AN ABSTRACT OF THE THESIS OF

Kathryn N. Higgs for the degree of Master of Science in Animal Science presented on September 12, 2003.
Title: Assessing the Phosphorus and Potassium Balances in Oregon's Dairies.

Abstract approved: Redacted for Privacy

Patrick D. French

A field study was conducted to assess phosphorus (P) and potassium (K) concentrations of both lactating and dry cow diets on Oregon's dairies. Thirty-seven dairy farms, located in western Oregon, were grouped according to geographic region, valley (V) or coast (C), and herd size, small (S) or large (L). Farms were visited on three separate occasions. During each visit, lactating and dry cow diets were recorded and corresponding feed ingredients were collected and analyzed for P and K. For each diet recorded, fecal and urine samples were collected and analyzed for P and K. When available, milk production data was obtained. During the initial visit, a survey was issued to producers to assess P and K knowledge as well as gather herd data and management information. Survey responses received indicated that two-thirds of participants were knowledgeable about P and its affects within the environment. Knowledge of K appeared to be less than that of P. Average P concentration of the lactating cow diet was 0.40% (DM basis) and did not differ between region ($P = 0.12$) or herd size ($P = 0.76$). Fecal P excretion did not differ between region ($P = 0.08$) or herd size ($P = 0.27$), however, a trend for larger fecal excretion in V farms contributed to the lower calculated apparent P digestibility for V than C. Potassium in lactating

cow diet was greater ($P = 0.01$) for C than V, however, but no difference between herd size ($P = 0.10$) was determined. Overfeeding of K also occurred in dry cow diet with no difference between region ($P = 0.40$) and herd size ($P = 0.72$). Combining the fecal and urinary fractions, an individual lactating cow consuming 0.40% P (89.8 g) and 1.71% K (384.3g) per day will excrete 24.0 kg of manure P and 76.3 kg of manure K annually. The magnitude of plant available P and K produced; requires Oregon producers to acquire additional land, an additional two-tenths ha/cow, to be to apply P and K at agronomic rates.

Assessing the Phosphorus and Potassium Balances in Oregon's Dairies

by

Kathryn N. Higgs

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented September 12, 2003
Commencement June 2004

Master of Science thesis of Kathryn N. Higgs presented on September 12, 2003.

APPROVED:

Redacted for Privacy

Major Professor, representing Animal Science

Redacted for Privacy

Head of the Department of Animal Sciences

Redacted for Privacy

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for Privacy

Kathryn N. Higgs, Author

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

ASSESSING THE PHOSPHORUS AND POTASSIUM BALANCES IN OREGON'S DAIRIES

INTRODUCTION

The livelihood of dairy farmers depends on the performance of the dairy cow. The predominant measure of performance is assessed by milk production, although factors such as reproductive performance and health also influence the longevity of the cow within the herd. Factors such as genetics, management, environment, and nutrition affect performance of the dairy cow. Some factors are fixed, such as genetics; however, others are variable and can be changed, such as nutrition. Nutrition, more specifically phosphorus (P), was thought to affect reproductive performance and milk yield. Physiological functions of dairy cattle are affected by deficiencies in dietary minerals (Kincaid, 1999). Often to minimize perceived risks, dietary P is overcompensated in the ration to insure that performance is not impeded.

Nutrient flow on a dairy farm occurs in a cyclical manner. Nutrients enter the farm as feed or fertilizer. Cows use the nutrients to produce milk, which is shipped off the farm, and maintaining biological functions. Unused nutrients are then excreted in manure, which is applied to cropland to supply nutrients to crops. Manure is a valuable fertilizer since more than half of the nutrients in dairy cow rations are excreted in manure (Hart et al., 1997). Finally, crops are harvested, fed to the dairy cattle and the flow of nutrients continues. When excess dietary P is provided, the majority is excreted in feces (Morse et al., 1992). This can complicate the challenge of agronomically applying P and over the long-term result in the accumulation of P within the soil. Soil P level exceeding crop needs due to manure application and/or long term fertilizer is one of the several potential sources of increased P losses in runoff from agricultural systems (Andraski and Bundy, 2003). Producers in the dairy industry have used manure recycling practices for five decades without much regard for nutrient balancing (Crill, 1998). Because excess P is excreted in feces, dairy cattle should be fed, as closely as possible, to their requirement to minimize the potential for environmental damage. Annually, a $10 to $15 savings per cow can be achieved with a 0.05% decrease (DM basis) of P fed a $100 million savings by the dairy industry (CAST, 2002).

The effects of dietary P on reproductive performance, milk yield and the environment continue to be issues concerning the dairy. This paper will explore the feeding trends, past and present, of P in lactating dairy cattle diets and the influence of these trends on P utilization, within the cow and on the farm. The use of P in current dairy production practices and environment will also be reviewed and assessed.

REVIEW OF PHOPSHORUS LITERATURE

Feeding History of P

Evidence suggests that reproductive performance and milk yield in dairy cattle would benefit from overfeeding P. Hignett and Hignett (1951) illustrated increasing P intake in dairy cattle positively affected reproductive efficiency and Kincaid et al. (1981) showed supplemental levels of P in lactating cow rations increased milk yield (Kincaid et al., 1981). A collection of scientific publications, dating back as early as 1971, consistently disagree with the previous findings. Further analysis revealed errors within the experimental design did contribute to the marked rise in reproductive performance and increased milk yield.

Reproductive performance. Correlations between P intake and conception rates of cattle were first discovered in the 1930's, but it would not be until later years when the effect of P on reproductive performance would be known. Hignett and Hignett (1951) reported conception rates were 26% higher for dairy cattle consuming diets containing excess levels of P, when compared to cows that were receiving the recommended levels of dietary P. In this study, low P diets contained 0.10 to 0.25% P (CAST, 2002) and high P were estimated to contain 0.49 % (French, 2003). In addition, Alderman (1963) stated that deficiencies in dietary P decreased reproductive performance in dairy cattle.

Milk production. Dietary P levels were shown to affect reproductive performance however; definitive data indicating milk production was jeopardized by low levels of dietary P is lacking. In 1981, Kincaid et al. suggested dietary P affected milk yield, feed intake, and milk production efficiency. Milk production was reduced

2 kg/d, or 7%, and feed intake was reduced 2% for dairy cattle consuming unsupplemented (0.31%) compared to P supplemented (0.55%) rations (Kincaid et al., 1981). The unsupplemented cows were also viewed as less efficient because of greater increases of body weight during lactation in (Kincaid et al., 1981).

Synopsis of P research. Several studies focusing on the effects of dietary P on reproductive performance and/or milk production in dairy cattle have been published. Parameters and results recorded from 11 different dietary P trials have been summarized and reported in Table 1.1. Characteristics of these experiments are presented in Table 1.2. Dietary P concentrations ranged from 0.24 to 0.67% P (DM basis), feeding durations spanned from a few weeks to as long as three consecutive lactations and milk production ranged from 17.3 to 49.5 kg/d.

Table 1.1. Effects of dietary P on reproductive performance and/or milk yield in lactating dairy cattle.

Research report	P (% DM)	Days to First estrus	Days open	Services/ conception	Milk yield (kg/d)
Steevens et al., 1971 (Year 1)	0.41	43	NR[a]	2.6	22.7
	0.60	36	NR	2.1	20.6
	0.63	37	NR	2.6	21.9
Steevens et al., 1971 (Year 2)	0.40	32	NR	4.4[x]	NR
	0.53	37	NR	1.9[y]	NR
	0.56	39	NR	2.8[y]	NR
Carstairs et al., 1981	0.40	NR	NR	NR	23.4
	0.50	NR	NR	NR	21.4
Kincaid et al., 1981	0.31	NR	NR	NR	27.3[x]
	0.54	NR	NR	NR	30.4[y]
Call et al., 1987	0.24	45	NR	1.3	17.3[b,x]
	0.32	66	NR	1.9	22.2[b,y]
	0.47	50	NR	1.5	21.2[b,y]
Brodison et al., 1989 (Year 1)	0.40-0.45	36	86	1.71	16.4
	0.60-0.65	36	94	1.47	15.4
Brintrup et al., 1993	0.33	NR	109	NR	25.4
	0.39	NR	99	NR	24.5
Valk & Šebek, 1999	0.24	NR	NR	NR	33.9[c]
	0.28	NR	NR	NR	34.2
	0.34	NR	NR	NR	33.1
Wu et al., 2000	0.31	40.6[x]	78	1.4	35.4
	0.40	77.6[y]	106	1.6	36.5
	0.49	43.6[x]	112	2.3	36.2
Wu & Satter, 2000 (Year 1)	0.38	52.2	115	2.5	29.6
	0.48	43.4	120	2.6	28.8
Wu & Satter, 2000 (Year 2)	0.38	47.8	103	1.6	32.0
	0.48	60.7	105	2.1	32.1
Knowlton et al., 2001	0.34	NR	NR	NR	33.3
	0.36	NR	NR	NR	33.8
	0.38	NR	NR	NR	36.3
Wu et al., 2001	0.31	74.8	160.2	2.4	42.3
	0.39	70.9	108.5	1.9	38.7
	0.47	83.2	128.1	1.8	39.4
Knowlton & Herbein, 2002	0.34	NR	NR	NR	49.5
	0.51	NR	NR	NR	48.4
	0.67	NR	NR	NR	45.8

[a] NR= Not reported.

[b] 4% fat corrected milk.

[c] The 0.24% P cows became P deficient on 22nd week of lactation. Cows were added to 0.28% P diet.

[x, y, z] Means with different letters significantly different (P< 0.05) within study.

Table 1.2. Characteristics of animals and length of trials investigating dietary P level and the effects on reproductive performance and/or milk yield in lactating dairy cattle.

Research report	Number of animals	Breed	Lactation number	Days fed ration
Steevens et al., 1971 (Year 1)	48	Holstein, Ayrshire, Guernsey	≥ 2	1 lactation
Steevens et al., 1971 (Year 2)	48	Holstein, Ayrshire, Guernsey	≥ 2	1-112 DIM[a]
Carstairs et al., 1981	24	Holstein	= 1	0-84 DIM
Kincaid et al., 1981	20	Holstein	≥ 2	1 lactation
Call et al., 1987	34	Holstein	≥ 2	1 lactation
Brodison et al., 1989	40	British Friesians	≥ 1	3 lactations
Brintrup et al., 1993	48	NR[b]	≥ 2	2 lactations
Valk & Šebek, 1999	24	Holstein	≥ 2	7-294 DIM
Wu et al., 2000	26	Holstein	≥ 2	1 lactation
Wu & Satter, 2000 (Year 1)	42	Holstein	≥ 1	1 lactation
Wu & Satter, 2000 (Year 2)	42	Holstein	≥ 1	1 lactation
Knowlton et al., 2001	36	Holstein	≥ 2	0-38 DIM, 117-151 DIM
Wu et al., 2001	37	Holstein	≥ 2	2-3 lactations
Knowlton & Herbein, 2002	13	Holstein	≥ 2	7-77 DIM

[a]DIM = Days in milk.
[b]NR = Data not reported.

According to Table 1.1, none of the studies was able to mimic the overwhelming results reported by either Hignett and Hignett (1951) or Kincaid and colleagues (1981). In general, researchers reported that reproductive performance was not affected by differing dietary levels of P. Steevens et al. (1971) noticed during the second year of the study, a larger number of services/conception were required for the low (0.40% P) group and Wu et al. (2001) reported days open appeared to be the highest for dairy cattle consuming the low P diet. However, other researchers indicated low P diets actually were beneficial to reproductive performance. Wu and Satter (2000) reported that services/conception in the second year tend to be lower (P=0.13) for the low P group and Wu et al. (2000) showed that services/conception and days open appeared to favor the low P group. Before definitive conclusions about reproductive performance can be implied, consideration of sample size is important. According to Wu and Satter (2000), an average of 250 cows could be needed to detect a 10% difference in a reproductive measure (i.e. days to first estrus, days open, and services/conception) at a 95% confidence interval. Individual studies provide insufficient number of cows to accurately draw conclusions about the relationship between dietary P and reproductive performance.

The importance of P in dairy cattle diets for reproductive performance was overstated. Revisiting Hignett and Hignett (1951), further evaluation revealed dietary P levels were typically deficient. At these low P concentrations, P is likely to be deficient for rumen microorganisms, resulting in decreased diet digestibility and lowered microbial protein synthesis, decreasing both available energy and protein ultimately resulting in a decrease reproductive efficiency (CAST, 2002). The reproductive success of P supplementation, in the Hignett and Hignett study, can be attributed to the fact that the dairy cattle were no longer in a P deficient status and thus more physically apt to conceive.

