|  |
| --- |
| Table 5. Cover crop treatment biomass yield and quality at Ft. Ellis, MT and NGV, MT |
| Treatment | Pre-termination Biomass | Post-termination Biomass | Pre-termination C:N\* |
|  | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
|  |  |  |  |  |  |  |
| *P*-values |  *0.16* | ***<0.01*** | ***<0.01*** | *0.43* | *0.10* | ***<0.01*** |
|  |  |  |  |  |  |  |
|  | ------ Mg ha-1 ------ | -------- Mg ha-1 -------- |  |
|  |  |  |  |
| Cool Graze | 4.65 | 2.59 | 1.41 | 0.22 | 18.3 | 17.8 |
| Cool Spray | 4.33 | 2.32 | N/A | N/A | N/A | N/A |
| Warm Graze | 4.04 | 1.10 | 1.43 | 0.16 | 15.0 | 12.0 |
| Warm Spray | 4.22 | 1.02 | N/A | N/A | N/A | N/A |
| Warm Hay | 4.09 | 1.14 | 0.28 | 0.27 | 14.8 | 12.8 |
|  |  |  |  |  |  |  |
|  |  |
| Contrasts | ------------------------------------- *P-values* ---------------------------------- |
|  |  |
| Cool v. Warm | ***0.03*** | ***<0.01*** | *N/A* | *N/A* | ***0.04*** | ***<0.01*** |
| Spray v. Graze | *0.70* | *0.20* | *N/A* | *N/A* | *N/A* | *N/A* |
| WG v. WH | *0.48* | *0.46* | ***<0.01*** | *0.29* | *N/A* | *N/A* |
|  |  |  |  |  |  |  |
| CG = cool graze, WG = warm graze, and WH = warm hay.\*All cover crop species combined per plot. † Results come from an omnibus ANOVA. |

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| Table 6. Treatment *P* values and means of cover crop mixtures from grazed and hayed plots at Fort Ellis (2015) and NGV (2016), MT. Dry matter (DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), and Relative Feed Value (RFV).  |
| Treatment | DM | CP | ADF | NDF | TDN | RFV | DM | CP | ADF | NDF | TDN | RFV |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| *p*-value | *0.63* | *0.02* | *0.02* | *0.01* | *0.02* | *0.02* | *0.26* | *<0.01* | *0.02* | *0.41* | *0.02* | *0.24* |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | --------------------------- 2015 ----------------------- | --------------------------- 2016 ------------------------- |
|  |  |  |  |  |  |  |
| CG | 907 | 158 | 426 | 526 | 540 |  99 | 901 | 155 | 351 | 475 | 625 | 121 |
| WG | 908 | 229 | 370 | 488 | 604 | 115 | 889 | 224 | 274 | 475 | 711 | 149 |
| WH | 914 | 185 | 370 | 561 | 604 | 100 | 899 | 212 | 303 | 430 | 680 | 130 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| LSDtreat | NS |  41 |  37 |  39 |  42 |  11 | NS |  28 |  49 | NS |  54 | NS |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| Contrast | ------------------------------------------------------ *p-*values ------------------------------------------------------- |
|  |  |
| Warm v. Cool | *0.58* | ***<0.01*** | ***<0.01*** | *0.94* | ***<0.01*** | *0.07* | *0.31* | ***<0.01*** | ***0.01*** | *0.50* | ***0.01*** | *0.20* |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| CG = cool graze, WG = warm graze, and WH = warm hayRFV Index = DDM x DMI / 1.29, where: DDM = Digestible Dry Matter = 88.9 – (0.779 x %ADF) on a dry matter basis DMI = Dry Matter Intake = 120 / %NDF on a dry matter basis |

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| Table 7. Soil penetration resistance measured Apr 13 2016 prior to wheat planting, following 2015 cover crop treatments, Fort Ellis, MT  |
|  | Depth (cm) |
| Treatment | 0 - 7.5  | 7.5 - 15 | 15 - 22.5  | 22.5 - 30  |
|  |  |
| *p*-values | *0.15* | ***<0.01*** | ***<0.01*** | *0.26* |
|  |  |  |  |  |
|  | ---------------------------kg cm-1----------------------- |
|  |  |
| Fallow | 7.2 |  8.2 |  7.9 | 8.0 |
| Cool Graze | 7.0 | 10.6 | 10.9 | 9.3 |
| Cool Spray | 8.3 | 10.0 |  9.5 | 9.4 |
| Warm Graze | 6.3 |  8.9 |  9.1 | 9.1 |
| Warm Spray | 6.3 |  9.4 |  8.9 | 8.1 |
| Warm Hay | 7.5 |  8.6 |  7.8 | 8.3 |
|  |  |  |  |  |
| LSDtreat | NS |  1.1 |  1.5 | NS |
|  |  |  |  |  |
| Contrast | ------------------------ *p*-values*----------------------* |
|  |  |
| Fallow v. All | *0.33* | ***<0.01*** | ***0.03*** | *0.17* |
| Cool v. Warm | *0.10* | ***<0.01*** | ***<0.01*** | *0.09* |
| Spray v. Graze | *0.28* | *0.94* | *0.13* | *0.41* |
|  |  |  |  |  |

