestibility and fiber fill and are not included in RFV calculations. The impact of negative forage quality parameters, ash and lignin, in alfalfa hay economic value can be partially mitigated through nutrient applications of P and K and viewed on a land area basis.

OBJECTIVE

To determine phosphorus (P_2O_5) & potassium (K_2O) application impacts on deficient soils from irrigated, bud stage harvested alfalfa in the PNW.

RESULTS FOR PHOSPHORUS AND POTASSIUM STUDIES

Fall phosphorus (P) soil tests levels were 6.7 and 5.7 ppm at the beginning of 2019 and 2020, respectively (Figure 1a and 1b). Spring soil test levels for potassium (K) study were 86 and

79 ppm at the beginning of 2018 and 2019, respectively. Failing to apply fertilizer in this experiment reduced yields by 15% for phosphorus and 11% for potassium (Figure 1a & 1b). Results were not significant different between years, so they were combined over years for each nutrient.

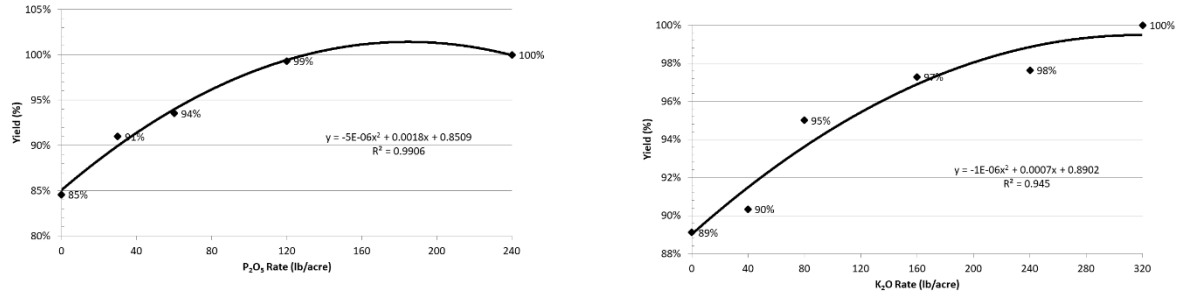

Figure 1a and 1b. The influence of P_2O_5 (Fig 1a) and K_2O (Fig 1b.) on yield of alfalfa averaged over the 2nd and 3rd years (2019 & 2020) of production at the Irrigated Research and Extension Center located near Prosser, WA.

Our interest in this study was to determine what impact on alfalfa quality would P or K applications make to quality parameters including total nutrient value of the alfalfa and study any differences by cutting. Total nutrient value is very useful for determining value of hay to the lactating dairy cow.

When the experiment started the beginning phosphorus (P) soil tests levels were 6.7 and 5.7 ppm at the beginning of 2019 and 2020, respectively which is considered deficient, alfalfa hay protein concentration in first cutting was increased by 3.25% by 240 lb P_2O_5 acre^{-1} much more than other cuttings (Figure 2). Interestingly, aNDF was not significantly affected by P rate but ash, lignin, NDFD 48 hr. and NEL were all influenced positively by increasing P application rate (Table 1). Laboratory analysis of alfalfa hay by P rate suggests no difference among treatments for aNDF. However, two negative forage quality parameters, ash and lignin, decreased as P rates increased. The positive forage quality parameter, NDFD 48 and the calculated NEL both increased as P rates increased, Table 1. Averaged over cuttings the largest impact of P on nutrient value was $25 ton found in the 240 lb acre treatment (Table 2). This treatment increased the quality adjustment ton^{-1} $12 which is computed from NDFD 48 hour $^{-1}$ and impacts fiber fill in the dairy animal. Other increases in value were in metabolizable protein at $8 and energy at $5 ton^{-1}. After combining current dollar value with nutrient analysis on a tonnage basis, provides more indepth assessment returns in protein, energy, and total by P rate, Table 2. These suggest positive economic returns from investment of P for protein, energy and total hay value.

