CORD IV Project
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Evaluation of forage varieties for tolerance to management stress.

Final Report to Ontario Forage Council

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EXECUTIVE SUMMARY

Forages are a primary feed source for many classes of animals in the province, including, but not limited to, dairy, beef, sheep, and equine. Although each of these sectors have different constraints and opportunities, a common theme is a desire to use plant varieties that are best suited to the production system. This is to ensure stability of feed production and reduced costs of their production, harvest, and storage. This research project was designed to provide a systematic evaluation of commercially available forage varieties in Ontario for specific attributes, namely, tolerance to machine traffic, tolerance to liquid manure application, and stem physical characteristics in hay systems. Since these characteristics are subject to genotype by environment interaction, assessment under Ontario conditions was necessary to provide relative variety performance within the province.

Herbage yield of 49 varieties of alfalfa managed under a standard, 3-harvest system, were obtained from trials conducted at Elora and Enniskillen. Yield results were incorporated into the Ontario Forage Crops Committee performance database and computations of relative variety performance for Ontario. Maturity and stem diameter measures were also recorded from these trials; for stem diameter measurement, diameters of Stage 4 stems (late bud stage, >2 buds with open flowers) were measured to avoid confounding effects due to maturity differences among stems. For both traits, variety differences were detected, however, there were no significant variety x environment interactions. This indicated that relative maturity and stem diameter were consistent from test to test, harvest to harvest, and that the data could be pooled. Combined over trials, six varieties (Macon, Amerigraze 401+Z, Steak, Oneida VR, Rhino, and Hybri-Force 400) were significantly less mature than the test mean and six varieties (Starbuck, Reliance, Genoa, Stallion, Exp636, and 4.2) were significantly more mature than the test mean. Three varieties (Affinity+Z, 53V52, and Rhino) had Stage 4 stems that were significantly smaller in diameter compared to the test mean. Seven varieties (GH700, Stallion, 134, FSG 300LH, WinterGold, OAC Superior, and Renaissance) had Stage 4 stems that were significantly larger in diameter compared to the test mean.

Herbage yield, maturity, and Stage 4 stem diameter were not correlated with each other. The absence of a strong correlation indicated that if maturity and/or stem diameter was an issue for producers, then both management (ie. harvest timing) and variety selection are factors to incorporate in the design of a system to produce the desired harvested product. For example, harvesting at an earlier stage of development will result in forage that has a greater proportion of finer stemmed, less mature material. However, varieties differ in their maturity as well as their diameter of Stage 4 stems. Thus, one could leave harvest date unchanged but modify the maturity/diameter by changing the variety. Since there was not a high correlation with herbage yield, the latter does not need to be sacrificed to obtain the desired forage characteristics. Bi-plots were constructed to assist in identifying varieties with the desired combination of attributes.

There were differences among varieties in their response to the application of traffic and liquid manure (4500 gal/acre) after first and second harvest, either with or without soil aeration. Differences among treatments became more pronounced as the trial continued into the second year. Traffic stress reduced yield in the second year by 5% averaged over all varieties. Application of liquid manure increased yield by 31% in the second year. Aeration in combination with liquid manure also resulted in higher seasonal yields in the second year but not as high when the manure was applied without the aeration treatment. In general, there was a positive correlation between herbage yield of the control treatment and yield under the various stresses (r ranged from 0.54 to 0.59, P=0.0001). However, the correlation was not tight as there were interactions in the responses of the varieties to either traffic or manure stress treatments. Some varieties were very sensitive to traffic (eg. Jolt), some were relatively unaffected to traffic (eg. AC Brador), some were highly responsive to manure application (eg. Reliance), and some were not as responsive to manure (eg. Jolt). Bi-plots were generated to summarize the variety reactions to the stress treatments relative to the control treatment.