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| Table 8. Soil bulk density measured Apr 13 2016 prior to wheat planting, following 2015 cover crop treatments, Fort Ellis, MT.  |
|  | Depth (cm) |
| Treatment | 0 - 0.3 | 0.31 - 0.6 | 0.61 - 0.9  |
|  |  |
| *p*-values | *0.51* | *0.99* | *0.44* |
|  |
|  | ----------------- kg cm3 -1 ----------------- |
|  |  |
| Fallow | 1.3 | 1.3 | 1.3 |
| Cool Graze | 1.3 | 1.4 | 1.3 |
| Cool Spray | 1.2 | 1.4 | 1.2 |
| Warm Graze | 1.3 | 1.3 | 1.3 |
| Warm Spray | 1.3 | 1.4 | 1.3 |
| Warm Hay | 1.3 | 1.4 | 1.2 |
|  |  |  |  |
| LSDtreat | NS | NS | NS |
|  |  |
| Contrasts | ------------------ *p*-values*-----------------* |
|  |  |
| Fallow v. All | *0.13* | *0.72* | *0.37* |
| Cool v. Warm | *0.34* | *0.86* | *0.66* |
| Spray v. Graze | *0.40* | *0.86* | *0.14* |

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| Table 9. Soil water (mm water equivalence) measured after cover crop termination, at Fort Ellis, MT, 2015, and NGV, MT, 2016.  |
|  | Fort Ellis 2015 | NGV 2016 |
| Treatment | 0 to 0.3 m | 0.31 to 0.6 m | 0.61 to 0.9 m | Total | 0 to 0.3 m | 0.31 to 0.6 m | 0.61 to 0.9 m | Total |
|  |  |
| *p-value* | ***<0.01*** | ***<0.01*** | ***<0.01*** |  | ***<0.01*** | ***<0.01*** | ***<0.01*** |  |
|  |  |
|  | ----------------------------------------------- Soil Water mm-1 -------------------------------------------------------- |
|  |  |
| Fallow (Cool) | 9.0 | 9.1 | 8.0 | 26 | 8.3 | 6.5 | 4.9 | 20 |
| Fallow (Warm) | 9.9 | 9.9 | 8.4 | 28 | 7.0 | 5.8 | 5.0 | 18 |
| Cool Graze | 5.6 | 6.0 | 6.5 | 18 | 6.2 | 3.9 | 4.0 | 14 |
| Cool Spray | 5.4 | 5.6 | 5.9 | 17 | 6.2 | 3.8 | 3.9 | 14 |
| Warm Graze | 6.1 | 7.7 | 7.6 | 21 | 4.7 | 4.8 | 4.5 | 14 |
| Warm Spray | 7.4 | 6.7 | 7.1 | 21 | 4.9 | 4.7 | 4.5 | 14 |
| Warm Hay | 7.7 | 7.2 | 7.5 | 22 | 5.3 | 5.0 | 4.7 | 15 |
|  |  |  |  |  |  |  |  |  |
| LSD | 1.3 | 1.1 | 0.7 |  | 0.7 | 0.7 | 0.6 |  |
|  |  |  |  |  |  |  |  |  |
|  Contrasts |  ------------------------------------------------ *p -*values *--------------------------------------------------* |
|  |  |
| Fallow v. All | ***<0.01*** | ***<0.01*** | ***<0.01*** |  | ***<0.01*** | ***<0.01*** | ***<0.01*** |  |
| Cool v. Warm | ***<0.01*** | ***<0.01*** | ***<0.01*** |  | ***<0.01*** | ***<0.01*** | ***<0.01*** |  |
| Spray v. Graze | *0.2* | *0.6* | *0.4* |  | *0.67* | *0.59* | *0.81* |  |