Results from traditionally the most high demand, first cutting, for combined current dollar value with respective RFV are reported in Table 3. Larger increases were found in the first cutting and jumped $42 and $23 for total value and metabolizable protein value, respectively, due to the huge increase in protein concentration in the hay in the first cutting (Table 3., Figure 2.). Since Relative Feed Value (RFV) does not include either protein or NDFD, none of the increases in

value from fertilizer was captured (Table 3). Again, the interaction of fiber composition changes in first cutting are real and differential compared to protein and energy in alfalfa hay.

Combining current dollar value with nutrient analysis on a land area basis, provides indepth assessment returns for protein, energy, and total by P rate as recognized by both alfalfa hay and dairy producers, Table 4. Protein, energy, fiber and total hay value all increase with increasing P rates. Adding land back into the assessment reduces the variability based only on tonnage. These results suggest both the alfalfa hay grower and the dairy producer gain economic value when P deficient soils are better managed by P applications.

We really need to shift from using RFV to determine hay value. When feeding your own hay to dairy cows, the total nutrient value increased over the control by 382, 519, 930 and 1004 \$ $acre^{-1}$ $year^{-1}$ when 30, 60, 120, 240 lbs. P_2O_5 $acre^{-1}$ was applied respectively (Table 4.).

Soil test in the potassium experiment was 85, and 78 ppm K in 2019 and 2020, respectively. Yield increases of 1.2- and 1.3-tons $acre^{-1}$ were received in 2019 and 2020, respectively (Figure 1b.). In this deficient condition, protein content increased from 24.5% to 25.5% as rate was increased from 0 to 320 lb. K_2O acre (Figure 3) and this increase was consistent over cuttings. After combining current dollar value with nutrient analysis on a tonnage basis, based on K rate, Table 5, protein quality adjustment and total alfalfa hay value increased by increasing K rate. Averaged over cuttings, total nutrient value was increased by \$12 ton^{-1} when 320 lbs K_2O $acre^{-1}$ was applied and came from value increases in protein (\$ 7 ton^{-1}), quality adjustment (\$7 ton^{-1}) (Table 5) although the quality adjustment change was not statistically significant.

The big value in potassium fertilization comes when considering the total nutrient value $acre^{-1}$ $year^{-1}$, which comes from the yield increase obtained and total nutrient value is reviewed on an acre basis, as dairy producers would. Total nutrient value in \$ $acre^{-1}$ $year^{-1}$ increase over the control was 121, 372, 407, 534, 722 when 40, 80, 160, 240, 320 lbs. K_2O $acre^{-1}$ was applied, respectively (Table 6.). These results suggest both the alfalfa hay grower and the dairy producer gain economic value when K deficient soils are better managed by K applications.

CONCLUSION

Increasing phosphorus increased protein, NDFD 48, and Net Energy for Lactation (NEL) concentration and decreased ash and lignin concentration. Phosphorous increased protein most in the first and second cutting. Applying 240 lb. P_2O_5 increased total nutrient value of hay by \$25 and \$42 ton^{-1} averaged over cuttings and first cutting, respectively. The total nutrient value increased over the control was 382, 519, 930 and 1004 \$ $acre^{-1}$ $year^{-1}$ when 30, 60, 120, 240 lbs. P_2O_5 $acre^{-1}$ was applied respectively.

In an 82 ppm K soil, applying 320 lb K_2O $acre^{-1}$ increased protein concentration 1% averaged over cuttings. Although not statistically significant applying 320 lb K2O acre-1 increased nutrient value of hay by \$12 ton^{-1}. Total nutrient value in \$ $acre^{-1}$ $year^{-1}$ increase over the control was 121, 372, 407, 534, 722 when 40, 80, 160, 240, 320 lbs. K_2O $acre^{-1}$ was applied, respectively.

In summary, these two experiments, conducted over multiple years with five seasonal cuttings per year, define strong, positive economic dollar return to all partners: hay producer, dairy costumer and American consumer, when deficient soils are managed in long-term sustainable alfalfa fields.

