Fertilization of Cool-Season Perennial Forage Grasses Under Irrigation to Improve Forage Yield and Quality

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It is well known that applying nitrogen (N) fertilizer generally increases the forage yield of perennial cool-season grasses, especially if soil moisture is sufficient for the grasses to take advantage of the added N. In addition, N fertilization can result in an increase in protein content of grass to a level that is adequate in meeting the protein needs of a lactating beef cow or sheep ewe. The amount of soil phosphorus (P) available for plant uptake in semi-arid areas is often low as can be assessed by analysis of the P content of forages which often is below livestock needs. Thus the application of a P fertilizer is periodically needed to meet both alfalfa and cool-season forage grass needs. Although the amount of available manganese (Mn) and zinc (Zn) in the soil for plant uptake may be sufficient to meet grass growth needs in the High Plains of Northeast Wyoming grass forage content of these two minerals is often not adequate to meet cattle or sheep nutrient needs, especially for Zn.

Objectives of this project were to determine if forage yield and quality of improved cool-season perennial forage grasses increased by fertilizing with N, P, Mn and Zn; and, determine if any increase in forage quality was sufficient to meet livestock nutritional needs. If applying P, Mn, or Zn fertilizers resulted in an increase in the forage content of these minerals it could result in reducing or possibly eliminating the need to provide any or all of them to livestock in a feed supplement. In addition, an increase in forage yield as a result of applying any one of these fertilizers could help increase the justification of this practice.

STUDY SITE AND METHODS

Single strips (E-W) of five cool-season perennial forage grasses [“NewHy” hybrid wheatgrass (HWG), “Oahe” intermediate wheatgrass (IWG), “Manska” pubescent wheatgrass (PWG), “Critana” thickspike wheatgrass (TWG), and “Regar” meadow bromegrass (MBG)] were seeded into a 35-acre side-roll irrigated field along Piney Creek in northern Sheridan County in late May 2003. Nitrogen (N) as urea (46-0-0) and phosphorus (P) as phosphate (11-52-0) were applied in 60’ widths across the grass strips (N-S) in mid-April 2005 with a broadcast spreader. Fertilizer rates were 100 lb N per acre, 50 lb P_2O_5 + 10 lb N per acre, 110 lb N + 50 lb P_2O_5 per acre, and no fertilizer applied (Check). Each fertilizer treatment was replicated three times. In addition, the N+P fertilizers were applied at the same rates to three additional widths per replication. These widths had either manganese (Mn) as manganese sulfate (32% Mn + 19% SO_4), zinc (Zn) as zinc sulfate monohydrate (35.5% Zn + 17.5% SO_4), or Mn + Zn applied with a broadcast spreader in mid-May 2005. Rates for the Mn and Zn fertilizers were 4 lb Mn + 2 lb SO_4 per acre, 4 lb Zn + 2 lb SO_4 per acre, and 4 lb Mn + 4 lb Zn + 4 lb SO_4 per acre.

Due to the abundant amount of precipitation that was received between April and June 2005 no irrigation occurred prior to an early July hay harvest (April: Buffalo – 1.3”, Sheridan – 1.84”; May: Buffalo – 6.39”, Sheridan – 6.18”; June: Buffalo – 3.53”, Sheridan – 2.00”).

Herbage of each grass by fertilizer treatment was harvested to a two-inch stubble height from a randomly placed 0.25 m^2 (2.7 ft^2) hoop on 22 June 2005 to determine dry matter yield in pounds per acre. All grasses had seed heads emerged at time of harvest with Regar MBG furthest in maturity followed by Critana TWG. Herbage from each replication of the grass by fertilizer treatments was composited, dried and then ground. Ground material of each grass by fertilizer treatment was analyzed by the University of Nebraska Soil and Plant Analytical Lab for % Acid Detergent Fiber (ADF) used to calculate Mega-calories (Mcal) of Net Energy maintenance (NEm) per pound of dry matter, % nitrogen used to calculate % crude protein, % phosphorus (P), % calcium (Ca), % potassium (K), % magnesium (Mg), % sulfur (S), parts per million (ppm) iron (Fe), ppm manganese (Mn), ppm zinc (Zn), and ppm copper (Cu). Funding for forage quality analysis was provided by the Wyoming Private Grazing Lands Team.

Due to significant regrowth following an early July hay harvest herbage of each grass by fertilizer treatment was harvested to a two-inch stubble height from a randomly placed 0.25 m^2 hoop on 12 October 2005 to determine dry matter yield in pounds per acre.

Soil samples were randomly collected throughout the field with a soil probe to a 12" depth on 18 April 2005 prior to fertilizer application. Soil samples were again taken on 29 September 2005 from each fertilizer treatment within the Manska PWG strip (middle of field). The 29 September soil samples from each replication were composited by fertilizer treatment prior to analysis. Soil samples were analyzed for pH, % organic matter, ppm NO_3-N, ppm P, ppm K, ppm Fe, ppm Mn, ppm Zn, and ppm Cu by the University of Nebraska Soil and Plant Analytical Lab. Funding for soil analysis was provided by the Wyoming Private Grazing Lands Team.

The amount of degradable intake protein (DIP) and minerals that a beef cow would potentially consume from the grasses was determined from the crude protein, mineral, and NEm contents of the grasses as NEm content influences the amount of forage a cow will consume (Agri-Concepts, Inc, Tucson, AZ). In addition, NEm, crude protein, and mineral content of the grasses by fertilizer treatments were compared to the amount needed by a mature sheep ewe during gestation and early lactation (average for ewe suckling single and twin lambs – Nutrient Requirements of Sheep, Sixth Revised Edition, 1985, The National Academy of Sciences).

RESULTS and DISCUSSION

Dry Matter Yields

Grass dry matter yields on 22 June 2005 were similar between the Check and P treatments averaging 4740 lb/ac (Table 1). Regar MBG produced the greatest amount of dry matter from these two treatments averaging 6615 lb/ac compared to an average of 4275 lb/ac for the other four grasses. Application of P appeared to benefit Oahe IWG as its dry matter yield was 2770 lb/ac more compare to the Check treatment. However, the added P may have been a detriment for Manska PWG as it produced 1425 lb/ac less dry matter compared to the Check.

Grass dry matter yields were greater with the addition of N by an average of 1955 lb/ac (Table 1). Regar MBG had the smallest yield increase at 875 lb/ac, and Manska PWG and Oahe IWG had the greatest increase with an average of 3210 lb/ac more dry matter with the application of N compared to without.

Dry matter yields of the grasses averaged 6700 and 6305 lb/ac for the N and N+P treatments, respectively (Table 1). However, NewHy HWG and Critana TWG produced an average of 830 lb/ac more dry matter with the N+P treatment compared to the N alone treatment. Thus the inclusion of P with N appeared to have reduced dry matter yields by an average of 1205 lb/ac for Regar MBG, Manska PWG and Oahe IWG.

The application of Mn and/or Zn fertilizers to N+P fertilized areas did not appear to have a significant affect on grass dry matter yields, except for Oahe IWG which produced an average of 1300 lb/ac more dry matter in the Mn and/or Zn + N+P treatments compared to the N+P only treatment (Table 1). Critana TWG produced an average of 575 lb/ac less dry matter with the addition of Mn and/or Zn compared to the N+P only treatment.

Regar MBG, Critana TWG and NewHy HWG produced an average of 530 lb/ac more regrowth dry matter harvested on 12 October 2005 compared to Manska PWG and Oahe IWG (Table 2). Although regrowth dry matter yields were significantly greater in the N+P and N+P+Mn+Zn treatments compared to the N+P+Zn and Check treatments by an average of 350 lb/ac no conclusions can be drawn as to whether these differences were due to the fertilizer treatments.

The total amount of dry matter harvested (22 June + 12 Oct) from the grasses was similar among the N treatments averaging 7855 lb/ac (Tables 1 and 2). Whereas total dry matter yield for the Check and P treatments averaged only 5900 lb/ac. Application of P with N did appear to increase total dry matter yield of NewHy HWG by an average of 1200 lb/ac.

Soil Analysis

Soil P levels were slightly less in late September 2005 compared to mid-April 2005 and they were similar among the treatments in late September, except for the P fertilizer only treatment which averaged 10 ppm less P than for the other treatments and 14 ppm less than what was present in mid-April (Table 3). Why this occurred is not known.

Based on soil NO_3-N levels in mid-April and late September 2005 Manska PWG and most likely the other grasses utilized all the applied N fertilizer (Table 3). Less soil NO_3-N was apparently removed by Manska PWG within the N and P only fertilizer treatments compared to the other treatments by an average of 0.72 ppm.

Soil Mn content in late September 2005 was 2.9 ppm greater in the Mn fertilizer treatments compared to the non-Mn treatments (Table 3). However, soil from all fertilizer treatments averaged 11.8 ppm less Mn in late September compared to the field average in mid-April.

The amount of soil Zn in the N+P+Zn fertilizer treatment was 1.5 ppm more in late September 2005 than what was present in the field in mid-April 2005 (Table 3). However, soil Zn in the

N+P+Mn+Zn fertilizer treatment was actually 0.3 ppm less in late September compared to mid-April. The amount of soil Zn in late September for the two Zn fertilizer treatments averaged 1.0 ppm more compared to the non-Zn fertilizer treatments.

Net Energy maintenance (NEm)

Nitrogen, especially in conjunction with Mn and/or Zn, appeared to increase the NEm content of 22 June 2005 harvested grass by an average of 0.03 Mcal/lb of dry matter (Table 4). NEm content was similar among the grasses, except for Regar MBG which contained an average of 0.045 Mcal/lb less. Regar MBG matured earlier than the other grasses and this is probably why it contained less energy compared to the other grasses.

Forage from all the grasses, regardless of fertilizer treatment, would provide a 1200 pound beef cow (BCS 6) with an adequate amount of NEm, except for Regar MBG from the Check treatment for medium and high milk producing cows when in peak lactation (Figure 1a). In addition, a sheep ewe would obtain an adequate amount of NEm during her first 15 weeks of gestation, and generally a sufficient amount during her last 4 weeks of gestation, except for Regar MBG (Figure 1b). None of the grasses would provide a sheep ewe during early lactation the recommended amount of NEm.

Protein

Crude protein content of the grasses averaged 10.6% for the N+ treatments compared to an average of 8.9% for the P and Check treatments (Table 4). The increase in crude protein content due to N fertilizer averaged 1.1% for NewHy HWG, Oahe IWG, and Manska PWG, whereas for Critana TWG the increase was 2% and for Regar MBG it was 3.1%. Crude protein is calculated from the N content of the forage, thus an increase in available soil N should result in an increase in forage crude protein content.

All the grasses, regardless of fertilizer treatment, provided an adequate amount of degradable intake protein (DIP) to a 1200 pound (BCS 6) beef cow in her third trimester of pregnancy (Figure 2a). Only NewHy HWG provided the cow an adequate amount of DIP when in peak lactation regardless of her level of milk production. The other grasses provided an adequate amount of DIP to meet the needs of a low level milk producing cow, except for Manska PWG and Regar MBG from the Check treatment, and Regar MBG from the P treatment. Forage of these grass by fertilizer treatments was not only lower in percent crude protein (Figure 2b) compared to the other grass by fertilizer treatments but also lower in NEm (Figure 1b) resulting in lower forage consumption thus less nutrient intake.

Grass forage from the Check and Phosphorus fertilizer treatments generally did not provide the sheep ewe with a sufficient amount of crude protein in all stages of production (Figure 2b). Whereas grass forage from the N+P and N+P+Mn+Zn fertilizer treatments generally provided the ewe with an adequate amount of crude protein during late gestation but not when in lactation.