With the exception of Kincaid et al. (1981) and Valk and Šebek (1999), milk production was not impaired by low levels of dietary P. As for Valk and Šebek

(1999), cows receiving the low P diet (0.24%) decline in milk production. When these cows were added to the 0.28% P group, milk yield resumed to normal. A P deficiency is likely to occur when low levels of dietary P are feed for extended periods. Similar to Valk and Šebek (1999), Call et al. (1987) also reported P deficiency to occur at 0.24% P; however, these researchers noticed a decline in dry matter intake before a drop in milk production occurred. Nevertheless, a decline in milk production was noticed only after the cows had been consuming the P deficient diet for three to four month span (Call et al., 1987). As for Kincaid et al., the increase in milk production was not a function of increasing dietary P levels but a result of improperly analyzed data. According to National Research Council (NRC) (2001), based on the description of the analysis of variance in that paper, the data were improperly analyzed, thus invalidating interpretation.

Summary of P Requirements for Dairy Cattle

Research studies, such as the ones included in Table 1.1, contribute to the development of P requirements. Published requirements for dairy cattle are based on peer reviewed research in ruminants, however, only a few studies reviewed include lactating cows (Knowlton and Kohn, 1999). Phosphorus requirements for dairy cattle, according to the NRC and other nutrient requirement publications, are reported in Table 1.3. Before the 2001 recommendation, the NRC reported 50% for the P absorption coefficient, which is lower when compared to other systems. The limited number of studies with appropriated tracers were not available to estimate true absorption coefficient for most feedstuffs (NRC, 2001), so a conservative value for absorption coefficient was reported. Between NRC editions, 1989 and 2001, an alternative approach for assessing P absorption coefficient was developed, which leads to a larger number of studies used in developing P requirements. The P absorption coefficient for a lactating cow ration was increased to from 50 (NRC, 1989) to 64% (NRC, 2001).

Table 1.3. Phosphorus requirements for lactating dairy cattle[a].

System	Year	True maintenance requirement	True milk requirement (g/kg milk)	Assumed digestibility of feed P (%)
NRC	1971	14.30 mg/kg BW	1.000	50
	1978	14.30 mg/kg BW	0.900	55
	1989	14.30 mg/kg BW	0.990	50
	2001	1.00g/kg DMI	0.900	64-70
ARC	1965	16.80 g/d for 600 kg	0.950	55
	1980	12.00 mg/kg BW	0.905	58
Netherlands	1983	25.20 mg/kg BW	0.900	60
France	1988	43.40 mg/kg BW	0.875	70
Germany	1987	24.00 mg/kg BW	1.000	60
	1993	1.00 mg/kg DMI	1.000	70

[a]Adapted from Knowlton and Kohn 1999

The P requirement for a cow is determined by the sum of the calculated requirement for maintenance based on body weight, the requirement for pregnancy and the requirement for milk yield based on the P content of milk. True requirements are divided by the efficiency of absorption of dietary P to yield total P requirements. Total P requirements for lactating cows are listed in Table 1.4 for a 650kg dairy cow producing 30 kg of milk/d and consuming 23kg DM/d.

Table 1.4. Phosphorus requirements for 650kg dairy cow producing 30 kg of milk/d.

		Maintenance	Milk	Total
		-----------------	g/d	-----------------
NRC	1971	18.6	60.0	78.6
	1978	16.9	49.1	66.0
	1989	18.6	59.4	78.0
	2001	34.1	40.3	74.4
ARC	1965	33.1	51.8	84.9
	1980	13.4	46.8	60.3
Netherlands	1983	27.3	45.0	72.3
France	1988	40.3	37.5	77.8
Germany	1987	26.0	50.0	76.0
	1993	32.7	42.9	75.5

The final feeding recommendations do not differ greatly between systems; however, the NRC and European P standards differ in their component parts (i.e. values assigned for maintenance, milk production and P availability) (Wu et al., 2000).

Phosphorus requirements according to stage of lactation. Nutrient requirements for an entire lactation are not static; rations are tailored to satisfy the changing needs of dairy cattle throughout lactation. The published NRC (2001) P requirements for both lactating and dry Holstein as well as lactating Jersey dairy cattle are provided in Table 1.5. High producing Holsteins and Jerseys were characterized as dairy cattle producing over 54.5 and 40 kg/d respectively. Holstein dairy cattle producing 45 kg/d and Jersey dairy cattle producing 35 kg/d are considered moderately producing cows whereas, low producing Holstein and Jersey dairy cattle yield 25 to 35kg/d and 25kg/d respectively. In addition to milk production, stage of lactation and breed can effect P requirements.

Table 1.5. Phosphorus requirements (as a percentage of diet) for 3.0 and 3.6% true protein milk for Holstein and Jersey cattle, respectively.

Stage of lactation	P (% of DM)	
	Holstein	Jersey
Fresh	0.38-0.42	0.40
High producing	0.38	0.36
Moderately producing	0.36	0.37
Low producing	0.32-0.35	0.33
Dry (240d of gestation)	0.22	NR[a]
Dry (270d of gestation)	0.23	NR
Dry (279d of gestation)	0.26	NR

[a]NR = Not reported

Phosphorus requirements are often increased during the first three weeks of lactation to accommodate for the suppressed DMI. In 1989, the NRC recommended 0.48% P be fed for the first three weeks of lactation however, current fresh cow recommendations find that amount of P unnecessary. An additional non-dietary source of P, often unaccounted for during the fresh period, is bone P. Bone is a metabolically active tissue that has the ability to mobilize Ca and P, especially during early lactation (Valk et al., 2000). The action of the parathyroid hormone stimulates the mobilization of Ca and P from bone (Valk et al., 2000) and the 500 to 600 grams of P mobilized (Wu et al., 2000) is sufficient to compensate for the reduced intake of P (Wu et al., 2001). When P requirements were increased to 0.48% during the fresh period, Wu et al. (2001) noticed a lag in milk production. Similar results were reported by Carstairs et al. (1981) and DeBoer et al. (1987) when feeding excess dietary P to early lactating Holstein cows. Over feeding of P during the fresh period is neither required nor desired.

Phosphorus secreted during milk production is associated with both yield (Forar et al., 1982; Morse et al., 1992) and milk constituents (De Boer et al., 1981; Call et al., 1987; Morse et al., 1992; Wu et al., 2000). Secretion of milk P remains relatively constant throughout the lactation ranging from 0.083 to 0.100% of milk (NRC, 2001), with half complexed with casein (Wu et al., 2000). Later stages of lactation are indicative of a decline in milk yield; however, milk components increase with milk P secretion remaining relatively constant. Late lactation also provides an opportunity for dairy cattle to replenish bone P lost during mobilization at the onset of lactation (Wu et al., 2001). The hormone calcitonin stimulates bone deposition of minerals by depressing intestinal absorption and stimulating salivary P secretion (Valk et al., 2000). Therefore, P needed for bone restoration and milk production, combined with the needs of growing fetus and uterine mass, suggest that P content of the diets should not be decreased relative to milk production for later lactation cows (Wu et al., 2001).

Numerous researchers have shown overfeeding P does not improve cow performance. According to Wu et al. (2001), typical US dairy producers are feeding 0.45 to 0.50% P in lactating cow rations. In three separate surveys, each author reported an average P diet for lactating cow rations greater than recommendations P established by NRC in both 1989 and 2001. Of the 617 producers surveyed in the Northeast and Mid-Atlantic, only 29% of the farmers were knowledgeable about the amount of P in lactating cow rations and reported an average of 0.44% P was fed (Dou and Ferguson, 2001). After surveying 30 farms in Wisconsin, Possin (2002) reported the average P in total mixed rations of high group milking cows was 0.53% with a range of 0.45% to 0.66%. Finally, the mean dietary P content of the 33 surveyed herds in Virginia was 0.49% (Sink et al., 2000). Despite the overwhelming evidence, dairy producers are overfeeding P to lactating cow diets.

Phosphorus Functions for Dairy Cattle

Phosphorus has more known biological functions than any other mineral (NRC, 2001) thus P requirements are formulated to contain adequate amounts of P not to impede performance. Phosphorus is responsible for structural as well as cellular functions. The majority of the P in the body (80%) is found in bones and teeth (NRC, 2001) and exists in primarily in two chemical forms: hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] and calcium phosphate [$Ca_3(PO_4)_2$] (NRC, 2001; Wu et al., 2001). At the cellular level, P is located in every cell and is responsible for energy metabolism, phospholipid and nucleic acid synthesis. The high-energy phosphate bonds from the chemical compound adenosine triphosphate (ATP) propel thermodynamically unfavorable reactions during the metabolism of carbohydrates, fats and amino acids. For example, during glycolysis, the conversion of glucose to glucose-6-phosphate will only occur if is coupled with the hydrolysis of ATP. Phospholipids, lipids with phosphate containing head groups, are important constituent of cellular membranes. Phospholipids are oriented to create a bilayer, containing proteins within the membrane or bound to the surface, to aid in the transport of materials, such as nutrients, across the cell membrane. Finally, nucleic acids are formed through the linkage of phospodiester linkage- phosphate between a pentose sugar and the corresponding purine and/or pyrimidine base.

Composition and Availability of Dietary P Sources

Formulating rations to insure adequate amounts of P are provided is easy to accomplish. Unsupplemented, organic diets typically fall within the range of 0.33 to

0.40% P (Wu et al., 2000). Without supplementation of P, many rations based upon corn, corn silage and alfalfa contain approximately 0.30% P (Kincaid et al., 1981). Forages are characteristically low in P; however, the P content of the plant is associated with maturity. Plant P levels are highest (0.40 to 0.50%) early in the growing season and levels declined during drier periods (0.25 to 0.30%) (Downing, 2002). In general, protein feeds, such as soybean meal, are traditional high in P (Tylutki, 2002) compared to forages. A summary of the P analyses of feed samples submitted to Dairy One Forage lab and corresponding protein content provided by NRC (2001) are listed in Table 1.6. Typical feedstuffs from Table 1.6 (Chase, 1999) incorporated into dairy cattle diets are able fulfill dairy cattle P requirements (Carstairs et al., 1981; Wu et al., 2000). Rations in excess of 0.40% P, and are achieved via mineral supplementation. Since a typical lactating cow diet in the US ranges from 0.45 to 0.50% P (Wu et al., 2001), supplements are frequently used in lactating rations; the most common being dicalcium phosphate (Church, 1988). The choice of supplements depends on availability and price, as well as the chemical and physical form and solubility of supplement (Valk et al., 2000).

Table 1.6. Phosphorus analyses of feed samples.

Feedstuff	Protein (% DM)	P (% DM)		n
		Mean	S.D.	
Alfalfa	20.2	0.26	0.06	11,962
Barley	12.4	0.28	0.16	126
Beet pulp	10.0	0.1	0.03	106
Canola meal	37.8	1.14	0.16	37
Corn grain	9.4	0.32	0.11	306
Corn silage	8.8	0.23	0.03	16,992
Distillers grains	29.7	0.82	0.12	183
Grass silage	12.8	0.31	0.07	2030
Oats	13.2	0.39	0.06	42
Soybean meal	50.0	0.68	0.11	277
Whole cottonseed	23.5	0.66	0.11	252

Recommended concentration of total P in rations of high producing cows is approximated 0.38% (NRC, 2001) of which 60 to 80% is from concentrates (Morse et al., 1986). Forages are low in P phytate whereas for concentrates, two-thirds of the total P is in phytate (Clark et al., 1986). Before phytate can be absorbed, the inositol ring in phytate must be hydrolyzed by the phytase (Clark et al., 1986). Fortunately, the natural phytase activity provided by ruminal microorganisms make P in grain and forages more available to ruminants (Knowlton et al., 2001).

Phosphorus Metabolism in Ruminants

According to Valk et al. (2000), P balance in ruminants is controlled within the gut by a process of either absorption or secretion or both. Rumen P content consists of both feed and salivary P, with salivary P contributing up to 50% of the total amount of P in the rumen (Valk et al., 2000). Saliva can provide up to 58 g/d in a mature cow (Church, 1988). Salivary P is an excellent source of P because it is highly available (75 to 80%) for rumen microbes (Challa et al., 1989). Salivary P insures a continual supply of P is available to the rumen. Khoransani et al. (1997) noticed that P flow in the duodenum is relatively constant and as P content of diet increases, the salivary secretion of P decreases. Animals must maintain a certain rate of salivary P secretion to ensure normal functioning of the rumen, in particular the rumen microbial population (Challa et al., 1989). Rumen bacteria, protozoa and fungi need P to maintain metabolism and growth (Valk et al., 2000). Although some P may be absorbed in the rumen (Valk et al., 2000), the majority of the absorption of P will occur in the duodenum.

The efficiency of absorption depends upon intake as well as demand (Braithwaite, 1983). Efficiency of absorption tends to decrease as the intake of P increases (Braithwaite, 1984; Challa et al., 1989; Martz et al., 1999; Wu et al., 2001). As dietary P approaches the animal's requirement, it is likely that true absorption decreases from when animals are clearly P deficient (Wu et al., 2000). A calculated absorption for a P deficient diet (0.22%) was determined to be 100% and declined to a minimum absorption coefficient of 64% when diets contain 0.49%P (NRC, 2001). Challa et al. (1989) reported unsupplemented mixed organic diets have an efficiency of P absorption of 50%. Corn silage fed to non lactating cows increased from 84.5 to 93.9% as dietary P decreased from 0.19 to .012% P. When feeding a total mixed ration, Wu et al. (2001) showed a decrease in apparent digestibility decreased from 45 to 24% as the P levels in the diets increased from 0.31 to 0.47% P, respectively. Other factors such as dietary protein content, starch degradability, and grain content of the diet may affect availability of feed P (Knowlton et al., 2000).