Nutrient values responded more to phosphorus at 8 ppm than potassium at 82 ppm in second- and third-year alfalfa. Relative Feed Value is a poor indicator of nutrient value and did not pick up on the increase of value and did not relate to nutrient value of hay in this study as protein and NDFD 48 which measures digestibility and impacts fiber fill of the dairy animal and both had a large impact in this study and are not included in RFV.

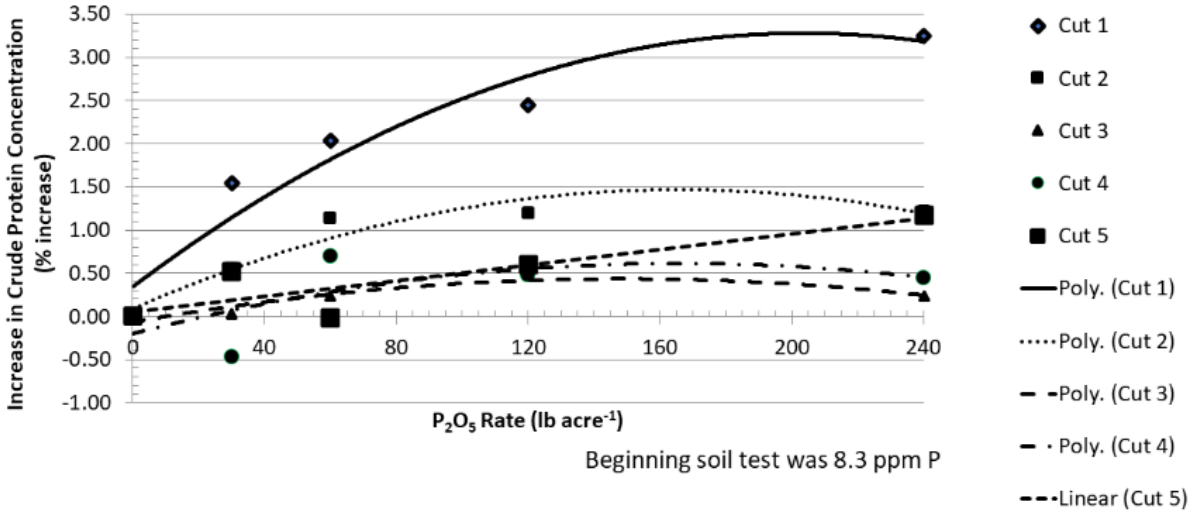

Figure 2. The influence of P_2O_5 on protein concentration of alfalfa by cutting averaged over the 2nd and 3rd years (2019 & 2020) of production at the Irrigated Research and Extension Center located near Prosser, WA.

Table 1. Influence of phosphorus application rate on amylase netural detergent fiber (aNDF), ash, lignin, neutral detergent fiber digestibility at 48 hrs. (NDFD 48hr.) and net energy of lactation (NEL) at mid bud stage averaged over cuttings.

P Application Rate	aNDF	Ash	Lignin	NDFD 48hr.	NEL
lb P_2O_5 acre^{-1}	%	%	%	%	
0	34.9	11.4c	5.84b	46.9b	0.601c

30	34.4	11.1bc	5.70b	47.4ab	0.610bc
60	33.9	11.0bc	5.56a	47.7ab	0.617ab
120	34.4	10.2ab	5.58a	48.6a	0.625a
240	34.8	10.0a	5.56a	48.6a	0.627a

Within column if letters differ then the means are significantly different using an alpha of 0.05.

Table 2. Nutrient value of alfalfa hay per ton as impacted by phosphorus rate averaged over cuttings and years. Nutrient values were used from values published from Progressive Forage Magazine for the Pacific Northwest from January through May 2023 including $0.7042 lb. for metabolizable protein, $0.1216 lb.$^{-1}$ for Mcal of energy, and $0.1962 lb.$^{-1}$ for effective neutral detergent fiber and $6 ton^{-1}. Also, quality adjustment was calculated by $6.55 ton^{-1} increase for each % NDFD 48hr over 47% and $6.55 ton^{-1} decrease for each % NDFD 48hr. less than 47%.