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| Table 10. Soil Nitrate-N (NO3-N) measured after cover crop termination, at Fort Ellis, MT, July 10, 2015, and NGV, MT, July 12, 2016.  |
|  | Fort Ellis 2015 | NGV 2016 |
| Treatment | 0 to 0.3 m | 0.31 to 0.6 m | 0.61 to 0.9 m | Total | 0 to 0.3 m | 0.31 to 0.6 m | 0.61 to 0.9 m | Total |
|  |  |
| *p-value* | ***<0.01*** | ***<0.01*** | *0.60* |  | ***<0.01*** | ***<0.01*** | ***<0.01*** |  |
|  |  |
|  | ----------------------------------------------------- kg ha-1 ------------------------------------------------------------- |
|  |  |
| Fallow (Cool) | 31 | 12 | 10 | 53 | 24 | 7 | 11 | 42 |
| Fallow (Warm) | 23 | 13 | 12 | 48 | 30 | 12 | 12 | 54 |
| Cool Graze | 8 | 3 | 6 | 17 | 7 | 3 | 18 | 28 |
| Cool Spray | 6 | 2 | 6 | 14 | 10 | 3 | 5 | 18 |
| Warm Graze | 13 | 2 | 10 | 25 | 12 | 3 | 6 | 21 |
| Warm Spray | 17 | 4 | 10 | 31 | 14 | 5 | 8 | 27 |
| Warm Hay | 7 | 3 | 6 | 16 | 12 | 5 | 8 | 25 |
|  |  |  |  |  |  |  |  |  |
| LSD | 10 | 4 | NS |  | 9 | 4 | 11 |  |
|  |  |  |  |  |  |  |  |  |
|  Contrasts |  ------------------------------------------------ *p -*values *--------------------------------------------------* |
|  |  |
| Fallow v. All | ***<0.01*** | ***<0.01*** | *0.64* |  | ***<0.01*** | *0.19* | *0.67* |  |
| Cool v. Warm | ***0.01*** | ***<0.01*** | *0.33* |  | *0.08* | *0.07* | *0.24* |  |
| Spray v. Graze | ***<0.01*** | ***<0.01*** | *0.22* |  | ***<0.01*** | ***<0.01*** | *0.50* |  |
| CG v WG | *0.62* | *0.75* | *0.44* |  | *0.77* | *0.32* | *0.28* |  |
| WG v. WH | *0.22* | *0.82* | *0.61* |  | *0.74* | *0.77* | *0.36* |  |
|  |  |  |  |  |  |  |  |  |
| CG = cool graze, WG = warm graze, and WH = warm hay |

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| Table 11. Soil water (mm water equivalence) and nitrate (kg ha-1), measured on Apr 12, 2016, prior to planting wheat and following 2015 cover crop treatments, Fort Ellis, MT.  |
|  | Soil Water | Soil NO3-N |
| Treatment | 0 to 0.3 m | 0.31 to 0.6 m | 0.61 to 0.9 m | 0 to 0.3 m | 0.31 to 0.6 m | 0.61 to 0.9 m |
|  |  |  |  |  |  |  |
| *p*-values | 0.09 | *0.54* | *0.82* | *0.06* | ***<0.01*** | ***0.02*** |
|  |  |  |  |  |  |  |
|  | ----------------Soil Water mm-1 ---------------- | -------------- Soil NO3-N kg ha-1 -------------- |
|  |  |  |
| Fallow  | 94 | 87 | 80 | 30 | 39 | 28 |
| Cool Graze | 87 | 85 | 78 | 25 | 24 | 18 |
| Cool Spray | 90 | 84 | 78 | 24 | 22 | 16 |
| Warm Graze | 90 | 86 | 77 | 18 | 14 | 12 |
| Warm Spray | 91 | 84 | 80 | 13 | 16 | 21 |
| Warm Hay | 91 | 83 | 80 | 16 | 17 | 15 |
|  |  |  |  |  |  |  |
| LSDTreat | NS | NS | NS | NS | 3.55 | 8.64 |
|  |  |  |  |  |  |  |
| Contrasts | ---------------------------------------------- *p-values-----------------------------------------------* |
|  |  |  |  |  |  |  |
| Fallow v. All | ***0.02*** | *0.17* | *0.57* | ***0.02*** | ***<0.01*** | ***<0.01*** |
| Cool v. Warm | *0.13* | *0.93* | *0.67* | ***0.03*** | ***<0.01*** | ***<0.01*** |
| Spray v. Graze | *0.19* | *0.36* | *0.45* | *0.40* | *0.87* | *0.87* |
| WG v. WH | *0.62* | *0.40* | *0.74* | *0.70* | *0.80* | *0.80* |
|  |  |  |  |  |  |  |
| CG = cool graze, WG = warm graze, and WH = warm hay.\*Results come from an omnibus ANOVA. |