Phosphorus not absorbed in the intestine, secreted in milk or deposited in bone and soft tissues, P is excreted in urine and feces. The route by which P is excreted is dependent upon intake of P. The primary route in which P is excreted is in feces with a small amount of P excreted in the urine. Dairy cattle consuming diets containing 0.41% P (82g/d) excreted 88.2% of P consumed in the following fractions: 68.6% in feces, 30.3% in milk, and 1.0% in urine (Morse et al., 1992). Small amounts of P are typically expelled through the urine since kidneys are not the primary routes for the secretion of P (Morse et al., 1992). Urinary P is generally negligible (less than 1g/d) for diets containing less than 0.35% P (Wu et al., 2000). As dietary P approaches levels greater then 0.40% P, excess P spills over into the urine and as much as 6 to 8g/d of P may be removed by urine excretion (Morse et al., 1992). Total P in feces is predominately affected by intake (Challa et al., 1989; Morse et al., 1992; Martz et al., 1999; Powell et al., 2001; Wu et al., 2001; Dou et al., 2002; Valk et al., 2002). When P intake increased 36.5% (0.41 to 0.56% P), fecal excretion increased 48.6% (Morse et al., 1992). When P intake declined by 26.8% (0.41 to 0.30% P), excretion of P in feces decreased by 22.7% (Morse et al., 1992). For dairy cattle that have attained P balance, each additional gram results in a 0.8g excreted (Morse et al., 1992). The fecal P is the portion regulated by intake and is the largest quantity and the most variable fraction. Other fecal fractions according to Spiekers et al. (1993) include the unavailable part of dietary P, which cannot be absorbed under any condition as well as the inevitable loss of P that is excreted under normal physiological conditions. The unavailable fraction for ruminants is likely to be a small fraction of dietary P (Wu et al., 2000). The inevitable loss of P consists of salivary P, P in sloughed gut tissue, and P from digestive secretions plus P in microbial residues excreted in feces (Wu et al., 2000). Inevitable losses range from 0.9 to 1.2 g/kg DMI as digestibility of diet increases from 85 to 100% (Spiekers et al., 1993).

Nutrient Loading and the Effects

Phosphorus fed at 30 to 100% in excess of requirement, although causes no observable physiological or nutritional effects may have detrimental effects (Morse et al., 1992). The effects of dietary P, manure P and subsequent number of hectares required to dispose of the manure at agronomically acceptable rates are listed in Table 1.7 (Hoard's Dairyman staff article, 2002). Feeding 0.38% P will require 0.73 hectare to properly dispose of the 21.4 kg of P produced during the year. A typical US dairy farm is feeding 0.45 to 0.50% P in lactating cow diets (Wu et al., 2001) thus an additional 0.24 hectare is required to accommodate the 8.1 kg increase of P excreted. One-quarter of a hectare may not seem like a significant amount of land, however, in a scenario with a 100 lactating cows, 25 additional hectare are required if nutrient loading is to be avoided.

Table 1.7. Effect of reducing dietary P on excretion of P in manure.

Dietary P (% DM)	Manure P (kg/cow/yr)	Spreadable hectares (hectares/cow/yr)
0.55	35.4	1.17
0.48	29.5	0.97
0.38	21.3	0.73
0.35	19.1	0.65

Manure amended soils provide nutrients that are removed by growing plants. Unfortunately, the efficiency of plant P uptake is only 56% (Sharpley and Rekolainen, 1997); so ideally, application rates of manure should closely match nutrient requirements for crop production. When nutrient levels in the soil are beyond the optimum requirement for plant growth some of the excess nutrients can accumulate in forages. This phenomenon in grasses is called 'luxury consumption'. If soil potassium (K) is elevated beyond ideal, the excess soil K is mirrored in the forage. Unlike K, there is little evidence that crops can accumulate P in luxury amounts (Russelle et al., 1999). This could be associated with the insolubility of soil P, thus there is an inability to remove soil P through crop production. Removal of soil P is dependent on both the forage variety and time of growing season. Downing (2002) reported that P from dairy cattle manure removal ranged from low as 8.3 kg/hectare in 2000 to levels approaching 11.8 kg/hectare in 2001. Below (Table 1.8-Downing, 2002) summarizes the average P removal perennial grasses during the 2000 and 2001 growing season. The removal of soil P does not appear to be a sizeable amount. Removal rate of high P soils, ranges from 0.1 to 30 ppm year but is dependent upon soil type and management (Sharpley and Rekolainen, 1997).

Table 1.8. Total P forage removal for 2000 and 2001(kg P/ha).

Forage variety	n	2000	2001
		P	P
Fescue	5	8.3	ND[a]
Orchard grass	4	8.1	11.8
Ryegrass	8	8.5	10.3
Intermediate ryegrass	2	9.1	9.1
Italian ryegrass	1	9.9	8.9
Festuolium	1	9.2	9.8
Prairie grass	1	8.6	9.8

[a]ND= No data. Fescue varieties were removed from trial due to lack of survival.

In an attempt to remain economically viable, changes in agricultural production have caused dairy farms to increase herd size. Between 1985 and 2001, the average number of cows per operation increased steadily from 88 to 158 (USDA-NASS, 2003) and crop acreage per farm only increased slightly. If land base is fixed, over feeding dietary P can create challenges for recycling manure nutrients and have profound effect on soil P levels. Manure of ruminant livestock typically has an average nitrogen (N) to P ratio of four whereas the N: P requirement of major grain and hay crop is eight (Powell et al., 2001). As P supplementation increases, the N: P ratio is affected such that the ratio decreases. If manure is solely used to meet N crop requirements, P is over applied. Continual application of P can increase soil P above levels required for optimum crop yield (Sharpley and Rekolainen, 1997). In Wisconsin, average soil P levels have been rising steadily in the past 25 years. Optimum soil test levels for P are typically 20 to 30 mg/kg (Russelle et al., 1999), however, repeated application of manure and fertilizer has increased the level of soil test P from an average of 34 mg/kg in the 1968 to 1973 period to 50 mg/kg in 1990 to 1994 (Powell et al., 2001). Due to the noticeable connection between application of manure over time and P accumulation in the soils (Robinson et al., 1995; Knowlton and Kohn, 1999), surplus nutrients within a ration compounds the existing problem.

Diet manipulation greatly affects amount of P excreted but it also effects the chemical composition of the manure. Increasing dietary P concentrations primarily increases the water-soluble fraction of feces (Dou et al., 2002) and it is the water soluble P that is associated with potential P loss to waters (Sharpley and Moyer, 2000). Addition of inorganic P sources simply increases the total P and water soluble fraction of feces (Powell et al., 2001; Dou et al., 2002). Potential P loss on animal farms is a combination between much P is excreted in manure, how much is applied to fields, in addition how easily the manure P is dissolved in rainwater and subjected to potential runoff (Dou et al., 2002).

Phosphorus and the Environment

Loss of P from land can occur in three ways as described by Ryden et al. (1973). The primary way in which water soluble P is lost from land is through surface runoff (overland flow), referring to P picked up by rainwater, which flows over land surfaces into streams or rivers. Conventional wisdom thought that excess P would accumulate in soils (because of the relative immobility of P in soils-Sims et al., 1998) and run-off only occurred if there was erosion. Management of P on farms was a matter of preventing erosion using favorable tillage and cropping strategies (Knowlton and Rick, 1999). Recently, it has been discovered that with excessive application of P to soils over a period of several years, the soils become saturated with P and runoff can occur even with erosion control (Sharpley, 1996). No-till farming practices may reduce erosion, but may make P run-off worse because P is kept near the soil surface. Water soluble P can also travel through soil by subsurface runoff (leaching), referring and moves through the soil to streams or rivers without ever reaching the main water table (Ryden et al., 1973). Phosphorus leaching has normally been considered to be inconsequential in most soils. But combinations of agricultural management practices, soil properties and climatic conditions can result in significant P accumulation in the subsoil (Sims et al., 1998). Ryden et al. (1973) reports that losses of P in subsurface runoff can be similar or even greater than those losses from surface runoff.

Subsurface runoff of P begins with downward movement of P, either by slow leaching through the soil profile or preferential flow thorough macrospores (e.g., soil cracks, root channels, earthworm borings) (Sims et al., 1998). Phosphorus leaching can occur in deep sandy soils, in high organic matter soils, and in soils where over fertilization and/or excessive use of organic wastes have increased soil P values well above those required by crops (Sims et al., 1998). Finally, water soluble P can flow to the water table and discharged to streams, rivers and lakes as seepage (Ryden et al., 1973) However, this is not a typical or common route for P to move through soil profile.

Of all of the essential dietary minerals for dairy cattle, P represents the greatest potential risk for environmental damage via pollution of surface water (NRC, 2001). Eutrophication, as described by Brady and Weil (1999), is an undesirable enrichment of surface water with excess nutrients. Eutrophication results in oxygen depletion (hypoxia), loss of submersed vegetation, and alteration of food webs (Boesh et al., 2001). Over enrichment of surface water stimulates a rapid growth (bloom) of algae. Continual respiration and decomposition of the alga blooms depletes levels of dissolved oxygen. Dissolved oxygen concentrations lower than required by indigenous organisms (hypoxia) (Boesch et al., 2001) are also suitable conditions for formation of toxins. Only severely affected lakes will fish population die, nevertheless, aquatic species production can be compromised in eutrophic waters.

Phosphorus is often considered the critical nutrient for eutrophication do to its limiting nature in the environment. The control of P is of prime importance in reducing the accelerated eutrophication of fresh waters (Sharpley and Rekolainen, 1997). Inorganic P, in excess of a little as 0.02mg/L, is likely to cause a problem with algal production (Ellis et al., 1989) and negatively effect the environment. Greater attention is also given to P, over N, because of the difficulty in controlling the exchange of N between the atmosphere and a water body (Powell et al., 2001). The water soluble P portion of manure is also a threat to eutrophication because it is readily available for algae uptake (Powell et al., 2001). Due to the minimal amounts of P responsible for causing environmental damage; management of P within the environment is essential.

Phosphorus in the US Dairy Industry

It has been shown several times that P is currently being overfed in lactating cow rations. Feed P is the largest single source of P coming onto the farm (Spears et al., 2002). Purchased feed accounted for 71% of P fed on the farm (Knowlton and Sink, 1999). Phosphorus management options should be targeted at minimizing imports onto the farm (Powell et al., 2001) as well as decreasing P levels in the diets. In Utah, 6.6 tonne/yr was calculated, indicating that more P was coming onto the farm, via feed imports, than was being accounted for in the sale of product, exported crops and exported manure (Spears et al., 2002). Decreasing the dependence on purchased feed by feeding homegrown forages can decrease the amount of P imported onto the farm. Increasing homegrown forages in the diet will reduce the level of P in the diets and may require additional land. Purchasing of land can be ideal since dairy farms have the tendency to over apply P. Importing less feed and acquiring more land will help reduce the whole farm P balance.

Nutrient balancing is important to improving water quality and complements the long-term sustainability of dairy production practices. To insure that this relationship is a success, the Natural Resources Conservation Service (NRCS) has developed a planning process they call a Comprehensive Nutrient Management Plan (CNMP). According to NRCS, the CNMP is a "grouping of conservation practices and management activities which, when implemented as part of a conservation system, will help to ensure that both production and natural resource protection goals are achieved. A CNMP incorporates practices to utilize animal manure and organic by-products as a beneficial resource." To achieve this goal, six components comprise the CNMP: (1) manure and wastewater handling and storage; (2) land treatment practices; (3) nutrient management; (4) record keeping; (5) feed management; and (6) other utilization activities (NRCS, 2003).

Incorporating feed management strategies addresses the issue of reducing nutrients in manure. Feeding less P will reduce the nutrient content of the manure that will result in less land being required to effectively utilize the manure (NRCS, 2003). Although the CNMP is currently a volunteer program for AFO (agricultural operations with less then 1000 animal units), the National Pollutant Discharge Elimination System (NPDES) permit requires confined animal feeding operations (CAFOs) to develop and implement CNMPs (USDA USEPA, 2003). CAFOs affected by a CNMP include large facilities with greater than 1000 animal units, facilities with unacceptable conditions (i.e. discharge animal waste into waters, waters that pass through facilities has are contaminated with animal waste discharge), or a facility that is a significant contributor to water quality impairment (USDA USEPA, 2003). This voluntary system may become mandatory for all dairy producers by 2006 (UDSA USEPA, 2003). The state of Oregon will require CNMPs for all dairies by the end of 2006.