Phosphorus (P)

Oahe IWG and Manska PWG contained more P compared to NewHy HWG, Critana TWG, and Regar MBG by an average of 0.03% (Table 4). Forage from the N+P and N+P+Mn fertilizer treatments contained significantly more P compared to N+P+Zn and N+P+Mn+Zn treatments by 0.04%. However, the amount of P the beef cow would obtain from the grasses regardless of fertilizer treatment was adequate to meet her needs in all stages of production (Figure 3a). Although forage from the grasses, regardless of fertilizer treatment, would provide a sufficient amount of P to the sheep ewe during her first 15 weeks of gestation, only about 30% of the grass by fertilizer treatment combinations contained an adequate amount of P to meet her needs during the last four weeks of gestation and during early lactation (Figure 3b).

Based on these results it would appear that the application of 50 pounds of phosphate fertilizer did not increase the P content of the grasses but Zn fertilizer may have had a negative influence on plant P uptake. Soil P levels for the field on 18 April and 29 September 2005 were more than sufficient (> 22 ppm; Table 3) for hay production of up to six T/ac (Guide to Wyoming Fertilizer Recommendations, B-1045, November 1996, University of Wyoming Cooperative Extension Service).

Calcium (Ca)

Manska PWG and Critana TWG contained an average of 0.05% more Ca compared to NewHy HWG, Oahe IWG, and Regar MBG; however, fertilizer treatments did not appear to affect grass Ca content (Table 4). Forage from the grasses would provide the beef cow an adequate amount of Ca beyond her seventh month of pregnancy and a sheep ewe enough during her first 15 weeks of pregnancy, except for Regar MBG from the Check (Figures 4a and 4b). Only Manska PWG and Critana TWG contained an adequate amount of Ca to meet the needs of the ewe during her last four weeks of gestation and during early lactation.

The Ca: P ratio in the diet of beef cattle is generally recommended to be at least 1.5:1 and 2:1 for sheep. However, if the ewe consumed the recommended Ca and P amounts the ratio would be 1.3:1. Ratios ranged from 1.1:1 for Regar MBG to 1.8:1 for Manska PWG both from the Check treatment. Whether the provision of a Ca supplement when feeding hay of these grasses to a beef cow or sheep ewe would be needed remains to be determined.

Potassium (K)

Fertilizer treatments appeared to have little effect on forage K content of the grasses, except N may have resulted in a slight increase (Table 4). Critana TWG generally contained the least amount of K whereas NewHy HWG and Regar MBG the most. A beef cow and sheep ewe would obtain an adequate amount of K from the grasses regardless of fertilizer treatment and stage of production they were in (Figures 5a and 5b).

Magnesium (Mg)

Although forage Mg content was not significantly different among the grasses and among fertilizer treatments there was much variation within each grass by fertilizer treatment (Table 4). The grasses would generally provide an adequate amount of Mg to the beef cow during her third trimester of pregnancy (Figure 6a). However, during lactation, especially if the cow was a medium level milk producer, she would generally have a better opportunity of meeting her Mg needs from grass fertilized with N+P.

Averaged over fertilizer treatments the grasses, except for Critana TWG, contained an adequate amount of Mg to meet the needs of a sheep ewe during her first 15 weeks of gestation (Figure 6b). Thus an Mg supplement would need to be provided if hay from these grasses was fed to a ewe in late gestation or when in lactation.

The potential for grass tetany in ruminants (cattle, sheep, etc.) occurs when the ratio of K to Ca and Mg in the diet is greater than 2.2 to 11 (Kemp, A. and t'Hart, M. L. 1957. Grass tetany in grazing milking cows. *Neth. J. Agric. Sci.* 5:4.). The ratios of K to Ca and Mg ranged from 3.9:1 for Manska PWG from the Check treatment to 8.1:1 for Regar MBG also from the Check treatment. Increasing Ca in the diet of the beef cow by an average of 0.01 lb per day to put it in balance with P consumption and adding an average of 0.4 lb Mg per day should minimize the potential for grass tetany. On average Ca in the diet of a lactating sheep ewe would need to be increased by at least 0.22%, especially if P was increased by 0.03% to meet her needs, and Mg would need to be increased by an average of 1.1% to minimize the potential for the occurrence of grass tetany.

Sulfur (S)

Regar MBG generally contained the lowest levels of S (Table 4) and coupled with its lower NEm content compared to the other grasses provided the lowest amount of S to the beef cow being border line insufficient (Figure 7a). In addition, it would not provide an adequate amount of S to the sheep ewe during her last fours weeks of gestation or when in lactation (Figure 7b). Fertilizer treatments did not appear to have an effect on the S content of the grasses.

Iron (Fe)

Iron content among the grasses was similar and though there were some differences in forage Fe content among fertilizer treatments differences can not necessarily be attributed to the treatments (Table 4). The grasses, regardless of fertilizer treatment, generally provided an adequate amount of Fe to the beef cow in her third trimester of pregnancy and when in lactation, especially if she is a low milk producer (Figure 8a). In addition, the grasses would provide a sufficient amount of Fe to a sheep ewe in all stages of production (Figure 8b).

Manganese (Mn)

Manganese fertilizer did not appear to increase the Mn content of the grasses (Table 4). Manska PWG and Oahe IWG contained an average of 20 ppm more Mn compared to NewHy HWG and

Critana TWG. Except for Critana TWG, the grasses would generally provide the beef cow an adequate amount of Mn during her third trimester of pregnancy (Figure 9a). Manska PWG and Oahe IWG would provide the beef cow an adequate amount of Mn during lactation, especially a low milk producer. The Mn content of the grasses, regardless of fertilizer treatment, was adequate for a sheep ewe during her first 15 weeks of pregnancy (Figure 9b). However, Mn content of Critana TWG may not have been sufficient for a ewe during her last four weeks of gestation, and Mn content of NewHy HWG may not have been adequate during early lactation.

Zinc (Zn)

Fertilizer treatments did not appear to affect grass Zn content (Table 4). Oahe IWG and Manska PWG contained an average of 6 ppm more Zn compared to NewHy HWG, Critana TWG, and Regar MBG. None of the grasses, regardless of fertilizer treatment, would provide the beef cow or sheep ewe, in all stages of production, an adequate amount of Zn (Figures 10a and 10b).

Copper (Cu)

Except for the N+P+Zn fertilizer treatment, Cu content of the grasses was greatest with N fertilizer than without (Table 4). The addition of Zn fertilizer probably was not the reason for the low average Cu content of the grasses from this treatment as Cu content of grass from the N+P+Mn+Zn treatment was significantly greater and not different from the N+P+Mn, N+P, or N treatments. As with Mn and Zn, Oahe IWG and Manska PWG contained the highest amounts of Cu by an average of 2 ppm and would provide the beef cow with an adequate amount of Cu during her third trimester of pregnancy and generally enough during lactation along with NewHy HWG (Figure 11a). In addition, these three grasses would probably provide an adequate amount of Cu to the ewe (Figure 11b). Critana TWG and Regar MBG generally would not provide an adequate amount of Cu to the beef cow when in lactation.

CONCLUSIONS

Nitrogen fertilizer increased dry matter yields of the grasses and their crude protein content, whereas P, Mn, and Zn fertilizers appeared to not have an affect on dry matter production nor did they appear to increase the concentration of these nutrients in the grasses. Generally forage from the grasses, regardless of fertilizer treatment, provided an adequate amount of nutrients to meet the needs of a beef cow in late gestation and in early lactation, except for Zn. Critana TWG and NewHy HWG did not contain an adequate amount of Mn to meet the needs of a cow in late gestation, and Critana and Regar MBG not enough Cu to meet her needs in early lactation. With regard to a sheep ewe the grasses, regardless of fertilizer treatment, generally did not provide an adequate amount of nutrients, except for K and Fe, to meet her needs, especially when she was in early lactation.

Table 1: Forage dry matter yields in pounds per acre for the five cool season perennial grasses subjected to seven fertilizer treatments harvested on 22 June 2005.

Fertilizer Treatments	NewHy HWG[1]	Oahe IWG	Manska PWG	Critana TWG	Regar MBG	Fertilizer Average
Check	4084	3469	5105	3987	6623	4654 b[3]
Nitrogen (N)	5656	7976	7687	4678	7488	6697a
Phosphorus (P)	4511	6237	3682	3118	6606	4831 b
N+P	6403	6392	6486	5591	6664	6307a
N+P+ Manganese (Mn)	6251	7371	6815	5091	7124	6530a
N+P+ Zinc (Zn)	6851	7588	7491	4571	7088	6718a
N+P+Mn+Zn	6188	8102	6522	5382	6427	6524a
Grass Average	5706 b[2]	6734a	6255ab	4631 c	6860a	

[1]HWG = Hybrid wheatgrass; IWG = Intermediate wheatgrass; PWG = Pubescent wheatgrass; TWG = Thickspike wheatgrass; MBG = Meadow bromegrass
[2]Grass average values followed by same letter not significantly different at $P \leq 0.05$
[3]Fertilzer average values followed by same letter not significantly different at $P \leq 0.05$

Table 2: Forage dry matter yields in pounds per acre for the five cool season perennial grasses subjected to seven fertilizer treatments harvested on 12 October 2005.

Fertilizer Treatments	NewHy HWG[1]	Oahe IWG	Manska PWG	Critana TWG	Regar MBG	Fertilizer Average
Check	1671	592	1046	1219	1630	1232ab[3]
Nitrogen (N)	1263	912	1093	1362	1380	1202ab
Phosphorus (P)	1078	716	1008	1125	1500	1085 b
N+P	1976	818	1107	1676	1723	1460a
N+P+ Manganese (Mn)	1799	902	967	1336	1196	1240ab
N+P+ Zinc (Zn)	1247	729	1024	1316	1366	1136 b
N+P+Mn+Zn	1744	1087	1183	1693	1571	1456a
Grass Average	1540a[2]	822 b	1061 b	1390a	1481a	

[1]HWG = Hybrid wheatgrass; IWG = Intermediate wheatgrass; PWG = Pubescent wheatgrass; TWG = Thickspike wheatgrass; MBG = Meadow bromegrass
[2]Grass average values followed by same letter not significantly different at $P \leq 0.05$
[3]Fertilzer average values followed by same letter not significantly different at $P \leq 0.05$

Table 3: Soil analysis results for the field on 18 April 2005 prior to fertilizer application and on 29 September 2005 by fertilizer treatment within Manska pubescent wheatgrass.

Date	Fertilizer Treatment[1]	NO_3-N[2] (ppm)	P (ppm)	K (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
18 Apr	Prior to	2.94	31.8	325	31.5	25.5	1.35	0.96
29 Sep	Check	1.32	30.5	248	31.2	13.1	0.95	0.88
29 Sep	Nitrogen	1.93	24.0	257	34.0	12.6	1.05	0.83
29 Sep	Phosphorus	2.13	17.9	286	22.6	11.3	0.92	0.86
29 Sep	N+P	1.07	30.9	252	45.2	13.8	0.98	0.86
29 Sep	N+P+Mn	1.51	25.9	299	43.8	15.2	1.16	0.92
29 Sep	N+P+Zn	1.13	30.0	266	27.5	13.4	2.88	0.85
29 Sep	N+P+Mn+Zn	1.51	25.0	256	76.7	16.3	1.09	1.02

[1]Fertilizer treatment: N – Nitrogen, P – Phosphorus, Mn – Manganese, Zn – Zinc
[2]NO_3-N – Nitrate nitrogen; P – Phosphorus; K – Potassium; Fe – Iron; Mn – Manganese; Zn – Zinc; Cu - Copper

Table 4: Dry matter quality averages of the five cool season perennial forage grasses harvested on 22 June 2005 for each of the seven fertilizer treatments.