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| Table 12. Soil PMN (kg NH4 ha-1) measured Apr 13, 2016 prior to wheat planting, Fort Ellis, MT. An omnibus ANVOA showed no treatment (*p* = 0.07) and a strong rep effect (*p <* 0.01).  |
| Treatment | Fallow | Cool Graze | Cool Spray | Warm Graze | Warm Spray | Warm Hay |
|  |  |  |  |  |  |  |
| PMN (kg NH4 ha-1) | 28.6 | 26.5 | 42.9 | 24.6 | 40.7 | 20.8 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Contrast | Fallow v. All | Cool v. Warm | Spray v. Graze | CG v. WG | WG v. WH |  |
|  |  |  |  |  |  |  |
|  *p-*values | *0.68* | *0.25* | ***0.01*** | *0.50* | *0.13* |  |
|  |  |  |  |  |  |  |
| CG = cool graze, WG = warm graze, and WH = warm hay. |

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| Table 13. Pre-planting soil phosphate (kg P2O5ha-1) Apr 13, 2016, prior to wheat seeding, Fort Ellis, MT. |
| Treatment | Fallow | Cool Graze | Cool Spray | Warm Graze | Warm Spray | Warm Hay |
|  |  |  |  |  |  |  |
|  | 121 | 136 | 139 | 143 | 134 | 134 |
|  |  |  |  |  |  |
| Contrast | Fallow v. All | Cool v. Warm | Spray v. Graze | CG v. WG | WG v. WH |  |
|  |  |  |  |  |  |  |
|  | ***0.03*** | *0.87* | *0.66* | *0.24* | *0.88* |  |
| CG = cool graze, WG = warm graze, and WH = warm hay. |

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| Table 14. Soil enzyme activity, measured Apr 13 2016, prior to wheat planting, For Ellis, MT. Mean treatment values of soil enzyme activity represent mg of p-nitrophenol (PN) produced per kg soil per hour. |
|  |  | Acid | Alkaline |  |
| Treatment | β-Glucosaminidase | Phosphatase | Phosphatase | β-Glucosidase |
|  |  |  |  |  |
| *p*-values | *0.21* | ***<0.01*** | *0.32* | *0.11* |
|  |  |  |  |  |
|  | ----------------------------------- Mg PN kg-1 soil h-1 --------------------------- |
|  |  |
| Fallow | 154 | 215 | 224 | 139 |
| Cool Graze | 204 | 377 | 291 | 209 |
| Cool Spray | 180 | 287 | 266 | 155 |
| Warm Graze | 223 | 363 | 283 | 193 |
| Warm Spray | 174 | 287 | 262 | 218 |
| Warm Hay | 164 | 235 | 279 | 168 |
|  |  |  |  |  |
| LSD | NS | 84.3 | NS | NS |
|  |  |  |  |  |
| Contrasts | ----------------------------------- *p*-values------------------------------ |
|  |  |
| Fallow v. All | *0.14* | ***<0.01*** | ***0.04*** | ***0.05*** |
| Cool v. Warm | *0.79* | *0.17* | *0.85* | *0.57* |
| Spray v. Graze | *0.09* | ***<0.01*** | *0.29* | *0.51* |
|  |  |  |  |  |
|  |  |  |  |  |

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| Table 15. Means for cover crop treatment effects on subsequent spring wheat at three N fertilizer rates on spring wheat at Fort Ellis, MT 2016. |
| Source of variation\* | Wheat Yield | Wheat Seed Protein |
|  |  |  |
|  | -------------- *p*-values ------------ |
|  |  |  |
| Treatment | *0.32* | ***0.04*** |
| Block | ***<0.01*** | ***<0.01*** |
| Fertilizer | ***<0.01*** | ***<0.01*** |
| Treatment x Fertilizer | *0.69* | *0.67* |
|  |  |  |
| Treatment | ---- Mg ha-1 ---- | ----- g kg-1 ---- |
|  |  |  |
| Fallow | 3.9 | 137 |
| Cool Graze | 3.7 | 132 |
| Cool Spray | 3.7 | 135 |
| Warm Graze | 3.7 | 133 |
| Warm Spray | 3.6 | 135 |
| Warm Hay | 3.7 | 133 |
|  |  |  |
| LSDtreat. | NS |  4 |
|  |  |  |
| Fertilizer Rate |  |  |
|  |  |  |
|  0 kg N ha-1 | 3.3 | 129 |
|  68 kg N ha-1 | 3.8 | 134 |
|  135 kg N ha-1 | 4.1 | 139 |
|  |  |  |
| LSDfert. | 0.2 |  3 |
|  |  |  |
| Contrasts | ------------ *p*-values ---------- |
|  |  |
| Fallow v. All | *0.06* | ***0.01*** |
| Cool v. Warm | *0.51* | *0.99* |
| Spray v. Graze | *0.32* | ***0.03*** |
| WG v. WH | *0.60* | *0.87* |
|  |  |  |
| \*Results come from omnibus ANOVA |

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