Reducing the amount of P loading on the farm positively affects the environment and your wallet. A reduction of dietary P will also reduce feed costs in the dairy cattle industry. Annually, a $10 to $15 savings per cow can be achieved with a 0.05% decrease (DM basis) of P fed a $100 million savings by the dairy industry (CAST, 2002). Although this may not appear as a significant financial savings, for a typical herd in the US, an excess of $1,500/yr can be saved.

INTRODUCTION

Potassium (K) is another nutrient of importance on dairy farms. It too, when overfeed is excreted, however, unlike P, excess K is excreted in the urine (McDowell, 1992; NRC, 2001). Forages grown in fields that receive an application of K enriched manure often produce crops that are also high in K. Grasses grown in these fields mirror the soils' increase in available K (Lutz, 1973). The popular use of grasses and legumes, especially in the dry cow diet, often makes it difficult to balance rations with the inclusion of high K forages. Unlike P, were overfeeding does not harm the health of the dairy cow, when K is overfeed to dry cows, metabolic disorders are likely to occur (Curtis et al., 1983; Goff and Horst, 1997; Horst et al., 1997).

This section will briefly explore the importance of K within the dairy cow, focusing primarily on importance of K in the dry cow diet. A method to which combat the inclusion of high K forages in dry cow diets will also be explored.

REVIEW OF POTASSIUM LITERATURE

Requirements and Functions of K

Potassium is the third most abundant mineral in the body (NRC, 2001). It must be supplied daily in the diet because there is little storage in the body and the animal's requirement for K is highest of all the mineral element cations (NCR, 2001). Requirements of K for lactating and dry cows are supplied in Table 2.1 (NRC, 2001). The requirements have been established to maintain important physiological roles within the animal, in addition to lactation. Physiological roles include maintenance of osmotic environment with the use of the Na+/K+ ATPase system, nerve impulse transmission, water balance, activation of enzymes and maintenance of cardiac and renal tissue (NRC, 2001). Lactating dairy cattle have a higher K requirement than that of dry dairy cattle because K is the mineral element present in highest concentration in milk 0.15% K compared to 0.11% Ca and 0.08% P (McDowell 1992). When formulating dry cow diets, K is limited to reduce the incidence of metabolic disorders during parturition (see below).

Table 2.1. Potassium requirements of lactating and dry dairy cattle.

Stage of lactation	K (% of DM)	
	Holstein	Jersey
Fresh	1.19-1.24	1.10-1.19
Lactation	1.00-1.07	1.02-1.07
Dry (240d)	0.51	NR[a]
Dry (279d)	0.62	NR

[a]NR = Not reported

Absorption of K takes place in the rumen, omasum as well as the lower gastrointestinal tract (McDowell, 1992), but K is primarily absorbed in the duodenum by simple diffusion (NRC, 2001). Unable to store K, the majority of excess K is excreted in the urine. Aldosterone is responsible for the excretion of K by renal tubes

(McDowell, 1992; NRC, 2001). Fecal loss accounts for only about 13% of the total loss of K in cows (McDowell, 1992). The true digestibility of K is relatively high (95%) for most feedstuffs (Hemken, 1983). An absorption coefficient value of 90% for K for feedstuffs and minerals was adopted by NRC (2001). Nevertheless, because K is excreted mainly in the urine, urinary excretion can be a reliable indicator of the efficiency of absorption.

Forages and K

In addition to the large amount of K excreted in the urine, K in the urine is a readily available form in the soil to forages (Grunes and Welch, 1989). When the available K component of the soil exceeds sufficient concentrations (250 ppm) (Crill, 1998), legumes and grasses can accumulated K in excess of their requirement for growth (luxury consumption). Both legumes and grasses are very heavy users of K, especially grasses, because of their extensive fibrous root system (Miller and Reetz, 1995). Since K excretion by the dairy cow is more than two times greater compared to P (Van Horn, 1994), compounded by the increasing number of animals per operation, more K becomes applied to fewer acres of land. Current agronomic practices often lead to the excess application of K required for plant growth. Soder and Stout (2003) also noted an increasing manure application rate increased forage K concentration. On a dry matter basis, grasses can increase from 1.5 to 4.5% K (Table 2.2). The high levels of K in forages can make is difficult to formulate rations, especially for dry cows.

Table 2.2. Normal and excessive concentrations of K in forages.

Type of Forage	Normal K	Excessive K
	-----------(% DM)---------	
Corn silage	0.74[a]	1.54[a]
Fescue hay, sun cured	1.8[b]	4.5[b]
Orchard grass hay, sun cured	3.0[b]	3.5[b]
Ryegrass hay, sun cured	1.4[b]	3.5[b]
Timothy hay, sun cured, mid-bloom	1.8[b]	3.0[b]

[a]From Beede, 1996a.
[b]From Crill, 1998.

Majority of feed ingredients for dry cow diet typically are forages (Van Saun, 1999). High forage rations (85%) have been thought to maintain maximal rumen fill and volume, stimulate rumen motility, and allow healing of rumen wall lesions resulting from high-grain lactation rations (Van Saun, 1991). Furthermore, quality forage sources are sufficient in meeting the nutritional needs of the prepartum dairy cow. However, forage mineral composition can have significant effect on animal performance and health as they are not often in balance with the nutrient requirements of the animals (Soder and Stout, 2003). The inclusion of high K forages in dry cow ration can result in metabolic problems.

Effects of overfeeding K in Dry Cow Diets

High levels of K, in prepartum diets, increase the incidence of parturient paresis (milk fever) (Goff and Horst, 1997; Horst et al., 1997). Milk fever is a metabolic disorder occurring at or near partition that is indicative of hypocalcemia, low blood calcium (Ca) (Horst et al., 1997) due to the onset of lactation. During the dry period, Ca requirements are minimal (10 to12g/d) (Horst et al., 1997), however at parturition, Ca requirements increase 2 to 3 fold to support milk production. As a consequence of this sudden Ca requirement, nearly all cows experience some degree of hypocalcemia during the first day after calving as the intestine and bone adapt to the Ca demands of lactation (Horst et al., 1997). Plasma Ca is controlled by the coordinated efforts of the parathyroid hormone (PTH) and 1,25-dihydroxyvitamin D_3 [1,25$(OH)_2D_3$] (Horst et al., 1997). In response to hypocalcemia, PTH and 1,25$(OH)_2D_3$ increases reabsorption of renal Ca, increase reabsorption of bone Ca as well as increase intestinal Ca absorption (Horst et al., 1997). The failure to maintain systemic Ca after calving has been attributed to an impairment of the kidney and bone to respond to parathyroid hormone (Goff et al., 1991; Goff and Horst, 1997).

Predisposing factors such as breed and age of cow also affects the incidence of milk fever (Curtis et al., 1984; Horst et al., 1997). Jersey cattle tend to be more susceptible to milk fever (Curtis et al., 1984). Jersey cattle displayed fewer 1,25$(OH)_2D_3$ receptors, than Holsteins, (Goff et al., 1995) and with fewer receptors, the sensitivity of 1,25$(OH)_2D_3$ is reduced. Normally, the elevated 1,25$(OH)_2D_3$ would result in enhanced bone Ca reabsorption and intestinal Ca absorption as the cow becomes hypocalcemic (Horst et al., 1997). With fewer receptors, the activation of this event is less efficient.

Incidence of milk fever also increases as a cow ages. First calf heifers rarely exhibit parturient paresis (Curtis et al., 1984; Horst et al., 1997). Advanced aging results in increased milk production, creating a higher demand for Ca, a decline in the ability to mobilize Ca from bone and intestine, as well as impaired production of 1,25$(OH)_2D_3$ (Horst et al., 1997). All of which makes the cow more susceptible to milk fever. Horst et al., 1997 also noted that intestinal receptors for 1,25$(OH)_2D_3$ also decline as age advances.

The incidences of milk fever can be reduced with the use of dietary cation-anion difference (DCAD). The most common expression of DCAD is: [mEq (Na + K) – (Cl + S)/100g dietary DM] (Beede, 1996b). Most typical feedstuffs and rations for dairy cows have a positive DCAD due to their relatively higher K and Na concentrations compared with Cl and S concentrations (Beede, 1996b). A negative DCAD of -10 to -15 meq/100g DM is desired for dry cow rations (Beede, 1996b; Bethard and Stokes, 2000). This negative DCAD causes milk metabolic acidosis, increasing mobilization of Ca from bone, and possibly enhancing absorption of Ca from the gut increasing the cow's ability to maintain normal blood Ca concentrations and reduces the incidence of milk fever and subclinical hypocalcemia in the early postpartum period (Beede, 1996b). The addition of anions to the ration to reduce the DCAD is limited because of palatability issues associated with anionic salt sources commonly used (Oetzel and Barmore, 1993; Beede, 1996b). Reducing cation levels by minimizing the amount of K and Na included in the diet is more effective. Including low K forages will reduce the DCAD and minimize the occurrence of milk fever.

Prevention of milk fever is critical for a variety of reasons. The average estimated cost per case of milk fever is $181 (Guard, 2003). In addition to cost, an estimated loss of 127.7kg of milk a 13 day delayed conception rate has also been noticed (Guard, 2003). Milk fever also increases the chances for more metabolic disorders to occur. Curtis et al. (1983) report cows recovering from milk fever have an eight fold greater incidence of ketosis and mastitis. Other related health disorders likely to occur in response to milk fever include: retained fetal membranes, left displacement of the abomasum, dystocia, and uterine prolapses (Horst et al., 1997).

INTRODUCTION

Phosphorus and K are essential nutrients needed for a variety of functions within dairy cattle. Both nutrients are required to support maintenance, growth, lactating, and pregnancy. Specifically, P has more known biological functions than any other mineral element (NRC, 2001). Phosphorus contributes to the formation of bone and teeth, is involved with energy metabolism, and is required by ruminal microbes for digestion of cellulose and synthesis of microbial protein (NRC, 2001). Potassium is the major intracellular electrolyte and is involved in acid-base regulation. In addition, K is required for nerve impulse transmission, muscle contraction as well as a cofactor in many enzymatic reactions.

In 1951, Hignett and Hignett made the seminal observation that P improved conception rate in dairy cattle. However, this improvement in conception rate was relative to cows consuming P deficient diets (less than 0.25%). Therefore, over the last 50 years the importance of the concentration of dietary P on reproductive performance has been overemphasized. In a field survey, Sink et al. (2000) reported that Virginia dairy producers were feeding 0.49% P. Similarly, Wu et al. (2000) reported that the average U.S. dairy producer fed 0.45 to 0.50% P. Recently, dietary P requirements have been reduced to 0.38% (NRC, 2001) compared to 0.41% P (NRC, 1989) for a cow producing 53 kg milk/d.

The reduction in dietary P was initiated because of the negative impact P can have on the environment. Of all of the essential dietary minerals for dairy cattle, P represents the greatest potential risk for environmental damage via pollution of surface water (NRC, 2001). Over enrichment of surface water with P accelerates the development of algal blooms. The rapid growth of algae leads to eutrophication which depletes dissolved oxygen levels and creates toxins within the water resulting in fish kills. The concentration of P in the feces is positively correlated to the concentration of P in the diet (Morse et al., 1992). Therefore, feeding P in excess of requirements will result in greater amounts of P being excreted. Recycling of P to crops, at rates greater than crop needs, allows P to accumulate in soil; increasing the amount of P available to potentially enter surface water. Thus, managing dietary P levels to reduce P excretion should minimize environmental contamination.

When applied in excess, some nutrients accumulate within the plant instead of the soil. Forges have the ability to consume K in luxury amounts (Brady and Weil, 1999). When excess K is applied to soil, this excess K is mirrored within the forage. Since forages are the primary feed ingredients of the prepartum cow's diet, the use of high K forages increases the incidence of parturient paresis (milk fever) (Goff and Horst, 1997; Horst et al., 1997), which can lead to other metabolic diseases (Curtis et al., 1993). In 1998, Crill reported that Oregon dairy producers were overfeeding K in prepartum diets.

The objectives of this study were 1) to determine if Oregon dairy producers have adapted new P feeding recommendations, and 2) to follow the progress of K feeding levels in dry cow rations.

MATERIALS AND METHODS

A field study consisting of 37 Oregon dairy farms was conducted for a ten-month duration beginning July 2002. Participants were commissioned with the help of extension newsletters and personal communication at dairy related meetings. Participating farms were located in the western region of Oregon and were divided in two regions based upon geographic location of farms: valley (V) and coast (C). V comprised 17 farms residing in the Willamette Valley, located in the following counties: Benton, Clackamas, Marion, Lane, Linn, Polk, Washington, and Yamhill. The remaining 20 farms were assigned to C and located on the coast of Oregon in Coos and Tillamook counties. In addition to geographic location, farms were classified either as small (S) or large (L) according to herd size. Farms with herd size smaller than the herd size median, for each region, were classified as S, likewise, farms with herd size larger than herd size median, for each region, were classified as L.

Each farm was visited on three separate occasions with a one to two month span between each visit. The time between each visit was determined by schedule of both the researchers and producers. Visits for grazing operations were arranged to include a minimum of one visit during the grazing period and a minimum of one visit while animals were in confinement. Results were reported to each producer upon completion of the study.