Quality Component	Check	N[1]	P	N+P	N+P+Mn	N+P+Zn	N+P+Mn+Zn
Mcal NEm[2]	0.58c[3]	0.61ab	0.59bc	0.59bc	0.62a	0.62a	0.63a
% Crude Protein	8.6d	10.1bc	9.1cd	11.2a	10.4ab	10.2ab	11.0ab
% P	0.25ab	0.25ab	0.26ab	0.28a	0.28a	0.24b	0.24b
% Ca	0.36a	0.34a	0.36a	0.39a	0.38a	0.34a	0.35a
% K	2.8b	2.9ab	2.7b	3.1a	2.9ab	2.7b	2.9ab
% Mg	0.17a	0.16a	0.15a	0.19a	0.17a	0.15a	0.16a
% S	0.20a	0.19a	0.20a	0.20a	0.19a	0.18a	0.18a
ppm Fe	47bc	50abc	58a	55ab	54abc	49abc	46c
ppm Mn	45a	34b	39ab	40ab	37ab	40ab	40ab
ppm Zn	18a	17a	16a	17a	18a	16a	17a
ppm Cu	6.6bc	8.2a	6.9b	7.6ab	7.1ab	5.7c	7.3ab

[1]N = Nitrogen; P = Phosphorus; Mn = Manganese; Zn = Zinc
[2]NEm = Net Energy maintenance; P = Phosphorus; Ca = Calcium; K = Potassium; Mg = Magnesium; S = Sulfur; Fe = Iron; Mn = Manganese; Zn = Zinc; Cu = Copper
[3]Fertilzer values for each quality component followed by same letter not significantly different at $P \leq 0.05$

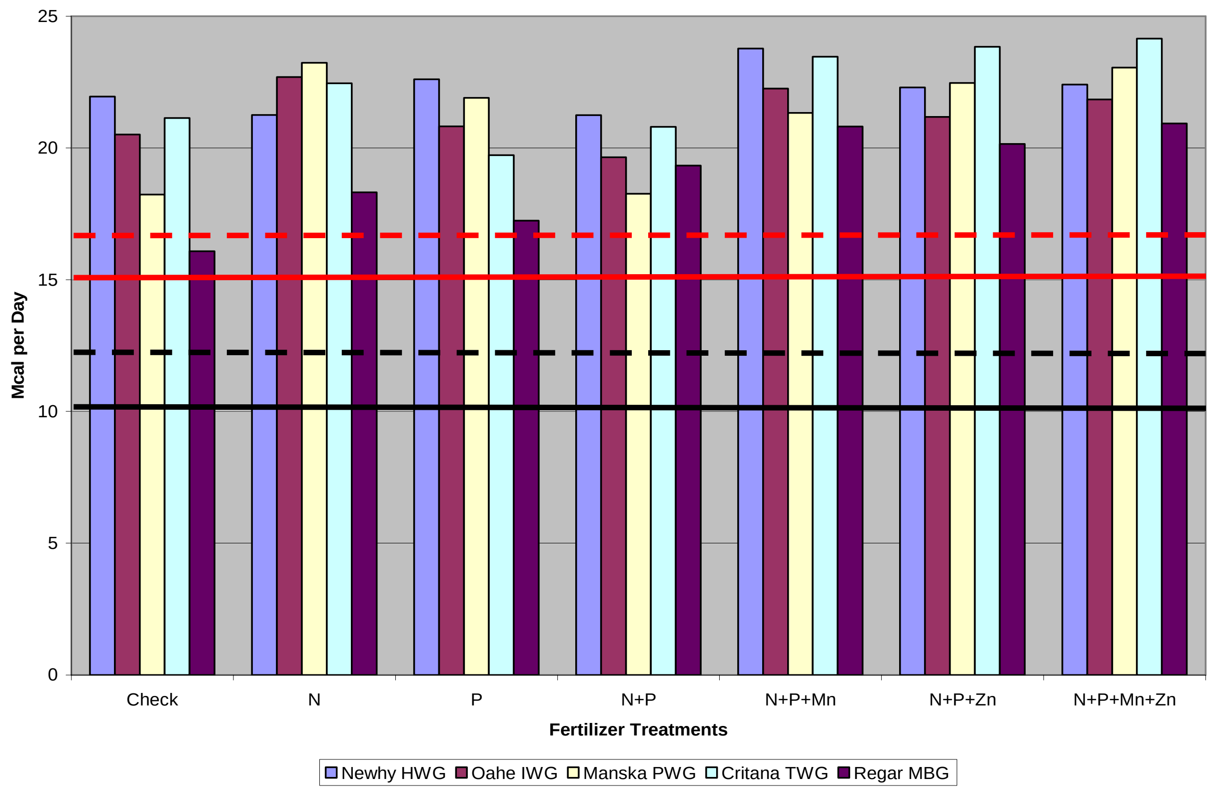

Figure 1a: Amount of net energy for maintenance a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

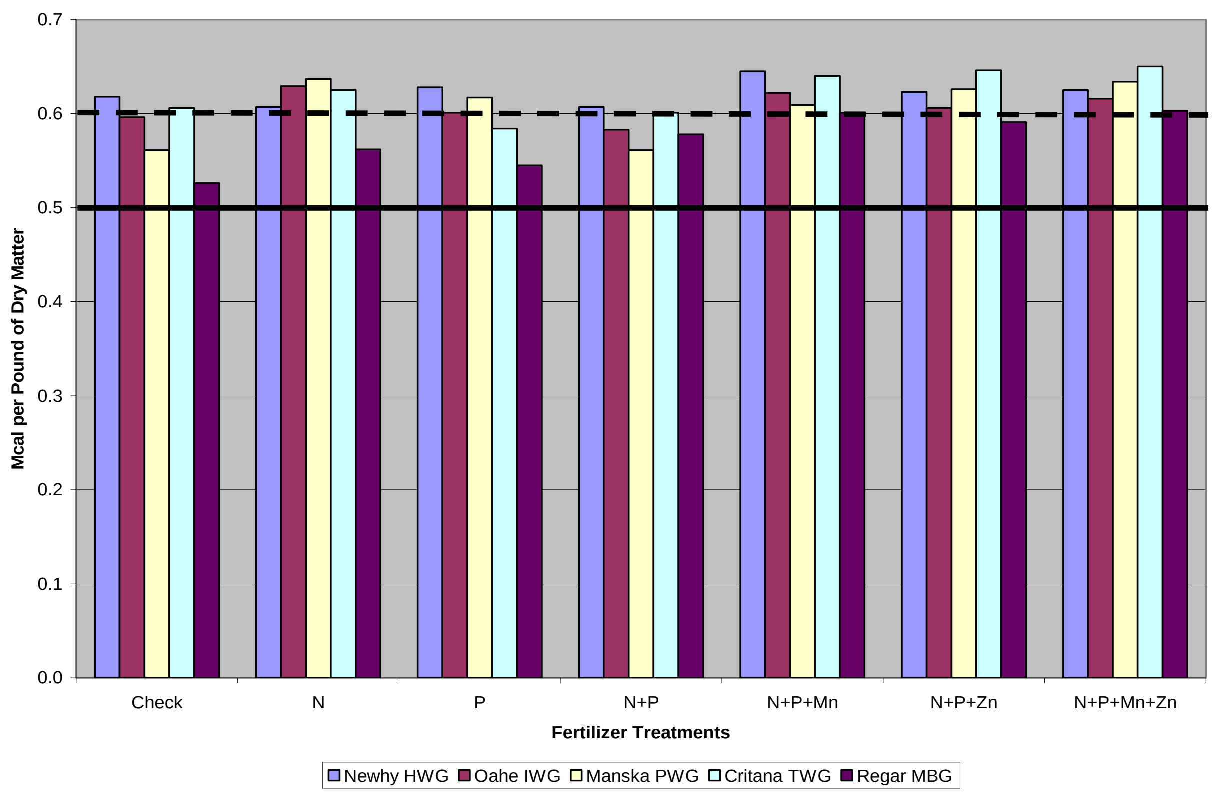

Figure 1b: Net energy maintenance content (Mcal/lb) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black lines**: Required amount for a sheep ewe in pregnancy – solid first 15 weeks; dashed last 4 weeks. A sheep ewe requires 0.7 Mcal NEm during her first 6 to 8 weeks in lactation.

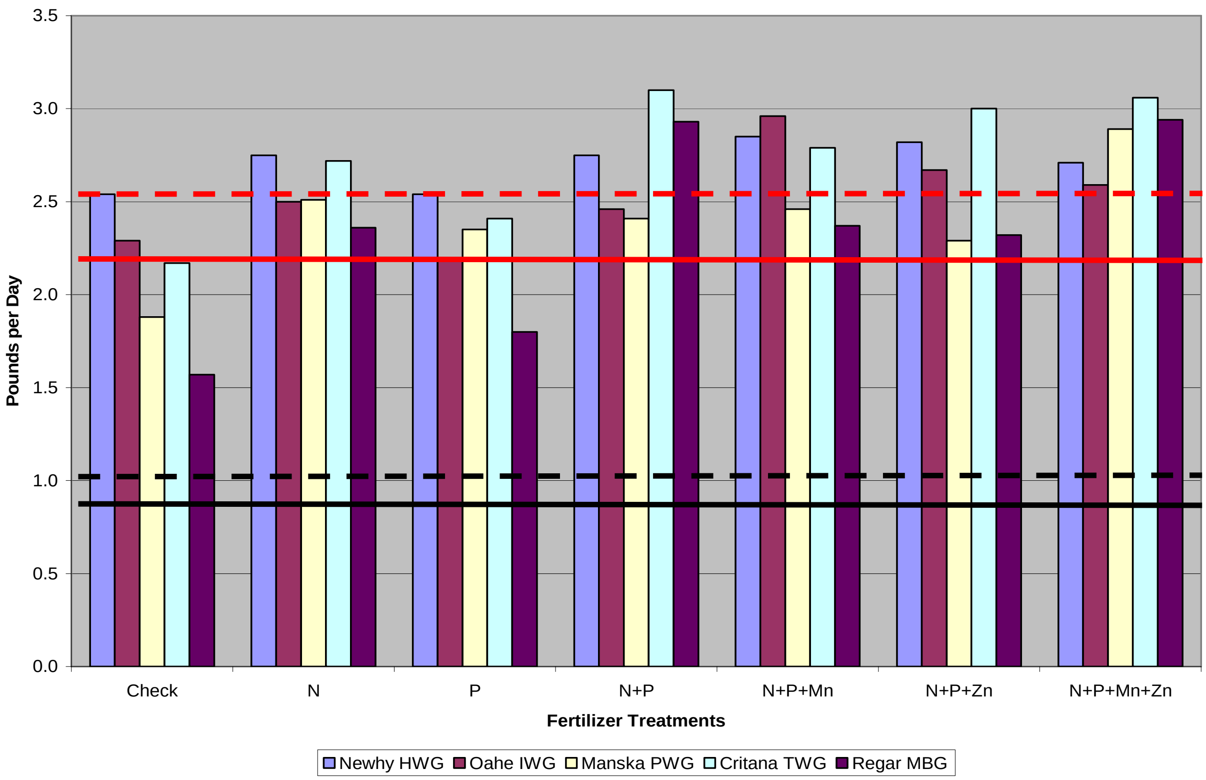

Figure 2a: Amount of degradable intake protein a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