Phosphorus Rate (lb. P_2O_5 acre$^{-1)}$	**$ Value of Protein Ton^{-1}**	**$ Value of Energy Ton^{-1}**	**$ Value of Fiber Ton^{-1}**	**$ Value of Quality Adjustment Ton^{-1}**	**$ Value Hay Ton^{-1}**
0	162c	129c	120	-1b	411b
30	166c	131c	119	3ab	418b
60	168b	132bc	117	4ab	422ab
120	170a	134ab	119	11a	433a
240	171a	134a	120	11a	436a
Max. Change	9	5	0	12	25

Within column if letters differ then the means are significantly different using an alpha of 0.05.

Table 3. Nutrient value of alfalfa hay per ton as impacted by phosphorus rate for <u>first cutting</u>. Nutrient values were used from values published from Progressive Forage Magazine for the Pacific Northwest from January through May 2023 including $0.7042 lb. for metabolizable protein, $0.1216 lb.$^{-1}$ for Mcal of energy, and $0.1962 lb.$^{-1}$ for effective neutral detergent fiber and $6 ton^{-1}. Also, quality adjustment was calculated by $6.55 ton^{-1} increase for each % NDFD 48hr over 47% and $6.55 ton^{-1} decrease for each % NDFD 48hr. less than 47%.

Phosphorus Rate (lb. P_2O_5 acre^{-1})	$ Value of Protein Ton^{-1}	$ Value of Energy Ton^{-1}	$ Value of Fiber Ton^{-1}	$ Value of Quality Adjustment Ton^{-1}	$ Value Hay Ton^{-1}	RFV
0	139	127	126	-22	371	163
30	150	129	119	-10	388	175
60	153	128	119	-18	383	176
120	156	131	123	-6	404	168
240	162	131	126	-6	413	164
Max. Change	23	4	0	16	42	1

Table 4. Nutrient value of alfalfa hay acre^{-1} year^{-1} as impacted by phosphorus rate for first cutting. Nutrient values were used from values published from Progressive Forage Magazine for the Pacific Northwest from January through May 2023 including $0.7042 lb. for metabolizable protein, $0.1216 lb.$^{-1}$ for Mcal of energy, and $0.1962 lb.$^{-1}$ for effective neutral detergent fiber and $6 ton^{-1}. Also, quality adjustment was calculated by $6.55 ton^{-1} increase for each % NDFD 48hr over 47% and $6.55 ton^{-1} decrease for each % NDFD 48hr. less than 47%.

Phosphorus Rate (lb. P_2O_5 acre^{-1})	$ Value of Protein Acre^{-1}	$ Value of Energy Acre^{-1}	$ Value of Fiber Acre^{-1}	$ Value of Quality Adjustment Acre^{-1}	$ Value Hay Acre^{-1}
0	1,503c	1,204c	1,151b	-42b	3,816c
30	1,656b	1,321b	1,218b	4ab	4,198b
60	1,733b	1,369b	1,236b	-4ab	4,335b
120	1,856a	1,476a	1,335a	79a	4,746a
240	1,892a	1,489a	1,354a	85a	4,820a
Max. Change	389	285	203	127	1,004
LSD	117	100	86	96	339