Data Collection

Survey and record collection. During the initial visit, a five-page survey was issued to dairy producers as a tool to assess the dairy farmer's knowledge of P and K.

The survey by Russelle et al. (2000) provided the framework for the survey used in this study (Appendix A). Several questions from the original survey were removed and/or adapted to be more applicable to dairy farming practices in the state of Oregon. Five topics were covered by this survey: 'soil testing and commercial fertilizer use', 'P information', 'K information', 'manure management', and 'your views and your farm'. The majority of the questions were multiple choice; however, the survey also contained a few fill in the blank questions. The survey was conducted in a manner that was compliant with the regulations of the Oregon State University Institutional Review Board, therefore completion of the survey was voluntary and all results remained anonymous.

Survey results were recorded and response percentages were tabulated for each question. A point system was devised to measure the accuracy of responses for multiple choice and true-false questions. An overall score for P and K questions was determined by summing the points received for each response within each question. This score was then divided by the total number of responses for that individual question.

On the final visit, producers that were identified as members of the Dairy Herd Improvement Association (DHIA) supplied herd summary reports. Parameters of interest on DHIA reports included reproductive performance and milk yield. The majority of producers provided a herd summary report.

Feed and ration analysis. During each farm visit, diets from all lactating and dry cow groups were recorded. Individual feed components of the rations were collected and analyzed for P and K. Wet forages, grains, concentrates and mineral mixes were collected via grab sample from the storage container (i.e., bunker silos, bins, commodity barns, and bags). Dry baled forages and wrapped and ensiled bales were collected using the Penn State Forage Sampler (a stainless steel, 2.9 x 45.7 cm corer). Five to 15 bales were selected at random and cored. For those farms grazing, pasture clippings were collected. Five to ten 30 cm^2 areas of representative pasture were clipped to grazing height. Wet feed ingredients were stored at -20 °C until a later date. Feed samples were dried in a forced air oven at 55 °C for 48 hours and ground through a 1-mm screen using a Thomas-Wiley Mill. Feed samples were prepared for mineral analysis by dry ashing (AOAC, 1995). Phosphorus was determined by the spectrophtometric molybdovanadophosphate method (AOAC, 1995) and K was determined by atomic absorption spectrophotometry (AOAC, 1995). Phosphorus and K content was determined, on a dry matter basis, for each diet recorded.

Fecal and urine collection. Fecal and urine samples were collected from each of the groups of lactating and dry cows in which the diets were recorded. Fresh feces (as excreted) were collected off the flooring surface or ground with caution to insure that feces were not contaminated with foreign particles (i.e. bedding, dirt). Small handfuls of feces were collected from 10 to 25 different piles, sealed in a plastic bag and frozen at -20 °C until a later date. Frozen fecal samples were dried in a forced air oven (55 °C) for 72 to 96 h and ground to 1-mm particle size using a Thomas-Wiley Mill. Fecal samples were analyzed for P and K using the same method as for feed analysis.

Urine samples were collected via external stimulation of the vulva. Urine was randomly collected from cows (two to nine) within each group and pooled. A 30 ml subsample was transferred into a plastic tube containing 2-μL of nitric acid, sealed and frozen (-20 °C) until lab analysis. Urine samples were analyzed for K using the same method as for feed. Urine P was determined using commercially available kit (Sigma Procedure #360-3; St. Louis, MO).

Statistical Analysis

Multiple lactating and dry cow diets existed on several of the farms visited. Many of the producers grouped cows (i.e. according to stage of lactation and/or number of lactations) to more closely meet nutrient requirements. As a result of grouping strategies on farms, each of the differing cow group diets were recorded and subsequent fecal and urine samples were collected. On average, the number of lactating and dry diets fed on farms was 2 and 1.4, respectively. In most cases, group size was recorded or obtained from DHI records. Consideration was given to group size in proportion to entire lactating/dry cow herd so each group was weighted appropriately when determining total P and K fed and excreted on the farm. The weighted average value was used to compare farms with multiple groups to those farms with single groups of lactating and dry cows. Due to multiple rations fed to cows within each farm, dietary, fecal and urinary P and K were reduced to one weighted mean for each of the six variables. Data were analyzed as repeated measures using the mixed procedure of SAS (1996). Differences were considered significant at $P < 0.05$. All results are reported as least square means. The linear model was:

$$Y_{ijk} = \mu + R_i + H_j + V_k + (RxH)_{ij} + (RxV)_{ik} + (HxV)_{jk} + (RxHxV)_{ijk} + e_{ijk}$$

Where μ = overall mean,

R_i = effect of region (i = C or V),
H_j = effect of herdsize (j = S or L),
V_k = effect of visit (k = 1, 2 or 3),
$(RxH)_{ij}$ = effect of interaction of R_i and H_j,
$(RxV)_{ik}$ = effect of interaction of R_i and V_k,
$(HxV)_{jk}$ = effect of interaction of H_j and V_k,
$(RxHxV)_{ijk}$ = effect of interaction of R_i, H_j, and V_k,
e_{ijk} = residual error.

RESULTS AND DISCUSSION

Description of Farms and Data Collection

Average herd size was 339 cows and ranged from 50 to 1650 cows. Average overall production was 30.8 kg milk at 4.0% fat. Milk yield was higher in the V because of the predominance of Holstein cattle within the herds. Jersey cattle were more frequently found on the C. On average, 112 hectares received manure application and the ratio of average area receiving manure to number of cows was 0.33:1. Interestingly, 96.8% of the farms surveyed, have surface water within or bordering property such as lake/pond, stream/river/creek or seasonal stream. Characteristics of farms are shown in Table 3.1.

Valley herds were larger than coastal herds, 517 versus 189 cows. The median for each region was 325 and 157 for V and C, respectively. The median was used to divide farms into S and L herds. Using the region appropriate median, herdsizes larger than the median were classified as L and herd sizes smaller than the median were classified as S. In addition to differences in herd size between the two regions, management practices differed between regions. In general, farms in the V were total confinement and grazing occurred less frequently when compared to C farms. The ratio of average number of hectares that received manure annually compared to number of cows was lowest for LV farms and highest for CS farms.

Table 3.1. Characteristics of participant farms by region and herdsize.

	Region			
	Coast		Valley	
Characteristic	Small	Large	Small	Large
Farms	10	10	8	9
Herdsize, cows	101	278	198	800
Milk yield, kg/d	25.6	29.5	35.3	35.5
Grazing farms	9	8	6	3
Grazing months	7.7	7.0	6.3	7.3
Total area receiving manure, ha	69.7	118.3	84.7	173.4
Owned	47.4	73.3	37.3	135.7
Rented	22.3	45.0	47.4	37.7
Hectares: Cows	0.69	0.43	0.43	0.22
Bordering bodies of water, farms	8	10	7	8

During visits, some farms were not able to provide accurate measure of daily feed intake while cows were grazing. Although producers were unsure of pasture intake, they knew amounts of concentrate and/or baled hay being fed. In these cases, total dry matter intake was predicted according to NRC (2001), and pasture intake was calculated by difference. Three variables were required for the DMI prediction equation: body weight, milk production and percentage of milk fat. Body weights of 682 and 500 kg for Holstein and Jersey, respectively, were used. Values for milk yield and milk fat percentage was taken from DHI records collected during farm visits. Valley farms were more apt to provide accurate ration information compared to Coast farms, since V producers had access to feeding practices which used scales to determine quantity of feed ingredients.

Since dietary P and K in excess of requirements are excreted in feces and urine, respectively, both fecal and urinary fractions were collected. Using book values for manure nutrient estimations could be problematic because the discrepancies between book standards and measured farm data varied widely from a small amount to several fold (Dou et al., 2001). The variability of fresh samples is less than stored manure (Dou et al., 2001), thus making the collection of fresh samples ideal. Several obstacles occurred during urine collection which limited the number of samples collected. Some farms visited did not have restraining devices (i.e. head lock-ups) accessible during collection, either because facilities did not contain these devices or cows were inaccessible to devices (i.e. cows were grazing). However, when using restraining devices, a restraint time of 15 to 20 minutes was placed to reduce lock-up time for cows and prevent a monopoly of researchers' time.

Survey

Out of the 37 surveys issued, a total of 34 surveys were completed for a 92 percent completion rate. Since the surveys were voluntary, two producers chose not to participant in the survey portion of this study. Another producer who owned/managed two of the farms completed only one survey. Although 34 of the surveys were completed and returned to researchers, participants were not required to answer all questions. The response rate for each question varied. The number of responses per question ranged from as low as 12 and as high as 53 (some questions allowed for multiple responses). Overall P and K knowledge within region were averaged separately. However, responses were numerically similar between regions, thus responses were combined and reported as a whole.

The original survey by Russelle et al. (2000) was issued to farmers in southeastern Minnesota and west central Wisconsin. Similarities in questions between the original and present survey allows for comparisons between soil testing and commercial fertilizer use, P information, manure management, and farm characteristics between the Midwest and Oregon.

Based upon the responses received from participating Oregon dairy producers, it appears that respondents were more knowledgeable about P information when compared to the Midwest producers. When asked about the P levels in manure and grass crops, 60% of Oregon respondents answered correctly, compared to a 40% correct response rate from the participating Midwest producers. Oregon respondents also had more knowledge of the rate at which P moves through the soil. However, when asked about the effect of excessive soil P on the environment, only 12% of Oregon respondents answered correctly-affects surface water. However, 61% indicated that both surface and ground water would be adversely affected by excessive soil P. By selecting the response of both surface and ground water, producers practiced more caution when considering effects of excess P in the soil, thus researchers considered this answer as a correct response. When combining the two responses, a total of 71% of Oregonian respondents are aware of the effects of excessive soil P.

Survey responses received regarding K information were as follows. When asked "what does excessive soil K affect" only 41.9% of the respondents correctly answered animal nutrition. Water quality, was also another popular answer (42%) indicated on the survey. Although K is easily leached from the soil (Brady and Weil, 1999), potential pollution caused by leaching has not been reported. Fifty-six percent of the producers surveyed were also aware that excessive K in rations can cause problems with dry cows. Finally, when asked to compare the amount of nitrogen to the amount of K in manure and in pasture, 72.7 and 57.9%, respectively, correctly responded less than.

Diet, Fecal, and Urine

The superior knowledge of P is reflected in feeding practices implemented by the farms (Table 3.2). Participating Oregon dairy producers were feeding 0.40% P (DM basis) to lactating dairy cattle. Based on milk yield, the average Oregon farm should have been feeding 0.32 to 0.35% P DM (NRC, 2001). Phosphorus levels in diets were 12 to 25% higher than currently recommended. In comparison, Sink et al. (2000) reported that Virginia dairy producers were feeding 0.49% P to lactating dairy cows.

Table 3.2. Least square mean concentration of P and K in diet, feces, and urine of lactating and dry cows.

Stage of Lactation	Region		Herdsize		SE	*P*	
	Coast	Valley	Small	Large		Region	Herdsize
Lactating							
Diet P (% DM)	0.41	0.39	0.40	0.40	0.01	0.12	0.76
Fecal P (% DM)	0.87	0.97	0.89	0.95	0.04	0.08	0.27
Urine P (mg/dl)	2.22	2.94	2.13	3.04	0.66	0.41	0.30
Diet K (% DM)	1.84	1.58	1.79	1.63	0.07	0.01	0.10
Fecal K (% DM)	0.60	0.58	0.62	0.56	0.03	0.61	0.12
Urine K (%)	1.08	0.87	1.08	0.87	0.10	0.12	0.13
Dry							
Diet P (% DM)	0.30	0.32	0.30	0.32	0.01	0.42	0.46
Fecal P (% DM)	0.77	1.02	0.88	0.91	0.07	0.01	0.71
Urine P (mg/dl)	1.40	2.05	1.52	1.94	0.26	0.08	0.25
Diet K (% DM)	2.05	1.93	2.02	1.96	0.11	0.40	0.72
Fecal K (% DM)	0.80	0.65	0.69	0.76	0.06	0.11	0.50
Urine K (%)	1.13	1.12	1.16	1.10	0.06	0.86	0.39

Dietary P levels of lactating diets between region ($P = 0.12$) or herdsize ($P = 0.76$) did not differ. A difference in feeding levels of dietary P between herdsize was expected, since L herds are more apt to use professional services, such as a nutritionist, compared to S herds. In addition, V herds were expected to have lower dietary P due to more consistent rations, since C herds graze more often.

Dietary P content of the dry cow diet was 0.31%. No difference in feeding levels of P to dry cow was detected between region (*P* = 0.42) or herdsize (*P* = 0.46). On day 240 of gestation, dietary P requirement is 0.22% and increases to 0.26% near parturition (NRC, 2001). Therefore, Oregon dairy producers are overfeeding P to dry cows by 19 to 41%. Dry cows constitute only 12 to 17% of the dairy herd; nevertheless, feeding as close to recommendations is ideal for all dairy cattle, regardless of despite stage of lactation.