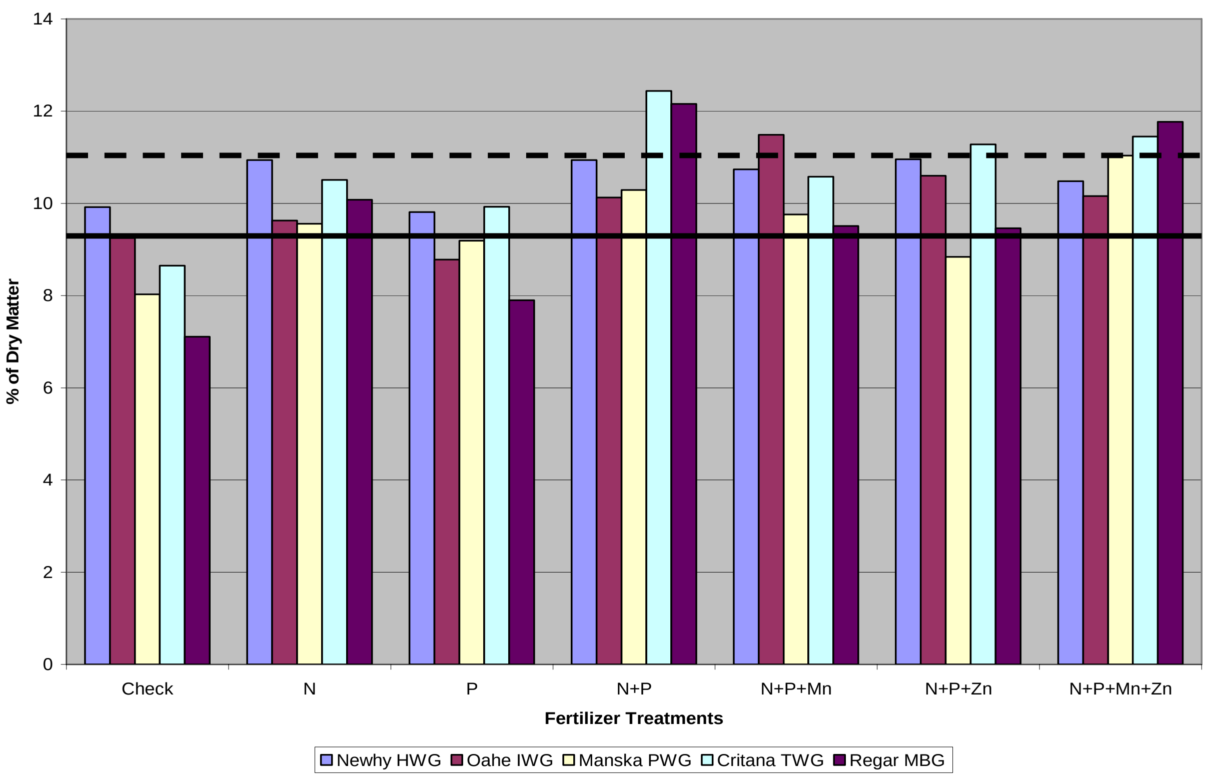

Figure 2b: Crude protein content (%) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black lines**: Required amount for a sheep ewe in pregnancy – solid first 15 weeks; dashed last 4 weeks. Required amount for a sheep ewe first 6 to 8 weeks lactation between 13.2% and 16.2% dependent upon her size and if suckling single or twin lambs.

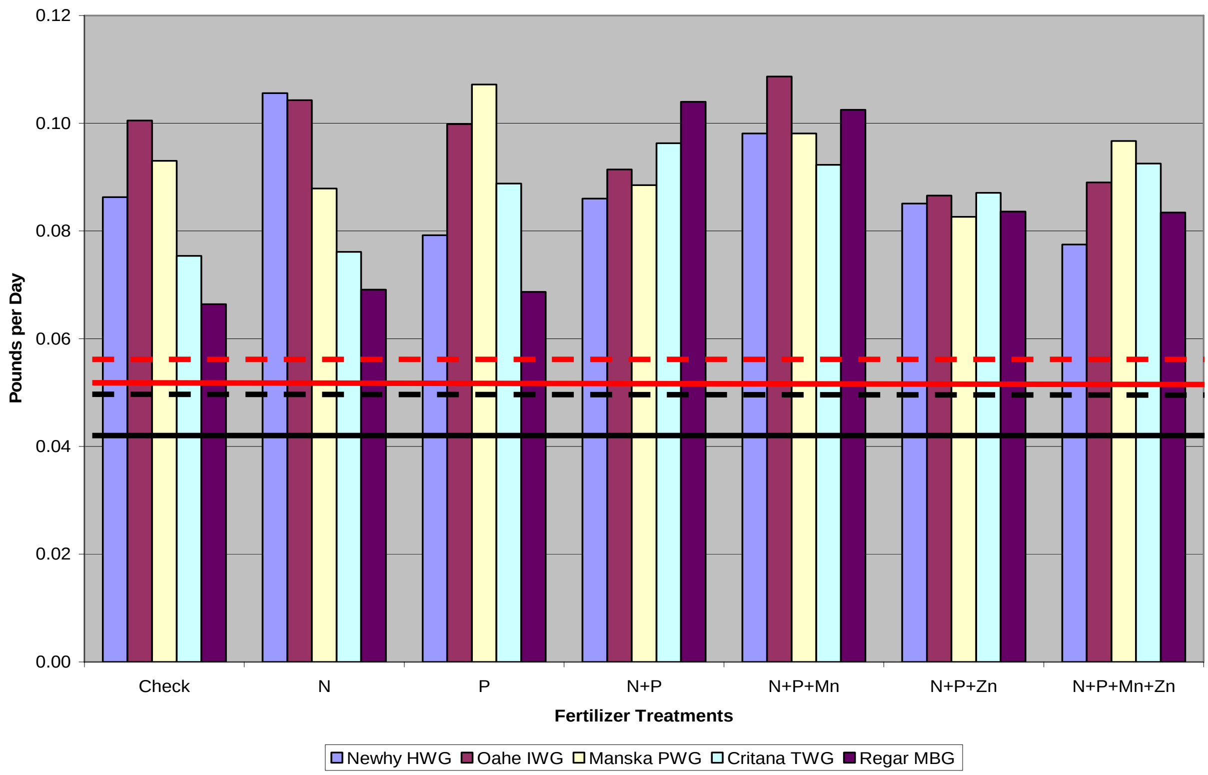

Figure 3a: Amount of phosphorus a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

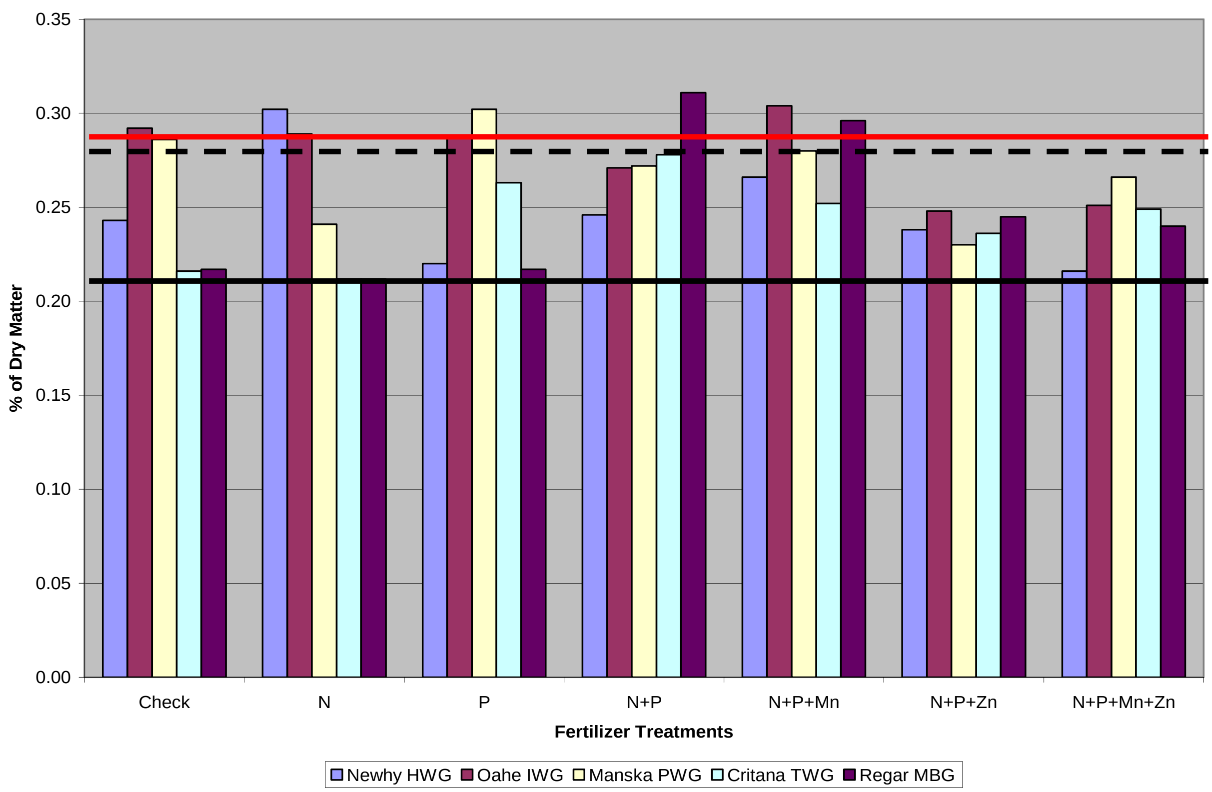

Figure 3b: Phosphorus content (%) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black lines**: Required amount for a sheep ewe in pregnancy – solid first 15 weeks; dashed last 4 weeks. **Red line**: Required amount for a sheep ewe first 6 to 8 weeks lactation suckling single or twin lambs.

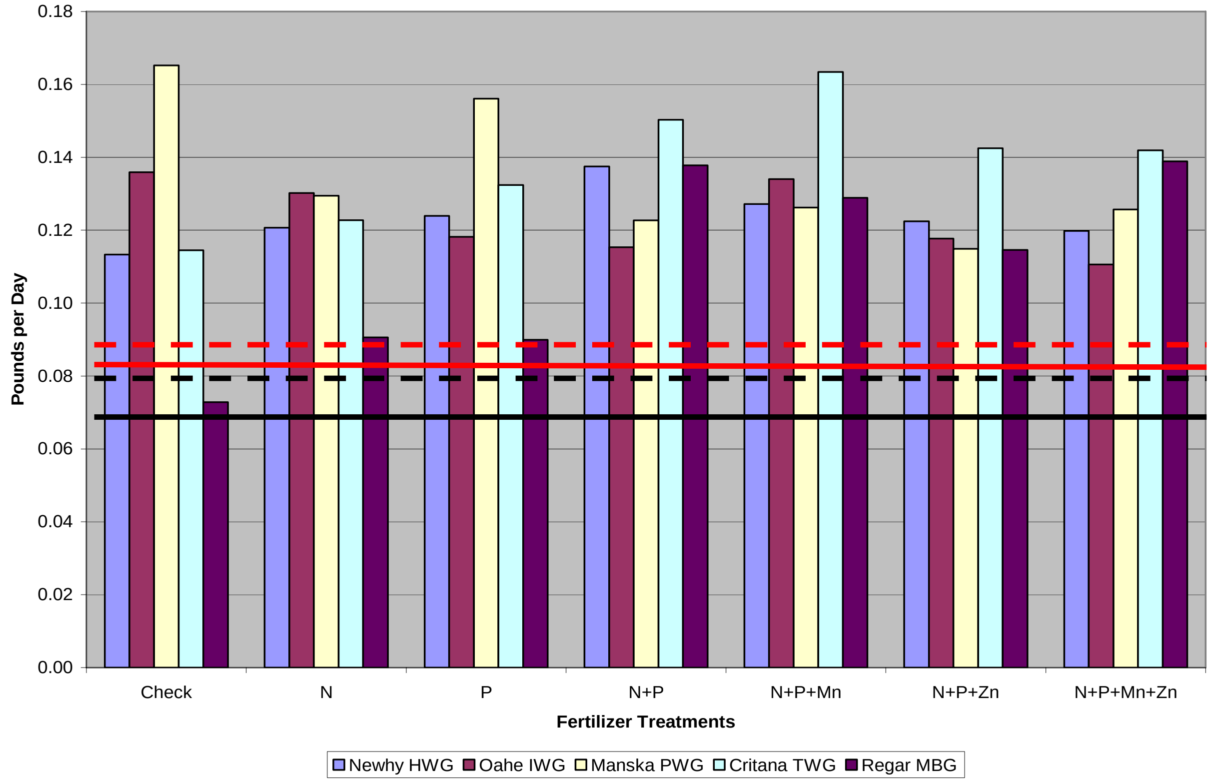

Figure 4a: Amount of calcium a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