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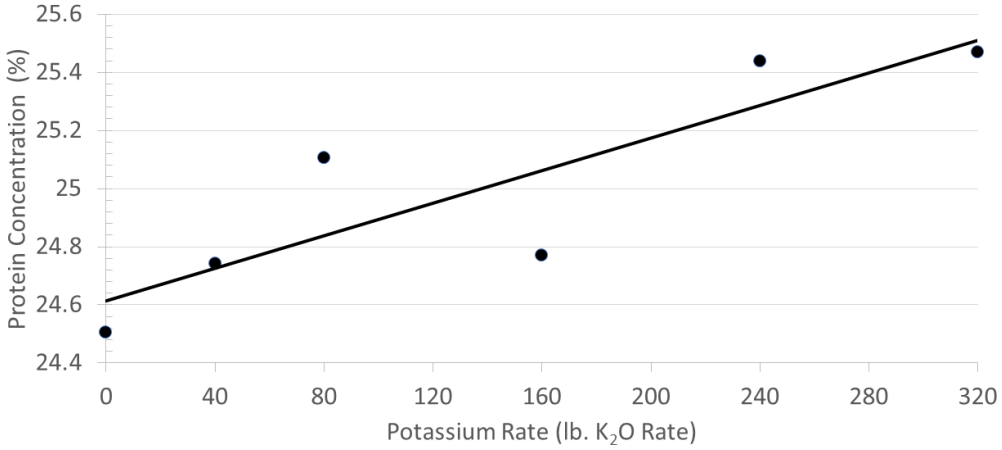

Figure 3. The influence of K_2O on protein concentration of alfalfa by cutting averaged over the 2nd and 3rd years (2019 & 2020) of production at the Irrigated Research and Extension Center located near Prosser, WA. Beginning soil test was 85 ppm K in 2019 and 78 ppm K in 2020.

Table 5. Nutrient value of hay per ton as impacted by potassium rate averaged over all cuttings. Nutrient values were used from values published from Progressive Forage Magazine for the Pacific Northwest from January through May 2023 including $0.7042 lb. for metabolizable protein, $0.1216 $lb.^{-1}$ for Mcal of energy, and $0.1962 $lb.^{-1}$ for effective neutral detergent fiber and $6 ton^{-1}. Also, quality adjustment was calculated by $6.55 ton^{-1} increase for each % NDFD 48hr over 47% and $6.55 ton^{-1} decrease for each % NDFD 48hr. less than 47%.

Potassium Rate (lb. K_2O Ton^{-1})	**\$ Value of Protein Ton^{-1}**	**\$ Value of Energy Ton^{-1}**	**\$ Value of Fiber Ton^{-1}**	**\$ Value of Quality Adjustment Ton^{-1}**	**\$ Value Hay Ton^{-1}**
0	167e	132	121	3	423
40	169c	133	120	6	428
80	171c	135	119	9	434
160	169c	133	120	4	427
240	173b	132	119	8	433
320	174a	134	117	10	435
Max. Change	7	2	-4	7	12

Within column if letters differ then the means are significantly different using an alpha of 0.05.

Table 6. Nutrient value of hay per acre as impacted by potassium rate averaged over all cuttings. Nutrient values were used from values published from Progressive Forage Magazine for the Pacific Northwest from January through May 2023 including $0.7042 lb. for metabolizable protein, $0.1216 $lb.^{-1}$ for Mcal of energy, and $0.1962 $lb.^{-1}$ for effective neutral detergent fiber

and \$6 ton^{-1}. Also, quality adjustment was calculated by \$6.55 ton^{-1} increase for each % NDFD 48hr over 47% and \$6.55 ton^{-1} decrease for each % NDFD 48hr. less than 47%.

Potassium Rate (lb. K_2O acre^{-1})	**\$ Value of Protein Acre^{-1}**	**\$ Value of Energy Acre^{-1}**	**\$ Value of Fiber Acre^{-1}**	**\$ Value of Quality Adjustment Acre^{-1}**	**\$ Value Hay Acre^{-1}**
0	1,710 d	1,360 b	1,277 b	-11	4,336 c
40	1,760 d	1,401b	1,297 b	2	4,457 c
80	1,851 c	1,467 a	1,329 a	61	4,708 b
160	1,877 bc	1,493 a	1,362 a	11	4,743 b
240	1,942 ab	1,494 a	1,361a	73	4,870 ab
320	2,010 a	1,559 a	1,371a	117	5,058a
Max. Change	301	199	94	128	722
LSD 0.05	86	67	68	119	216

Within column if letters differ then the means are significantly different using an alpha of 0.05.