Average fecal P from all lactating cow samples was 0.92% (DM basis). The overall mean for urinary P was 2.58 mg/dl. Wu et al. (2001) reported that the concentration of fecal and urinary P excreted by lactating cows consuming 0.39% P (87.6g/d) was 0.85% (DM basis) and 2.8 mg/dl, respectively. Fecal and urinary P values were similar to that of Wu et al (2001).

Oregon producers are overfeeding K to both the lactating and dry cows. Herds in the coast were feeding higher levels of K in lactating cow diet than V farms (*P* = 0.01) (Table 3.2). Lactating K content of diet for C and V herds was 1.84 and 1.58%, respectively. No difference (*P* = 0.10) in dietary K for lactating cows was found between herdsize. Dietary K for dry cows averaged 1.99% (DM basis) with no difference detected between region (*P* = 0.40) or herdsize (*P* = 0.72) (Table 3.2). Potassium feeding recommendations for lactating cow diets ranged between 1.00 to 1.07%, whereas dietary K should be limited to 0.51% in the dry cow diet (NRC, 2001). Oregon producers were overfeeding K by 58% in lactating diets and 300% in dry cow diets. Because of the implications of K and metabolic disease in dry cow diets, we expected to see lower levels than that fed to lactating cows. In 1998, average K in prepartum diets fed in Oregon was 1.67% (Crill, 1998).

The use of forages in diets contributed to the overfeeding of K to lactating and dry cows. Forages are major ingredients in rations for lactating and dry dairy cattle. Forty-six percent of the lactating diets in the V contained forages and diets in the C are composed of 58.3% forage. Forages are also a major source of K within the diets. Table 3.3 shows the concentration of K in forages collected. In general, forages collected have elevated K levels. For example, Beede (1996a) reports normal corn silage to be 0.74% K (DM basis); however, corn silage samples collected in the present were 1.27% K (DM basis). The prevalence of forages in the diet in combination with the excessive K levels found within the forages contributed to overfeeding of K.

Table 3.3. Potassium levels of forages used in the composition of rations (DM basis).

Forage Source	n	Mean K (% DM)	S D	Minimum	Maximum
Corn, cannery	13	0.99	0.19	0.65	1.27
Hay, alfalfa	147	2.73	1.07	0.98	8.10
Hay, alfalfa-grass	5	2.77	0.27	2.51	3.08
Hay, bent grass	4	1.71	1.04	0.80	3.20
Hay, clover	3	1.74	1.14	0.42	2.40
Hay, grass	32	2.03	0.94	0.98	4.86
Hay, oat	47	2.22	0.96	0.74	5.38
Pasture	39	3.00	0.86	1.27	4.77
Silage, clover	16	2.63	0.39	1.80	3.38
Silage, corn	58	1.27	0.85	0.48	4.33
Silage, grass	50	2.91	0.87	0.32	5.08
Silage, triticale	1	3.75			

Although producers overfeed K, V farms were feeding lower levels of dietary K in lactating rations (*P* = 0.01). However, there was no difference in K feeding rates in dry cow diets. This may be attributed to the fact that V farms were less likely to graze lactating cows. As shown in Table 3.3, pasture samples had higher K level (DM basis) than that of other forage sources. In addition, the estimation of pasture intake may have also contributed to the difference in K feeding levels. An overestimation of pasture intake compounded with the high K level may have contributed to the difference in K feeding levels observed. The use of corn silage contributed to the reduced K feeding levels in milking cow rations.

Dietary K can affect dry cow health. Excess K has been shown to cause milk fever in the just fresh cow (Goff and Horst, 1997; Horst et al., 1997). In addition, milk fever increases the risk of other metabolic disorders, such as mastitis, left displaced abomasum and retained fetal membranes (Horst et al., 1997). Although Crill (1998) reported excessive levels of K in the prepartum diets (1.67% K), the incidence of milk fever was only 3.6%, which was lower than national average (Crill, 1998). The occurrence rate of other metabolic disorders associated with calving, such as retained fetal membranes, left-displaced abomasums and early post partum mastitis, were within the normal range (Crill, 1997). Unfortunately, occurrence of metabolic disorders was not recording during this study thus, no comparisons can occur.

Interestingly, although diet P was similar for region and herd size, the fecal P output was greater (*P* = 0.08) for V herds, resulting in a lower apparent digestibility for V herds (Table 3.4). Total fecal and urine output and apparent digestibility were predicted using equations developed by Nennich et al. (2002). Average overall production was 30.8 kg milk at 4.0% fat, therefore predicted DMI is 24.4 kg thus 64.3 g/d of P is estimated to be excreted at the 0.40% feeding level. A net absorption and apparent digestibility for P, at 0.40%, would be 32.7 g/d and 34%, respectively. An apparent digestibility of less than 40% may be indicative of excess P intake (Wu et al., 2000), thus P should be reduced in lactating rations. The apparent digestibility predicted for C, V, S, and L were 39.2, 28.6, 36.1 and 32.0%, respectively. Comparison between VS, VL, CS, and CL produced an apparent digestibility of 28.8, 26.7, 42.5, and 34.7%, respectively. Again, V farms had lower apparent P digestibility in lactating cow diets when compared to C. Research determining the availability of P within feedstuffs is limited to only a few feeds. The P absorption coefficient has been determined for alfalfa hay and corn silage fed to lactating cows (Martz et al., 1990) and corn silage fed to dry cows (Martz et al., 1999). As shown in Table 3.5, by-product feeds such as beet pulp, canola, distillers, soybean meal and whole cottonseed were more commonly fed on V farms (Table 3.5). Researchers speculate that the availability of P from these feedstuffs is low and thus caused a decrease in apparent digestibility. In addition, the V dry cows also excreted more fecal P ($P = 0.01$) when compared to C, resulting in a lower apparent digestibility, 23.2 versus 38.8% for V and C, respectively. When comparing dry cow feed ingredients between the two regions, the feeding rate of these by-products did not differ readily. Although feed ingredients may not have differed as much, they still were fed at higher rates. Corn silage was the only feed ingredient that was more frequently fed in both dry and lactating rations in the V.

Table 3.4 Calculated daily (g/d) P and K intake and excretion for lactating and dry cows.

Stage of Lactation	Region		Herdsize	
	Coast	Valley	Small	Large
Lactating				
Diet P	92.1	87.6	89.8	89.8
Fecal P	61.6	68.6	63.0	67.2
Urine P	0.50	0.66	0.48	0.68
Apparent P Digestibility (%)	36.7	27.7	33.6	29.2
Diet K	413.3	354.9	402.0	366.8
Fecal K	42.5	41.0	43.9	39.6
Urine K	251.4	202.5	251.4	202.5
Dry				
Diet P	47.6	50.8	47.6	50.8
Fecal P	27.2	36.1	31.1	32.2
Urine P	0.30	0.50	0.30	0.40
Diet K	325.5	306.5	320.8	311.3
Fecal K	56.6	46.0	48.8	53.8
Urine K	263.0	260.7	270.0	256.0

Lactating DMI of 20.3, 21.6, 20.4, and 21.5kg/d assumed for C, V, S, and L, respectively.

Dry cow DMI of 16.6 kg/d, assumed.

Table 3.5. Comparison of frequency of feedstuffs between regions in lactating and dry cow rations.

Feedstuffs	P (%DM)	Frequency of use (%)			
		Lactating		Dry	
		Coast	Valley	Coast	Valley
Alfalfa	0.25	85.0	98.0	30.0	70.6
Amino Plus®	0.61	-	5.9	-	-
Apples	0.09	-	5.9	-	5.9
Barley	0.30	-	19.6	-	5.9
Beet pulp	0.10	5.0	49.0	-	15.7
Bent grass straw	0.10	-	-	-	7.8
Brewers malt	0.24	-	5.9	-	-
Cannery silage	0.30	11.7	9.8	5.0	9.8
Canola meal	0.97	-	37.3	-	23.5
Citrus pulp	0.11	3.3	13.7	-	3.9
Clover, harvested	0.17	5.0	31.4	5.0	21.6
Corn grain	0.20	8.3	3.9	8.3	54.9
Corn silage	0.22	25.0	86.3	-	60.8
Distillers	0.69	10.0	52.9	5.0	31.4
Flax	0.78	-	9.8	-	2.0
Grain	0.63	90.0	23.5	31.7	9.8
Grain (close-up)	1.04	-	-	6.7	13.7
Grass, harvested	0.20	30.0	49.0	53.3	60.8
Green beans	0.29	1.7	2.0	-	2.0
High fat pellet	0.58	-	3.9	-	-
High-P mineral	6.94	10.0	5.9	-	-
Mineral (dry)	2.02	-	-	1.7	84.3
Mineral (milk)	1.35	16.7	84.3	-	-
Oat hay	0.21	10.0	9.8	20.0	47.1
Oats	0.30	-	9.8	-	-
Pasture	0.28	46.7	21.6	21.7	2.0
Roasted soybean	0.43	-	3.9	-	-
Ryegrass hay	1.00	-	-	-	2.0
Ryegrass screenings	0.22	-	2.0	-	5.9
Screenings	0.70	5.0	-	5.0	-
Soy hulls	0.12	-	3.9	-	3.9
Soy Pass®	0.68	-	3.9	-	5.9
Soybean meal	0.81	-	41.2	-	21.6
Triticale silage	0.39	-	-	-	2.0
Wheat	0.22	-	5.9	-	-
Wheat millrun	0.53	-	9.8	-	5.9
Whole cotton seed	0.72	20.0	68.6	-	17.6
Whole cotton seed, beet pulp, corn	0.28	8.3	-	5.0	-

Application Rates of P and K

Total amount of manure produced by lactating cows can be calculated based upon the results obtained from Table 3.4. The average lactating cow excreted 65.1g of P and 41.7g of K in feces (Table 3.4) on a daily basis. On average, 0.58 and 227 g/d of P and K, respectively, will be excreted in the urine. Combining the fecal and urinary fractions, a lactating cow consuming 0.40% (89.8g/d) P and 1.71% (384.3g/d) K will excrete 24.0 kg P and 98.0 kg K annually. According to Hart et al. (1997), each year a 625 kg cow producing 31.3 kg of milk/d will excrete the following amounts of nutrients in manure: 20.1 kg of P and 73.6 kg of K. Compared to Hart et al., (1997) P and K excretion is atypically high and is a reflection of the overfeeding of P and K in the lactating cow diet.

Since fresh fecal samples were collected, it would be inaccurate to assume this is amount of P and K would be available for crop production. The final nutrient profile of manure is affected by duration and type of storage. From the animal source through field application, 5 to 15% of the original P and K are lost in handling (Moore and Gamroth, 1993). If 15% of the calculated manure P and K were lost, a total of 20.4 and 83.3 kg/head of P and K, respectively, would be applied to cropland annually. To use these nutrients efficiently and responsibly, application rates should be consistent to that of the crop removal rate. The rate at which nutrients are removed depends upon crop type, yield, geographic location, and management (i.e. irrigation). The application rate of P and K to pasture land are reported in Table 3.6 (Miner, 1995). Using the plant available P and K values, the average amount of P excreted annually in C and V was 3850 and 10,166 kg, respectively whereas the average amount of K excreted annually in C and V was 15,755 and 41,597 kg, respectively. Based upon the annual manure production of P and K and the agronomic application rate for pastures (Table 3.6), the number of ha needed for the application of P and K are summarized in Table 3.7.

Table 3.6. Recommended nutrient application rates for pastures, by location, harvested or grazed (kg/ha).

Region	Harvested		Grazed	
	P	K	P	K
Coast	30.9	145.5	26.5	121.3
Valley				
Irrigated	26.5	132.3	24.3	110.2
Non irrigated	23.1	104.7	22.0	101.4

Table 3.7. Nutrient coverage for pastures, by location, harvested or grazed (ha).

Region	Harvested		Grazed	
	P	K	P	K
Coast	124.6	108.3	145.3	129.9
Valley				
Irrigated	383.6	314.4	418.4	377.5
Non irrigated	440.1	397.3	462.1	410.2

With the amount of available P and K excreted annually, there are excessive amount of nutrients available to supply crop needs. Based on 94 and 129 ha, for C and V respectively, P and K are being applied in excess of crop requirement. To dispose of this P at an agronomical rate, approximately 0.53 ha of land would be required for each lactating cow/yr (Hoards' Dairyman staff article, 2002). The average number of hectares which receive manure and number of cows per farm was 112.2 and 339, respectively, which are approximately three-tenths ha/cow. Therefore, Oregon producers need an additional two-tenths of a ha to prevent the over application of P. However, not all farms are over applying nutrients. When using the above application rate for the current P feeding level, some farms (n = 4) do not have enough manure for all of the available crop land. Furthermore, in discussion with producers during data collection, two farmers were exporting solids off the farm which will reduce the amount of P, and some K, applied to land.