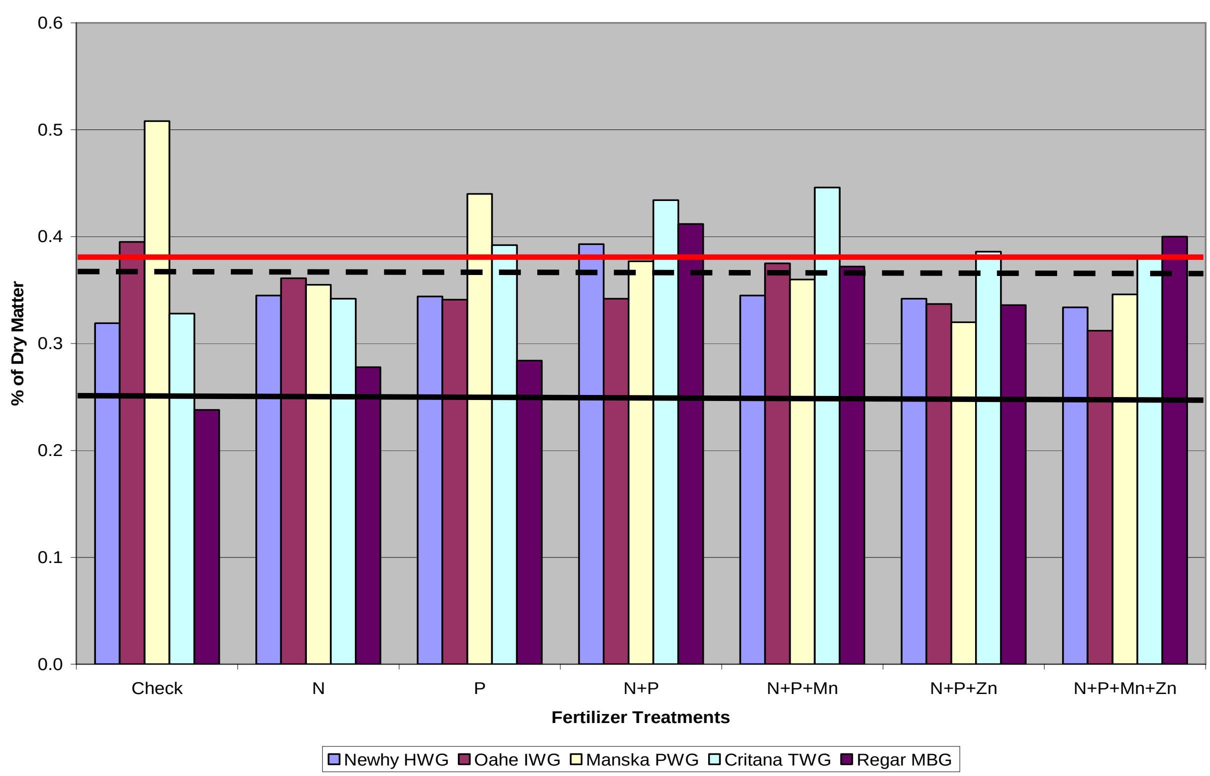

Figure 4b: Calcium content (%) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black lines**: Required amount for a sheep ewe in pregnancy – solid first 15 weeks; dashed last 4 weeks. **Red line**: Required amount for a sheep ewe first 6 to 8 weeks lactation suckling single or twin lambs.

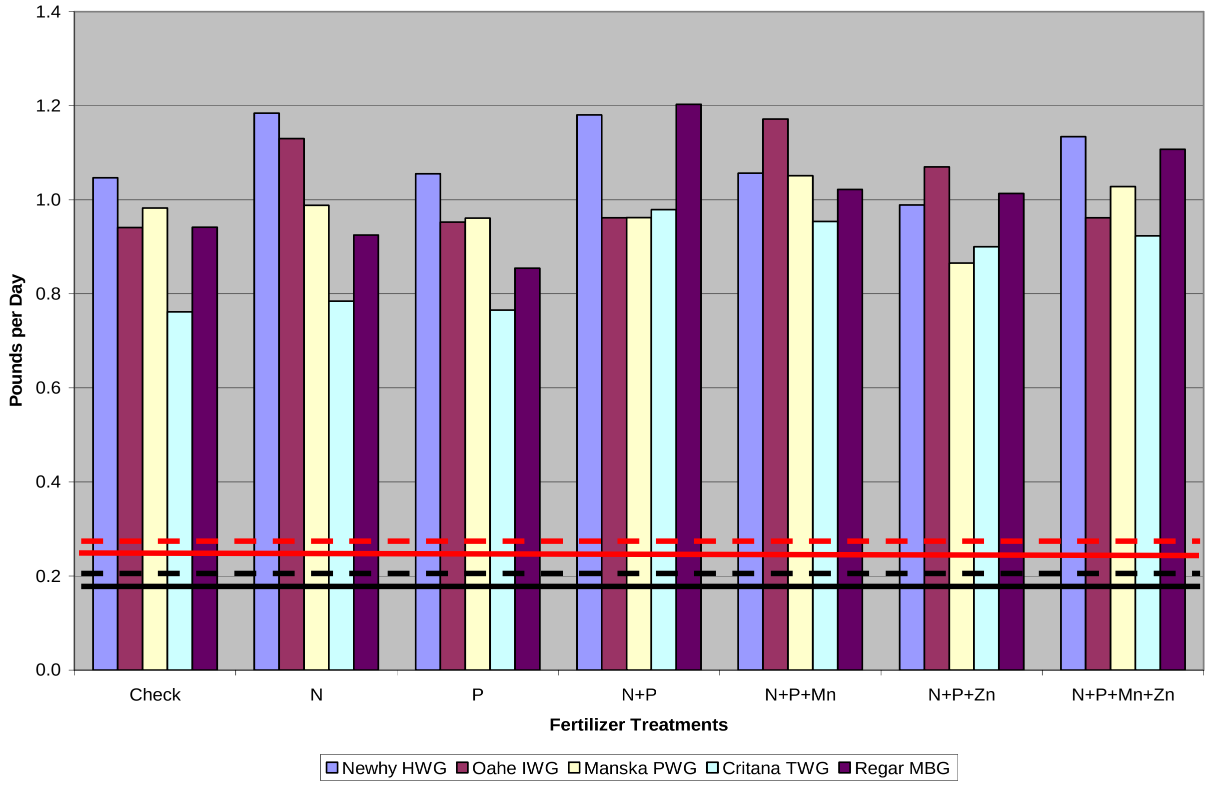

Figure 5a: Amount of potassium a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

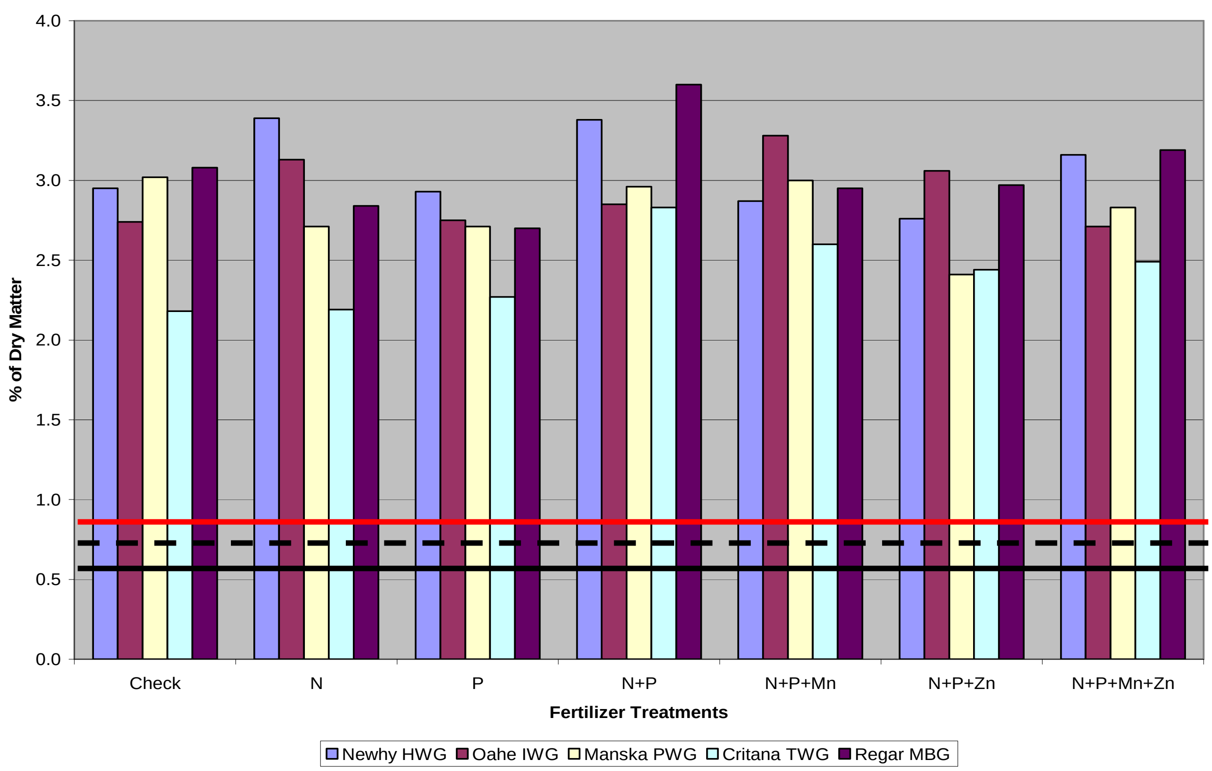

Figure 5b: Potassium content (%) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black lines**: Required amount for a sheep ewe in pregnancy – solid first 15 weeks; dashed last 4 weeks. **Red line**: Required amount for a sheep ewe first 6 to 8 weeks lactation suckling single or twin lambs.

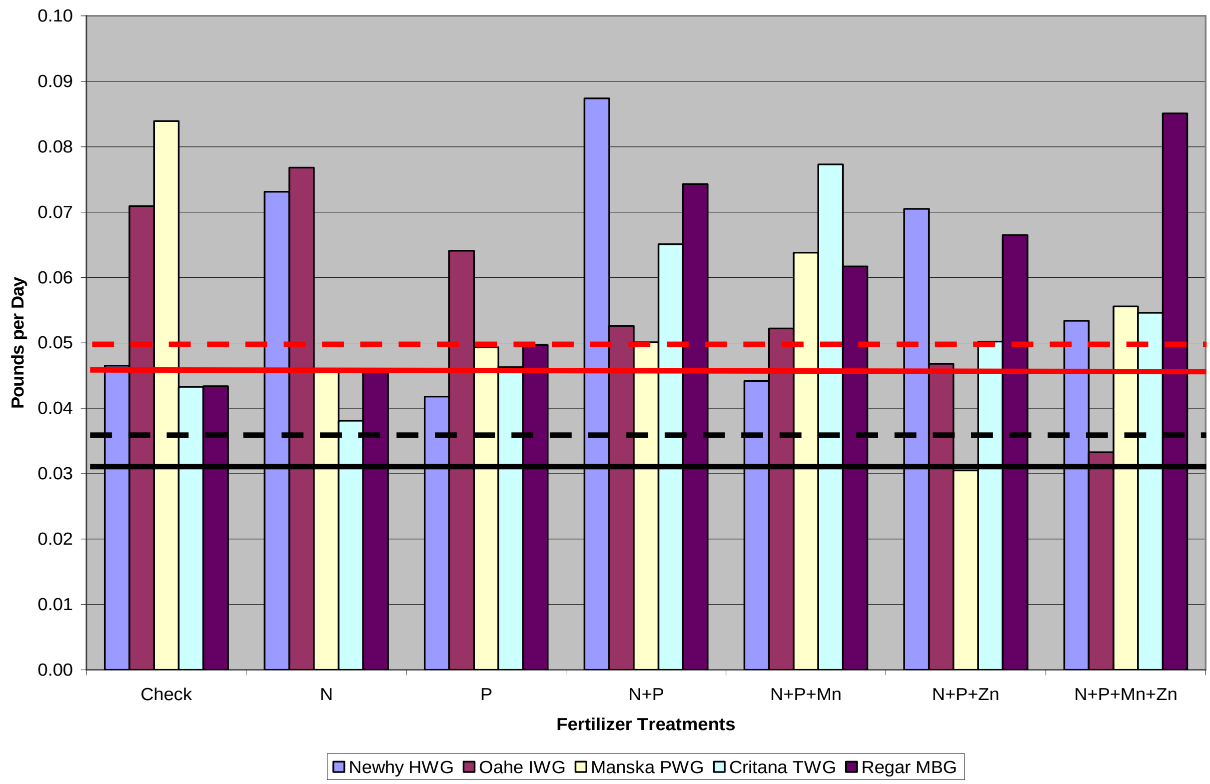

Figure 6a: Amount of magnesium a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