In addition to over application of P, the application method of manure may increase the susceptibility for P runoff. The majority (89.4%) of manure is applied by broadcast, without incorporation. Manure, or fertilizer, that is left unincorporated on the surface of cropland or pastures usually leads to increase losses of P dissolved in runoff water (Brady and Weil, 1999).

CONCLUSION

Oregon dairy producers are slightly overfeeding P in lactating cow rations. A potential problem may exist with the limited land base which receives manure. The inability to apply manure at agronomic rates leads to accumulation of soil P and the potential for surface water damage. This should be of concern since the majority of Oregon producers reported surface water borders farm property.

Potassium in lactating and dry cow rations is in excess of feeding recommendations. The use of high K forages significantly contributes to the elevated levels of K within the diet, primarily in dry cow diets. Because of this, the amount of K excreted in manure is in excess of typical K excretions. The high level of K excreted in combination with the small land base which receives the manure, contributes to the K available for forage uptake and compounds the problem of high K forages.

BIBLIOGRAPHY

Agricultural Research Council. The Nutrient Requirements of Farm Livestock, No. 2 Ruminants. 1965, London.

Alderman, G. 1963. Mineral nutrition and reproduction in cattle. Vet. Record. 75:1015-1018.

Andraski, T. W., and L. G. Bundy. 2003. Relationship between phosphorus levels in soils and in runoff from corn production systems. J. Environ. Qual. 32:310-316.

AOAC. 1995. Official Methods of Analysis (16th Ed.). Assoc. of Official Analytical Chemists, Arlington, VA.

Beede, D. K. 1996 a. Cation-anion difference in dairy rations: dealing with high potassium content of alfalfa. Pages 30-37 *in* Proc. 26th Natl. Alfalfa Symp., Kellogg Center, East Lansing, MI.

Beede, D. K. 1996 b. Update on cation-anion difference in dairy rations. Pages 73-85 *in* Proc. Professional Dairy Management Seminar, Dubuque, IA.

Bethard, G., and S. Stokes. 2000. Managing transition cows for better health and production. Western Regional Extension Publication. WREP 149.

Boesch, D. F., R. B. Brinsfield, and R. E. Magnien. 2001. Chesapeake bay eutrophication: scientific understanding, ecosystem restoration, and challenges for agriculture. J. Environ. Qual. 30:303-320.

Brady, N. C., and R. R. Weil. 1999. The nature and properties of soils. (12th Ed.). Prentice-Hall, Inc., Upper Saddle River, NJ.

Braithwaite, G. D. 1985. Some observations on phosphorus homeostasis and requirements of sheep. J. Agric. Sci. 102:295-306.

Brintup, R., T. Mooren, U. Meyer, H. Spiekers, and E. Pfeffer. 1993. Effects of two levels of phosphorus intake on performance and fecal phosphorus excretion of dairy cows. J. Anim. Physiol. Anim. Nutr. 69:29-36.

Brodison, J. A., E. A. Goodall, J. D. Armstrong, D. I. Givens, F. J., Gordon, W. J. McCaughey, and J. R. Todd. 1989. Influence of dietary phosphorus on the performance of lactating dairy cattle. J. Agric. Sci. (Camb.) 112:303-311.

Call, J. W., J. E. Butcher, J. L. Shape, R. C. Lamb, R. L. Woman, and A. E. Olson. 1987. Clinical effects of low dietary phosphorus concentrations in feed given to lactating cows. Am. J. Vet. Res. 48:133-136.

Carstairs, J. A., R. R. Neitzel, and R. S. Emery. 1981. Energy and phosphorus status as factors affecting postpartum performance and health of dairy cows. J. Dairy Sci. 64:34-41.

Challa, J., and G. D. Braithwaite. 1989. Phosphorus and calcium metabolism in growing calves with special emphasis on phosphorus homoeostasis. 1. Studies of the effect of change in the dietary phosphorus intake on phosphorus and calcium metabolism. J. Agric. Sci. (Camb.) 110:573-581.

Challa, J., G. D. Braithwaite, and M. S. Dhanoa. 1989. Phosphorus homoeostasis in growing calves. J. Agric. Sci. (Camb.) 112:217-226.

Chase, L. E. Phosphorus nutrition of dairy cattle-update. November 11, 1999. http://www.ansci.cornell.edu/dm/dm.html. Accessed January 15, 2003.

Church, D. C. 1988. The ruminant animal: Digestive physiology and nutrition. Waveland Press, Inc, Prospect Heights, IL.

Clark Jr., W. D., J. E. Wohlt, R. L. Gilbreath, and P. K Zajac. 1986. Phytate phosphorus intake and disappearance in the gastrointestinal tract of high producing dairy cows. J. Dairy Sci. 69:3151-3155.

Council for Agricultural Science and Technology (CAST). July 2002. Animal diet modification to decrease the potential for nitrogen and phosphorus pollution-Issue paper. 4420 West Lincoln Way, Ames, Iowa.

Crill, R. L. 1998. Potassium disorders associated with high potassium forages in Holstein cows. M.S. Thesis, Oregon State Univ., Corvallis.

Curtis, C. R., H. N. Erb, C. J. Sniffen, and R. D. Smith. 1984. Epidemiology of parturient paresis: Predisposing factors with emphasis on dry cow feeding and management. J. Dairy Sci. 67:817-825.

Curtis, C. R., H. N. Erb, C. J. Sniffen, R. D. Smith, P. A. Powers, M. C. Smith, M. E. White, R. B. Hillman, and E. J. Pearson. 1983. Association of parturient hypocalemia with eight periparturient disorders in Holstein cows. J. Am. Vet. Medical Assoc. 183:559-561.

De Boer, G., J. G. Buchanan-Smith, G. K. Macleod ,and J. S. Walton. 1981. Responses of dairy cows fed alfalfa silage supplemented with phosphorus, copper, zinc, and manganese. J. Dairy Sci. 64:2370-2377.

Dou Z. and J.D. Ferguson. 2001. Dairy Producer Survey: Phosphorus feeding management on northeast and Mid-Atlantic Dairy Farms. http://cahpwww.vet.upenn.edu/ifafs/survey_results.pdf. Accessed July 1, 2003.

Dou Z., D. T. Galligan, R. D. Allshouse, J. D. Toth, C. F. Ramberg, Jr., and J. D. Ferguson. 2001. Manure sampling for nutrient analysis; variability and sampling efficacy. J. Environ. Qual. 30: 1432-7.

Dou, Z., K. F. Knowlton, R. A. Kohn, Z. Wu, L. D. Satter, G. Zhang, J.D. Toth, and J.D. Ferguson. 2002. Phosphorus characteristics of dairy feces affected by diets. J. Environ. Qual. 31:2058-2065.

Downing, T. 2002. Nitrogen, phosphorus, and potassium uptake in perennial grasses fertilized with dairy manure. Oregon State University Extension Service. Special Report 1043.

Ellis, K.V, G. White and A. E. Warn. 1989. Surface water pollution and its control. MacMillan Press LTD, England.

Forar, F. L., R. L. Kincaid, R. L. Preston, and J. K. Hillers. 1982. Variation of inorganic phosphorus in blood plasma and milk of lactating cows. J. Dairy Sci. 65:760-763.

French, P. D. 2003. Personal Communication.

Goff, J. P, T. A. Reinhardt, and R. L. Horst. 1991. Enzymes and factors controlling vitamin D metabolism and action in normal and milk fever cows. J. Dairy Sci 74:4022-4032.

Goff, J. P., and R. L. Horst. 1997. Effects of the addition of potassium or sodium, but not calcium, to prepartum rations on milk fever in dairy cows. J. Dairy Sci. 80:176-186.

Goff, J. P., T. A. Reinhardt, D. B. Beitz, and R. L. Horst. 1995. Breed affects tissue vitamin D recptor concentration in periparturient dairy cows: a milk fever risk factor? J. Dairy Sci. 78 (Suppl.)1: 184 (Abstr.)

Grunes, D. L., and R. M. Welch. 1989. Plant contents of magnesium, calcium and potassium in relation to ruminant nutrition. J. Anim. Sci. 67:3485-3494.

Guard, C. 2003. Controlling fresh cow disease costs. Page W98 *in* Hoard's Dairyman, W.D Hoards and Sons Company, Fort Atkinson, WI.

Hart, J, M. Gangwer, M. Graham, and E. S. Marx. 1997. Dairy manure as a fertilizer source. Oregon State University Extension Service. EM 8586.

Hemken, R. W. 1983. Potassium in ruminant nutrition. Page 1 *in* Sodium and potassium in ruminant nutrition. West Des Moines: Natl. Feed Ingredients Assoc., IA.

Hignett, S. L and P. G. Hignett. 1951. The influence of nutrition on reproductive efficiency in cattle. Vet. Rec. 63:603-609.

Hoard's Dairyman staff article. 2002. Balance dietary phosphorus with spreadable acres. Page 180 *in* Hoard's Dairyman. W.K. Hoard and Sons Co., Fort Atkinson, WI.

Horst, R. L., J. P. Goff, T. A. Reinhardt, and D.R. Buxton. 1997. Strategies for preventing milk fever in dairy cattle. J. Dairy Sci. 80:1269-1280.

Khorasani, G. R., R. A. Janzen, W. B. McGill, and J. J. Kennelly. 1997. Site and extent of mineral absorption in lactating cows fed whole-crop cereal grain silage or alfalfa silage. J. Anim. Sci. 75:239-248.

Kincaid, R. L. 1999. Assessment of trace mineral status of ruminants: A review. Pages 154-172 *in* Proc. of the Am. Soc. of Anim. Sci.

Kincaid, R. L., J. K. Hillers, and J. D. Cronrath. 1981. Calcium and phosphorus supplementation of rations for lactating cows. J. Dairy Sci. 64:754-758.

Knowlton, K. F., and J. H. Herbein. 2002. Phosphorus partitioning during early lactation in dairy cows fed diets varying in phosphorus content. J. Dairy Sci. 85:1227-1236.

Knowlton, K. F., and R. Kohn. 1999. Feeding management to reduce phosphorus losses from dairy farms. Pages 63-71 *in* Proc. Mid Atlantic Dairy Management Conf., Hershey, PA.

Knowlton, K. F., J. H. Herbein, M. A. Meister-Weisbarth, and W. A. Wark. 2001. Nitrogen and phosphorus partitioning in lactating Holstein cows fed different sources of dietary protein and phosphorus. J. Dairy Sci. 84:1210-1217.

Littell, R.C., G.A. Milliken, W. W. Stroup, and R.D. Wolfinger. 1996. SAS® System for Mixed Models. SAS Inst., Inc., Cary, NC.

Lutz, J. A., Jr. 1973. Effects of potassium fertilization on yield and K content of alfalfa and on availability of subsoil K. Commun. Soil. Sci. Plant Anal. 4:57-65.

Martz, F. A., A. T. Belo, M. F. Weiss, and R. L. Belyea. 1990. True absorption of calcium and phosphorus from alfalfa and corn silage when fed to lactating cows. J. Dairy Sci. 73:1288-1295.

Martz, F. A., A. T. Belo, M. F. Weiss, and R. L. Belyea. 1999. True absorption of calcium and phosphorus from corn silage fed to nonlactating, pregnant dairy cows. J. Dairy Sci. 82:618-622.

McDowell, L. R. 1992. Minerals in animal and human nutrition. Academic Press inc., San Diego, CA.

Miller, D. A, and H. F. Reetz, Jr. 1985. Forage fertilization. Pages 71-87 *in* Forages, an introduction to grassland agriculture. R. F. Barnes, D. A. Miller and C. J Nelson, ed. Iowa State Univ. Press, Ames.

Miner, R. 1995. Reducing the risk of groundwater contamination from livestock manure management. Oregon State University Extension Service. EM 8597.

Moore, J. A., and M. J. Gamroth. 1993. Calculating the fertilizer value of manure from livestock operations. Oregon State University Extension Service. EC 1094.

Morse, D., H. H. Head, and C. J. Wilcox. Disappearance of phosphorus in phytate from concentrates in vitro and from rations fed to lactating dairy cows. J. Dairy Sci. 75:1979-1986.

Morse, D., H. H. Head, C. J. Wilcox, H. H. Van Horn, C. D. Hissem, and B. Harris, Jr. 1992. Effects of concentration of dietary phosphorus on amount and route of excretion. J. Dairy Sci. 75:3039-3049.

National Research Council. 1971. Nutrient Requirement of Dairy Cattle (4th Rev. Ed.) Natl. Acad. Sci., Washington D.C.

National Research Council. 1978. Nutrient Requirement of Dairy Cattle (5th Rev. Ed.) Natl. Acad. Sci., Washington D.C.

National Research Council. 1989. Nutrient Requirement of Dairy Cattle (6th rev. Ed.) Natl. Acad. Sci., Washington, DC.

National Research Council. 2001. Nutrient Requirement of Dairy Cattle (7th rev. Ed.) Natl. Acad. Sci., Washington, DC.