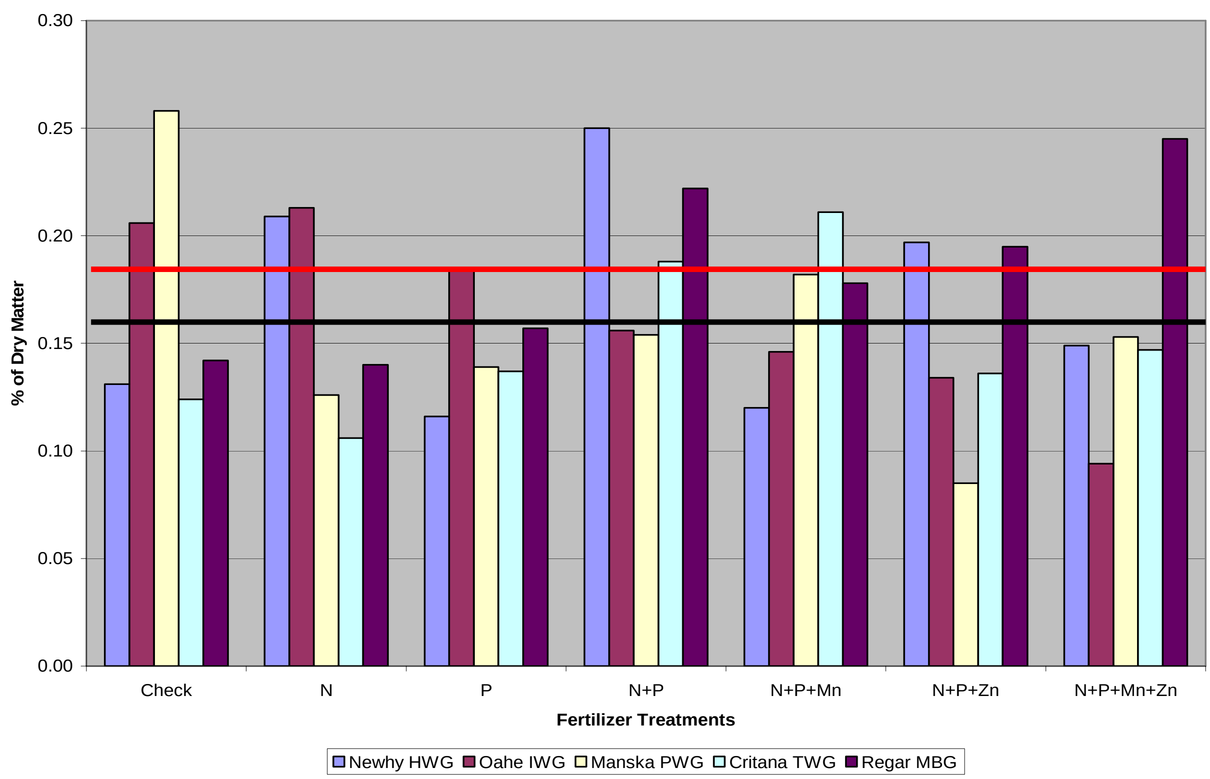

Figure 6b: Magnesium content (%) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black line**: Required amount for a sheep ewe in pregnancy. **Red line**: Required amount for a sheep ewe first 6 to 8 weeks lactation suckling single or twin lambs.

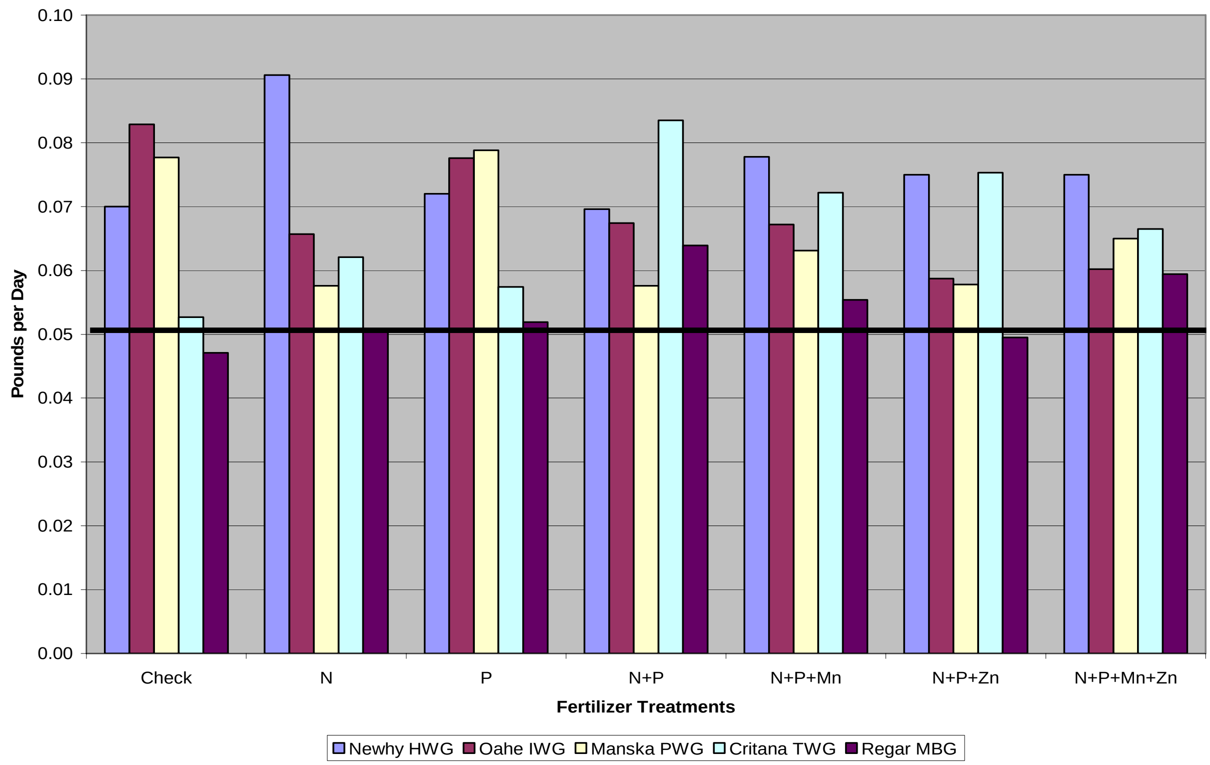

Figure 7a: Amount of sulfur a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black solid line**: required amount regardless of stage of production.

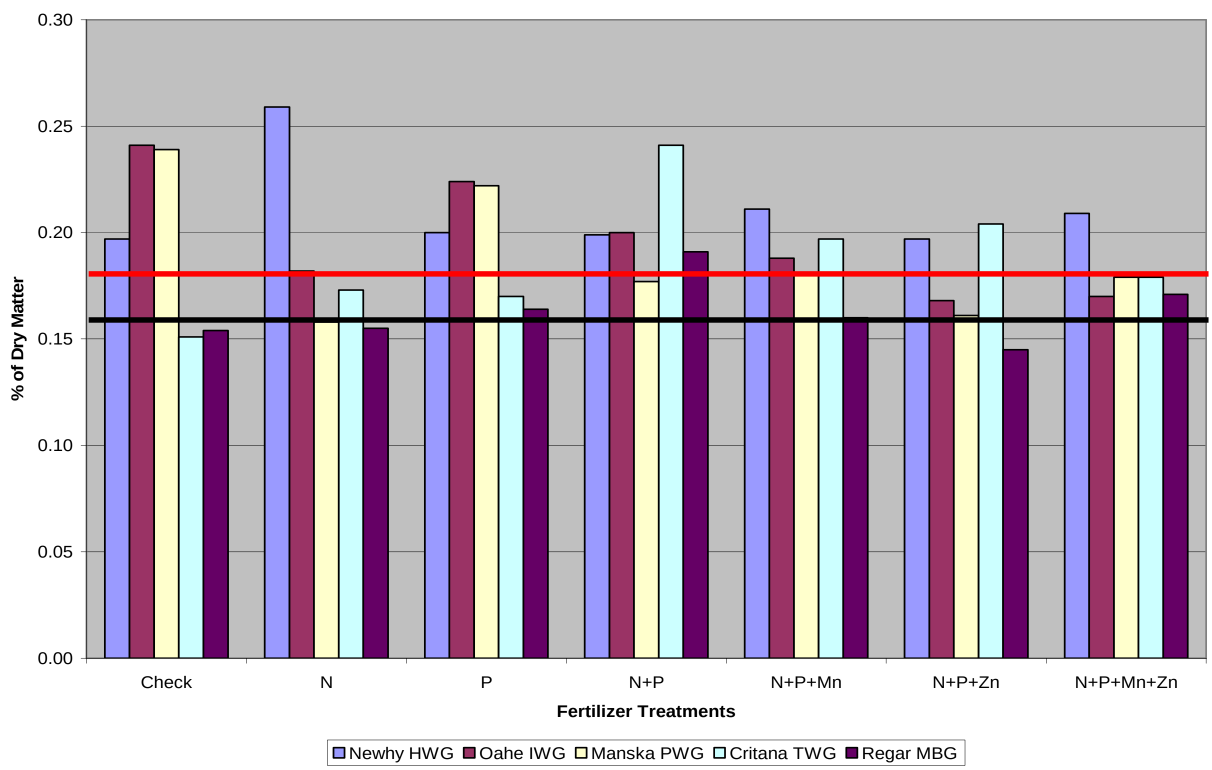

Figure 7b: Sulfur content (%) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black line**: Required amount for a sheep ewe in pregnancy. **Red line**: Required amount for a sheep ewe first 6 to 8 weeks lactation suckling single or twin lambs.

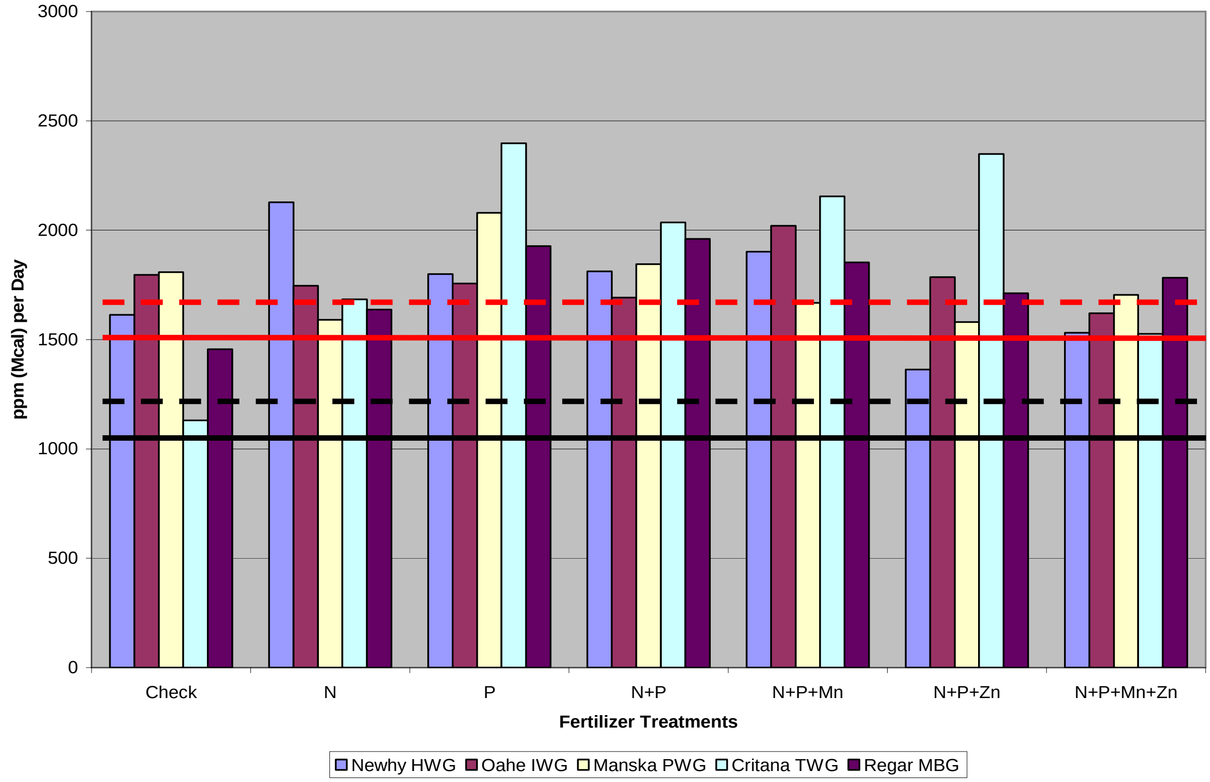

Figure 8a: Amount of iron a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

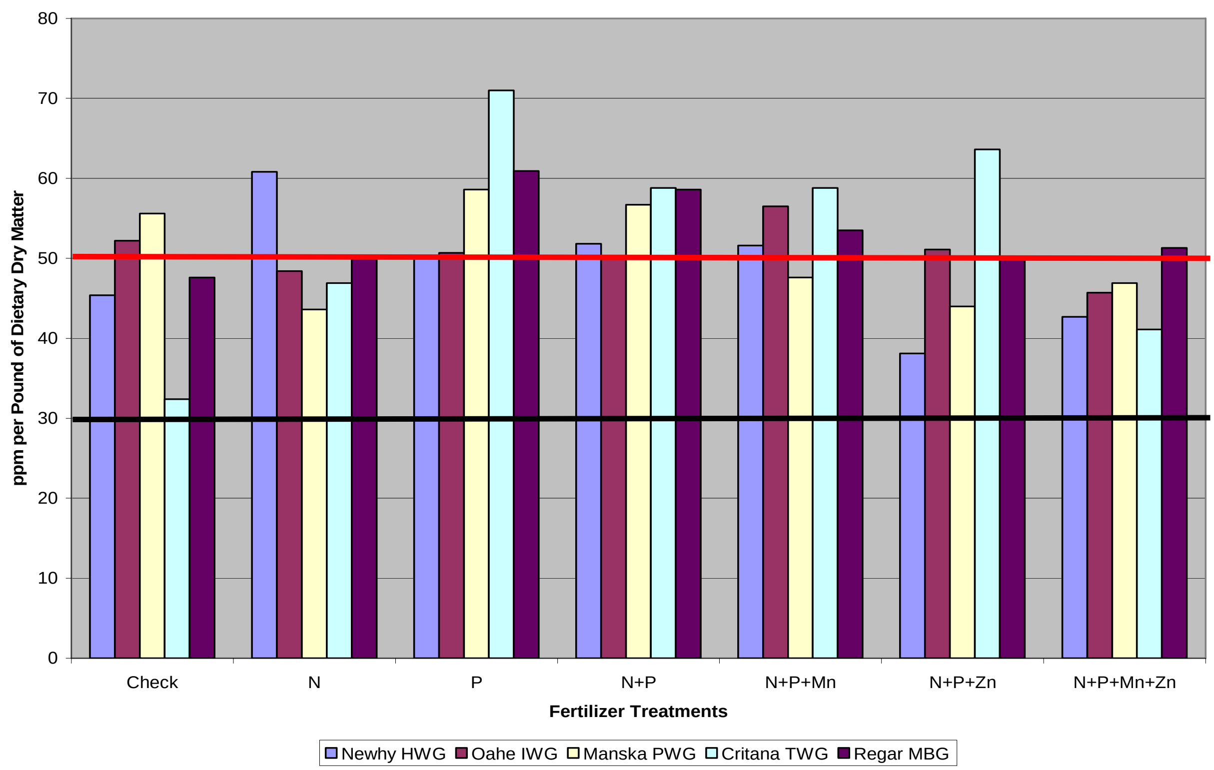

Figure 8b: Iron content (ppm) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black line**: Required amount for a sheep ewe in pregnancy. **Red line**: Required amount for a sheep ewe first 6 to 8 weeks lactation suckling single or twin lambs.

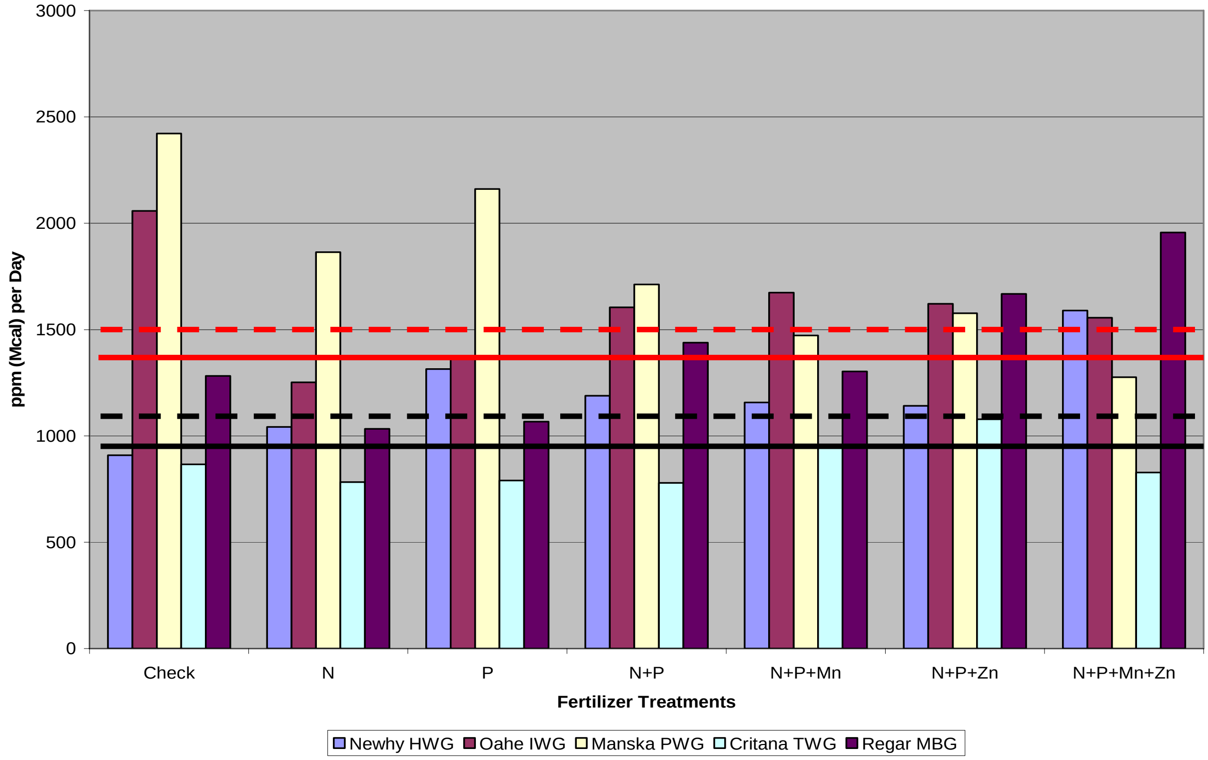

Figure 9a: Amount of manganese a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

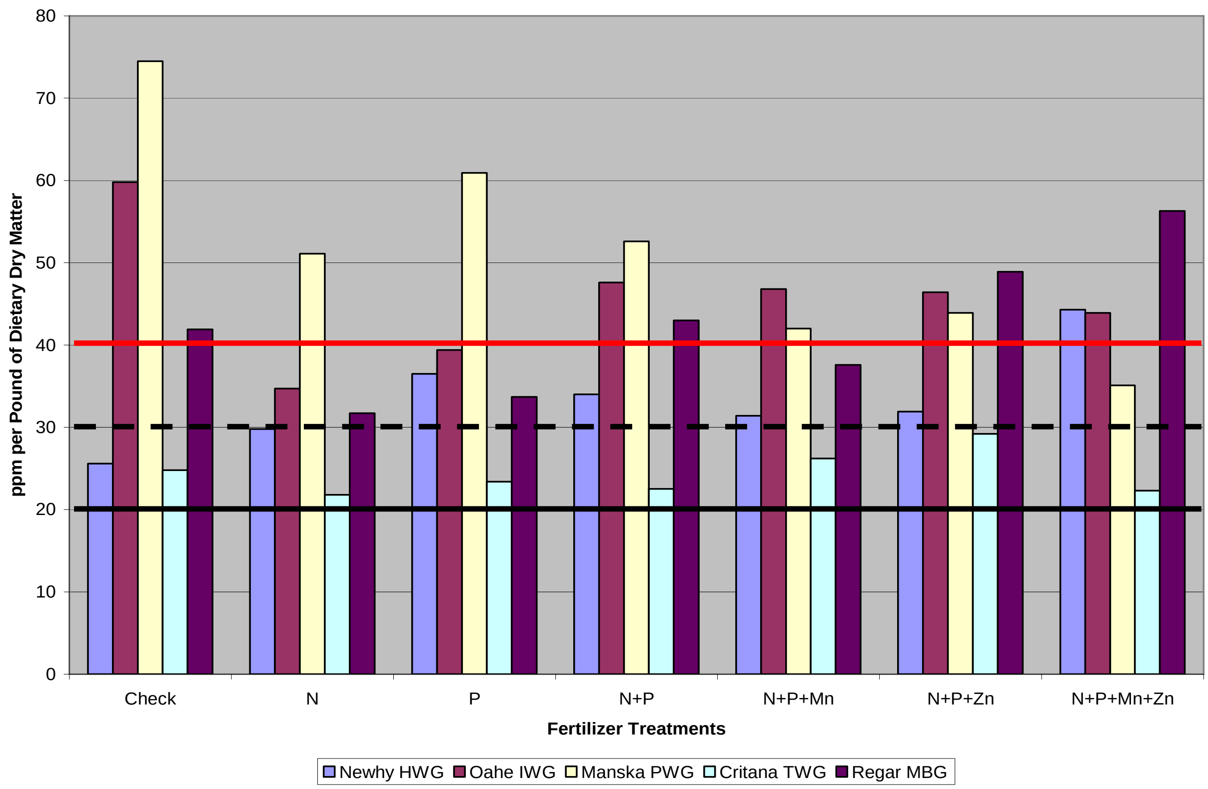

Figure 9b: Manganese content (ppm) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Black lines**: Required amount for a sheep ewe in pregnancy – solid first 15 weeks; dashed last 4 weeks. **Red line**: Required amount for a sheep ewe first 6 to 8 weeks lactation suckling single or twin lambs.