Nennich, T. D., J. H. Harrison, L. M. Johnson, D. Meyer, A. J. Heinrichs, W. Weiss, N. R. St-Pierre, R. L. Kincaid, D. Davidson, and E. Block. 2002. Prediction of manure output from dairy cattle. Page 183 *in* Proc. Pacific Northwest Anim. Nutr. Conf., Vancouver, BC.

Oetzel, G. R., and J. A. Barmore. 1993. Intake of a concentrate mixture containing various anionic salts fed to pregnant, non-lactating cows. J. Dairy Sci. 76:1617-1623.

Possin, I. February 2002. Briefings: A report from UW-Extension, Fond du Lac County. http://www.uwex.edu/ces/cty/fonddulac/documents/brffeb02.pdf. Accessed July 1, 2003.

Powell, J. M., Z. Wu, and L. D. Satter. 2001. Dairy diet effects on phosphorus cycles of cropland. J. Soil Water Conserv. 56:22-26.

Preston, R. L., N. L. Jacobson, K. D. Wigger, M. H. Wigger, and G. N. Jacobson. 1977. Phosphorus in ruminant nutrition. Natl. Feed Ingredients Assoc., West Des Moines, Iowa.

Robinson, J. S., A. N. Sharpley, and S. J. Smith. 1995. The effect of animal manure applications on the forms of phosphorus. Pages 43-48 *in* Animal Waste and the Land-Water Interface. CRC Press, Boca Raton, Florida.

Russelle, M, M. Schmitt, J. M. Powell, and C. Hasthorpe. 1999. Forages show little response to high soil P levels. Pages 4-5 *in* Research summaries. US Dairy Forage Research Center, Univ. of Minnesota, Agriculture Victoria, and US Dairy Forage Research Center.

Russelle, M., M. Schmitt, C. Hasthorpe, and J. M. Powell. 2000. What do you know and what will you do about P? A survey of dairy farmers. US Dairy Forage

Research Center, Univ. of Minnesota, Agriculture Victoria, and US Dairy Forage Research Center. Personal Communication.

Ryden, J. C., J. K. Syers, and R. F. Harris. 1973. Phosphorus in runoff and streams. Adv. Agron. 25:1-45.

SAS User's Guide: Statistics, Version 8 Ed. 1999. SAS Inst., Inc., Cary, NC.

Satter, L. D., and Z. Wu. 2001. Phosphorus nutrition of dairy cattle-what's new? US Dairy Forage Research Center USDA-Agriculture Research Service and Dairy Science Department University of Wisconsin Madison. http://www.ansci.cornell.edu/tmplobs/doc181.pdf. Accessed January 15, 2003.

Sharpley, A. N. 1996. Myths about phosphorus. Pages 60-67 *in* Proc. from Anim. Agric. and the Environ. North Am. Conf. Rochester, NY.

Sharpley, A. N., and B. Moyer. 2000. Phosphorus forms in manure and compost and their release during simulated rainfall. J. Environ. Qual. 29:1462-1469.

Sharpley, A. N., and S. Rekolainen. 1997. Phosphorus in agriculture and its environmental implications *in* Phosphorus loss from soil to water. CAB International, New York, NY.

Sims, J. T., R. R. Simard, and B. C. Joern. 1998. Phosphorus loss in agriculture drainage: Historical perspective and current research. J. Environ. Qual. 27:277-293.

Sink, S. E., K. F. Knowlton, and J. H. Herbein. 2000. Economic and environmental implications of overfeeding phosphorus on Virginia dairy farms. J. Anim. Sci. 78 (Suppl. 2): 4. (Abstr.).

Soder, K. J., and W. L Stout. 2003. Effect of soil type and fertilization level on mineral concentration of pasture: Potential relationships to ruminant performance and health. J. Anim. Sci. 81:1603-1610.

Spears, R. A., A. J. Young and R. A. Kohn. 2002. Whole-farm phosphorus balance on western dairy farms. J. Dairy Sci. 86:688-695.

Spiekers, H., R. Brintrup, M. Balmelli, and E. Pfeffer. 1993. Influence of dry matter intake on faecal phosphorus losses in dairy cow fed rations low in phosphorus. J. Anim. Physiol. Anim. Nutr. 69:37-43.

Steevens, B. J., L. J. Bush, J. D. Stout, and E. I. Willams. 1971. Effects of varying amounts of calcium and phosphorus in rations for dairy cows. J. Dairy Sci. 54:655-661.

Tylutki, T. 2002. Phosphorus, cow, and environment. Where can we go? Page 277 *in* Hoard's Dairyman. W.K. Hoard and Sons Co., Fort Atkinson, WI.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2003. National planning procedures handbook, subpart B, Part 600.54. http://www.nrcs.usda.gov/programs/afo/cnmp_guide_600.51.html. Accessed June 23, 2003.

United States Department of Agriculture – National Agriculture Statistics Service (USDA-NASS). Accessed: http://www.usda.gov/nass. July 3, 2003.

United States Department of Agriculture and U.S. Environmental Protection Agency (USDA USEPA). 2003. Unified national AFO strategy executive summary. http://www.epa.gov/npdes/pubs/exexsum.pdf. Accessed June 27, 2003.

Valk, H., and L. B. J. Šebek. 1999. Influence of long-term feeding of limited amounts of phosphorus on dry matter intake, milk production, and body weight of dairy cows. J. Dairy Sci. 82:2157-2163.

Valk, H., J. A. Metcalf, and P. J. A. Withers. 2000. Prospects for minimizing phosphorus excretion in ruminants by dietary manipulation. J. Environ. Qual. 29:28-36.

Valk, H., L. B. J. Šebek, and A. C. Beynen. 2002. Influence of phosphorus intake on excretion and blood plasma and saliva concentrations of phosphorus in dairy cows. J. Dairy Sci. 85:2642-2649.

Van Horn, H. H. 1994. Recycling manure nutrients to avoid environmental pollution *in* Large Dairy Herd Management. Ed H.H. Van Horn and C. J. Wilcox. Am. Dairy Sci. Assoc., Champaign, IL.

Van Saun, R. J. 1991. Dry cow nutrition-The key to improving fresh cow performance. Vet. Clin. North Am. Food Anim. Pract. 7:599-620.

Vitti, D. M. S. S., E. Kebreab, J. B. Lopes, A. L. Abdalla, F. F. R. De Carvalho, K. T. De Resende, L. A. Crompton, and J. France. 2000. A kinetic model of phosphorus metabolism in growing goats. J. Anim. Sci. 78:2706-2712.

Wu Z., L. D. Satter, A. J. Blohowiak, R. H. Stauffacher, and J. H. Wilson. 2001. Milk production, estimated phosphorus excretion and bone characteristics of dairy cows fed different amounts of phosphorus to two to three years. J. Dairy Sci. 84:1738-1748.

Wu Z., L. D. Satter, and R. Sojo. 2000. Milk production, reproductive performance, and fecal excretion of phosphorus by dairy cows fed three amounts of phosphorus. J. Dairy Sci. 83:1028-1041.

Wu, Z., and L. D. Satter. 2000. Milk production and reproductive performance of dairy cows fed two concentrations of phosphorus for two years. J. Dairy Sci. 83:1052-1063.

APPENDIX:
OSU Nutrient Management Survey

Soil Testing and Commercial Fertilizer Use

1. How do you decide how much commercial fertilizer to use on a field? (Check more than one if applicable)
   - Fertilizer dealer or consultant recommendations [ ]
   - Soil test results [ ]
   - Cost [ ]
   - My farm nutrient management plan [ ]
   - My knowledge and experience [ ]
   - I always use the same rate [ ]
   - Other ______________________

2. When you decide to have soil testing done, how many fields are typically tested? (Check all that apply)
   - What the fertilizer dealer or consultant says [ ]
   - What I can afford [ ]
   - Corn fields only [ ]
   - I don't use soil tests [ ] Go to question 6
   - Other ______________________

3. In general, how often are routine soil tests taken on the same field?
   - Never [ ]
   - Every 3 – 5 years [ ]
   - Every 2 years [ ]
   - Every year [ ]
   - No pattern [ ]
   - Other ______________

4. Who takes the soil samples?
   - Yourself / employee [ ]
   - Private consultant [ ]
   - Fertilizer dealer [ ]
   - Other______________________

5. Based on the soil test results, do you usually adjust the rates of manure to spread?
   - Yes [ ]
   - No [ ]

Phosphorus Information

6. What does excessive soil phosphorus affect? (Check all that apply)
   - Ground water quality [ ]
   - Surface water quality [ ]
   - Both [ ]
   - Don't know [ ]

7. What are the sources of phosphorus in your milking cow ration? (Please list)

   ____

   ____

   ____

8. Compared to nitrogen, the amount of phosphorus in manure is
   - Greater [ ]
   - About the same [ ]
   - Less than [ ]

9. Compared to nitrogen, the amount of phosphorus in pasture (or grass) is
   - Greater than [ ]
   - About the same [ ]
   - Less than [ ]

10. Once manure or fertilizer is incorporated in a soil, how deep is the phosphorus most likely to move in a year?
    - Less than 2 inches [ ]
    - 2 - 5 inches [ ]
    - 5 -10 inches [ ]
    - More than 10 inches [ ]
    - Don't know [ ]

Potassium Information

11. What does excessive soil potassium affect? (Check all that apply)
    - Ground water quality [ ]
    - Surface water quality [ ]
    - Nothing [ ]
    - Animal nutrition [ ]
    - Don't know [ ]

12. What are the sources of potassium in your milking cow ration? (Please list)

____

____

____

13. What are the sources of potassium in your dry cow ration? (Please list)

____

____

____

14. Compared to nitrogen, the amount of potassium in manure is

Greater than [ ]
About the same [ ]
Less than [ ]

15. Compared to nitrogen, the amount of potassium in pasture (grass) is

Greater than [ ]
About the same [ ]
Less than [ ]

16. Once manure or fertilizer is incorporated in a soil, how deep is the potassium most likely to move in a year?

Less than 2 inches [ ]
2 - 5 inches [ ]
5 - 10 inches [ ]
More than 10 inches [ ]
Don't know [ ]

17. Excessive potassium in the ration can cause problems in

Dry cows [ ]
Milk cows [ ]
Heifers [ ]
None of the above [ ]

Manure Management

18. Which one of these best describes how often you apply manure?

Daily	[ ]
Weekly	[ ]
Monthly	[ ]
Fall and spring	[ ]
Fall only	[ ]
Spring only	[ ]
Winter only	[ ]
Other_________________	

19. About how many acres receive manure each year _____ Acres owned
_____ Acres rented

20. If any of your fields don't receive manure, please explain why.

____

____

____

____

____

21. How far away is the farthest field that manure is applied on your farm?

About _________ miles

22. Of the manure you apply, approximately how much is applied in the following ways? (Total should equal 100%)

Injected	____%
Broadcast without incorporation	____%
Broadcast and incorporation (within 3 days)	____%
Other	____%
	100%

Your Views

23. In your opinion, what soil phosphorus level is required to get a good crop of corn? (ppm stands for parts per million)
    - Less than 10 ppm [ ]
    - 10 - 20 [ ]
    - 20 - 50 [ ]
    - Over 50 [ ]
    - Don't know [ ]

24. Do you consider commercial fertilizer expensive?
    - Yes [ ]
    - No [ ]

25. Is there too much fuss over nutrients, fertilizers and the environment?
    - Yes [ ]
    - No [ ]

26. Do you think more manure management regulations are needed?
    - Yes [ ]
    - No [ ]

27. In your opinion, is over application from the past causing problems for your operation today?
    - Yes [ ]
    - No [ ]

Why or why not

____

____

____

____

28. Do you consider manure a good source of nutrients for crops?
    - Yes [ ]
    - No [ ]

29. Do you consider hauling manure a hassle?
    - Yes [ ]
    - No [ ]

As a part of my student project, I will use the following section "Your Farm" to group farm details from all surveys for general comments only.

Your Farm

30. How many milkings do you do daily?
    - Two [ ]
    - Three [ ]
    - Four [ ]

31. How many cows do you typically milk? ______

32. How many heifers are on the dairy? ______

33. How many months per year do you graze pastures?

    ____ Cows

    ____ Heifers

34. What soil types are most common on your farm? (Check more than one if appropriate)
    - Sandy [ ]
    - Silty [ ]
    - Clay [ ]
    - Not sure [ ]

35. On average, approximately what percentage of your tillable acres are in the following crops? (Should equal 100%)

Corn (silage)	____%	
Alfalfa	____%	
Grass silage	____%	
Pasture	____%	
Other	____ %	____________ (Please specify)
	100%	

36. Which of the following types of surface water are within or bordering your property? (Check all that apply)
    - Ponds / lakes [ ]
    - Creeks / rivers / streams [ ]
    - Seasonal streams [ ]
    - None [ ]

37. If you have ponds or lakes, which of the following changes have occurred over the past 10 years? (Check all that apply)

The water is clearer [ ]
There is more algae [ ]
There are more fish and water creatures [ ]
None [ ]
Other (Please specify) ____________________

Thank you so much for taking time to fill out my survey!
Your cooperation is very helpful and essential for my studies.