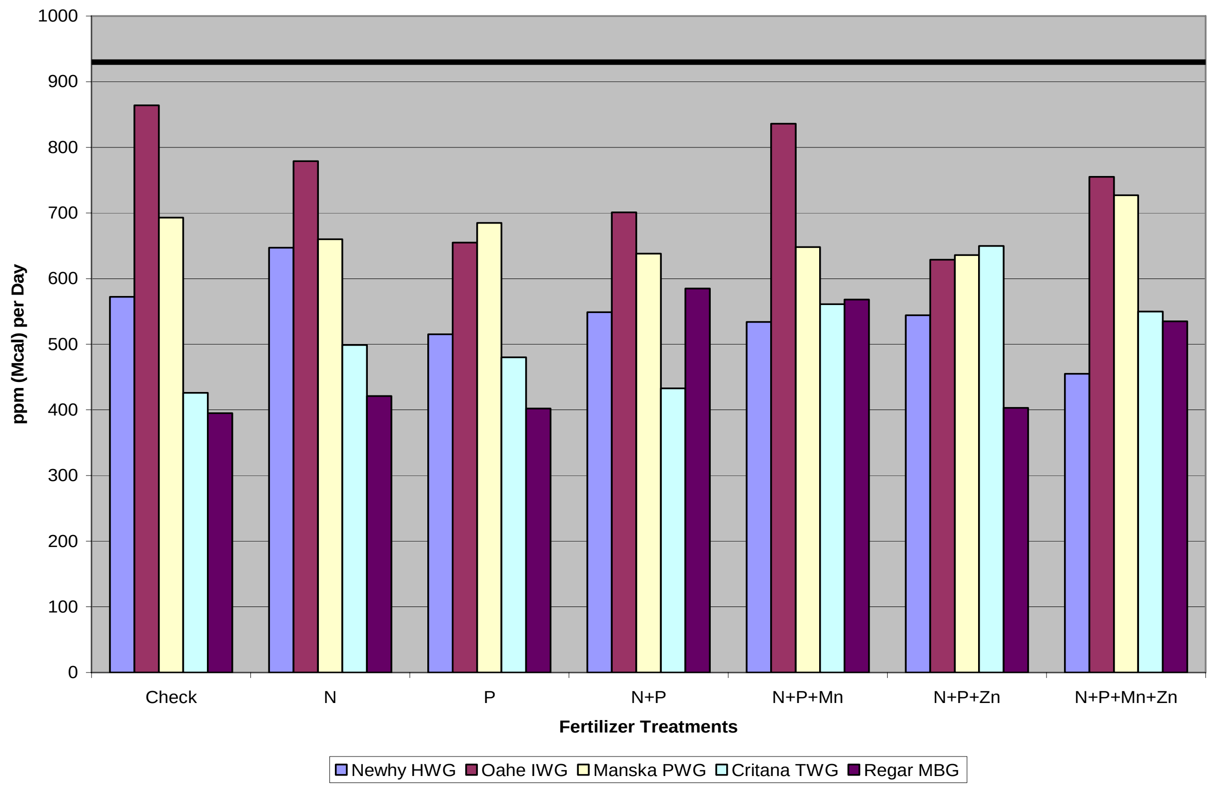

Figure 10a: Amount of zinc a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black solid line**: required amount 7th month of pregnancy.

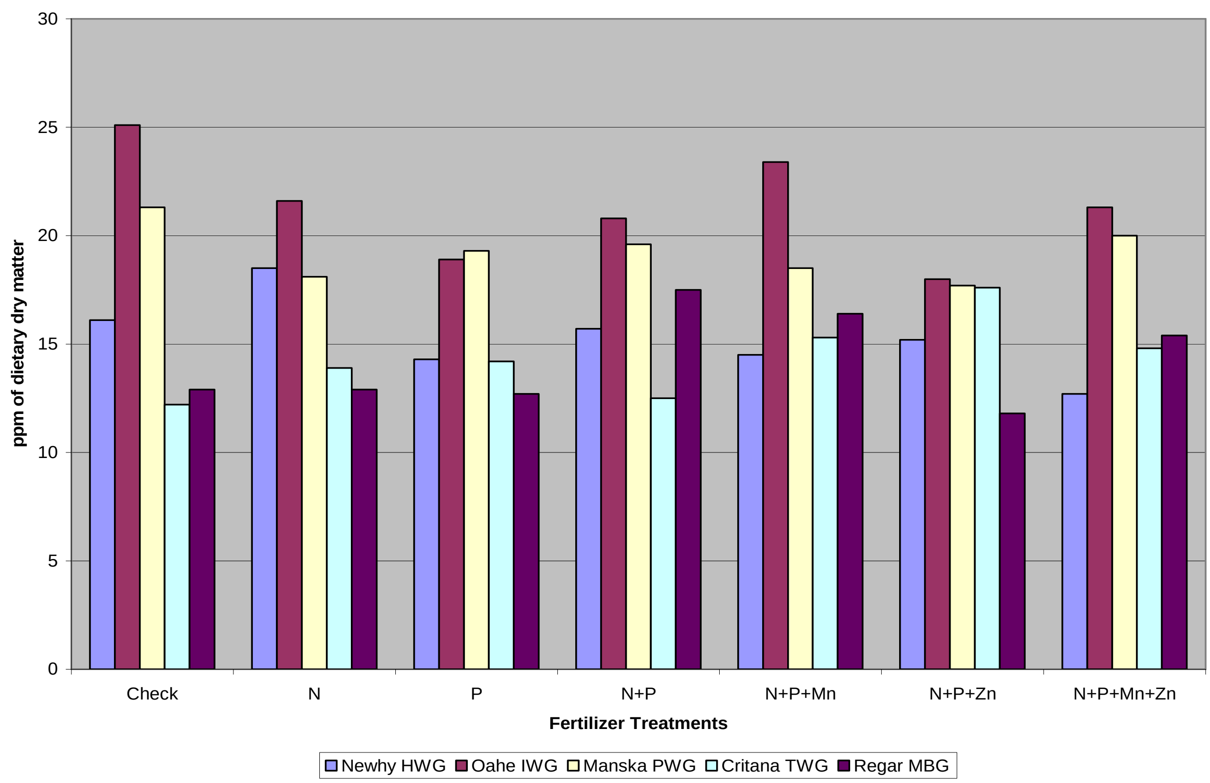

Figure 10b: Zinc content (ppm) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. Minimum required amount for a sheep ewe 33 ppm.

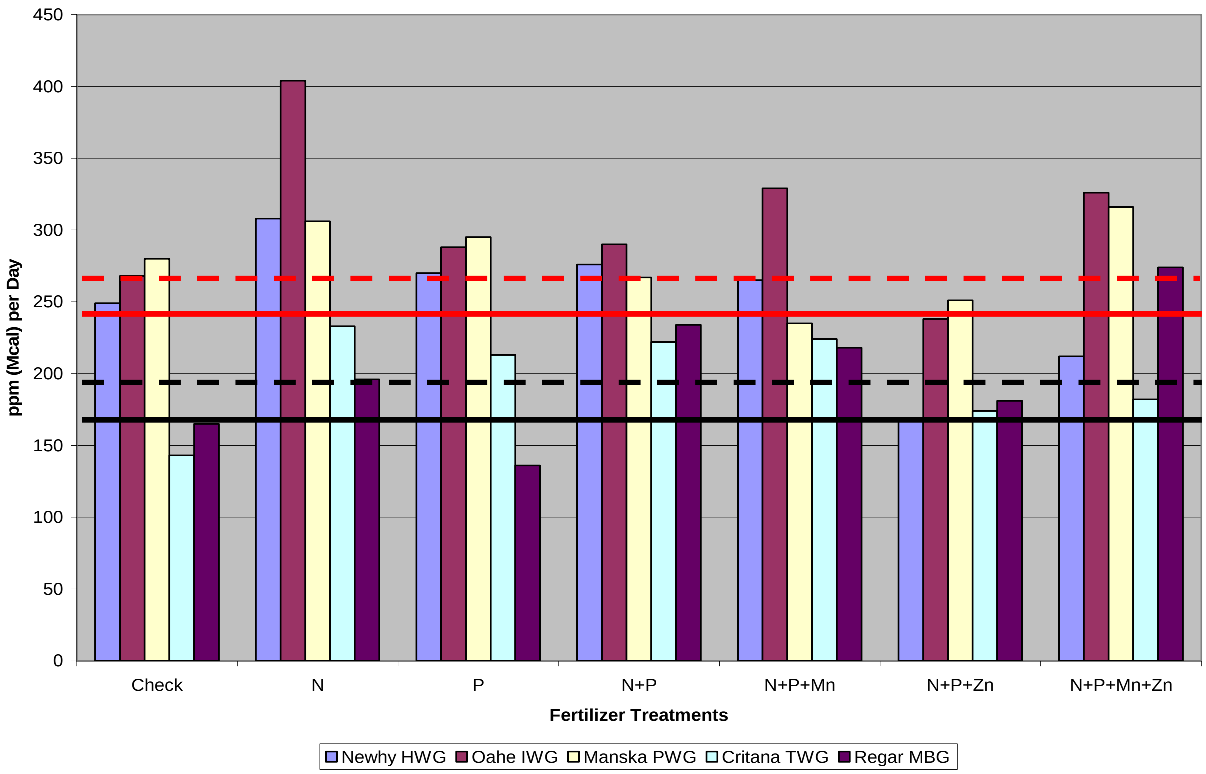

Figure 11a: Amount of copper a 1200 pound beef cow in body condition score 6 would potentially consume from 22 June 2005 harvested forage of the five grasses subjected to seven fertilizer treatments. **Black lines**: required amount third trimester of pregnancy – solid 7th month; dashed 9th month. **Red lines**: required amount at peak lactation – solid low milk (15.5 lb/day); dashed medium milk (19.3 lb/day).

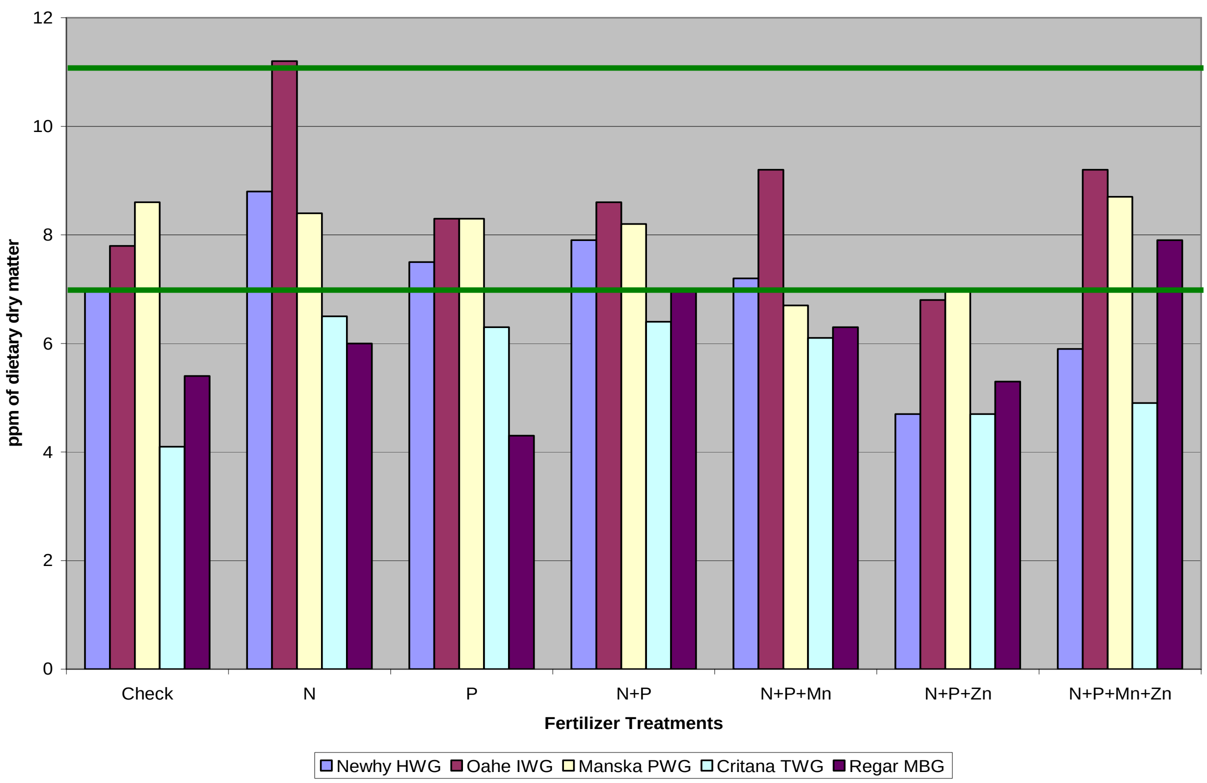

Figure 11b: Copper content (ppm) of the five grasses subjected to seven fertilizer treatments harvested on 22 June 2005. **Green lines:** Suggested range for a sheep ewe.