Studies were also conducted to evaluate liquid manure treatments, aeration, and their combination

when applied after first harvest, after second harvest, and after both harvests. This study also included control treatments including: standard management, water, and nitrogen fertilizer. As in previous studies, traffic reduced yield; in this particular set of trials, traffic reduced third harvest yield 7-8% within the year of application, and reduced yield 3-4% in the first harvest the following year. The effect of aeration depended on the time of its application, when applied after the first harvest, it reduced third harvest yield 4-8% but when applied after the second harvest it increased yield (as much as 26%) of the subsequent harvest that year. This effect was carried over into the following year in which first harvest yields were 3-11% higher for plots that had received one or more aeration treatments the previous season.

Although the stand was not old, 90%+ alfalfa, and nodulated, there was a 9-32% increase in third harvest yields from application of nitrogen fertilizer. There was a carry-over effect into the following year, first harvest yields increased up to 12% under the nitrogen treatment, the greatest response when the application occurred after the second harvest of the season. Normally, applications of nitrogen fertilizer do not result in yield increases in alfalfa. These findings indicate that in this trial the third growth cycle in these trials had less than optimal nitrogen, either through N2-fixation or supply from the soil ecosystem.

Herbage yields increased as manure rates increased. Third harvest yields increased as much as 50% with the application of 6000 gal/acre of liquid manure. In comparing the response to the water and to the nitrogen controls, this yield increase could be attributed to the nutrients (ie. Nitrogen) in the liquid manure, not the water *per se*. The interaction between manure application and aeration was quite variable, however, under the manure+aeration treatment, as the rate of manure application increased, the yield response decreased compared to the same manure application without aeration. This indicates that direct manure-root contact may be detrimental to the alfalfa stand.

Incorporation of liquid manure into an alfalfa production system is of benefit for forage yield production. For producers, this provides for two additional times of the year (late May/early June and Mid-late July) for application/disposal of liquid manure for livestock farms. These application times may also have less nutrient losses compared to late fall or late winter applications. However, the impact of these applications of liquid manure on the nutritional composition of the feed and changes in the soil system also need to be assessed.

BACKGROUND

Forages are a primary feed source for many classes of animals in the province, including, but not limited to, dairy, beef, sheep, and equine. Each of these sectors have different constraints and opportunities. A common theme is the desire to use plant varieties and species mixtures that are best suited to the production system. This ensures stability of feed production and reduced costs of their production, harvest, and storage.

In past years, yield performance assessment has been conducted on forage varieties through a cooperative testing arrangement within the umbrella of the Ontario Forage Crops Committee (a sub-committee of the OASCC Field Crop Research and Service Committee). This evaluation was conducted at specific sites with forage yield under a standardized testing protocol (2002 Variety Testing Procedures, Ontario Forage Crops Committee). This protocol was designed to obtain relative yield information under management conditions that would provide maximal yield potential. This information was supplemented with laboratory assessments of disease and pest reaction to provide guidance to producers for selecting varieties (2005 Variety Performance, Ontario Forage Crops Committee). It was recognized that pest reaction was not subject to genotype x environment interaction so evaluations of these attributes in laboratories within or outside of Ontario/Canada could be used to provide this information. On the other hand, yield and persistence were highly subject to genotype x environment interaction, thus there was a need to obtain this data from fields in Ontario was necessary (Variety Testing Procedures, Ontario Forage Crops Committee). These testing protocols have been recognized by the Variety Registration Office, Canadian Food Inspection Agency, and have been accepted protocols for determination of merit for registration of new varieties for sale in Canada.

Reductions in public research effort in Ontario, both Federal and Provincial, have reduced the extent of the evaluation. For forages, Federal stations are no longer involved, and a number of the Provincial research sites, now managed by the University of Guelph, have either terminated or have significantly lower levels of activity. Nonetheless, third-party variety performance information is still identified as a high priority among forage producers in the province (Ontario Forage Council priorities; OFCC priorities; FCRSC research priorities.

Concurrently, there is a desire for additional varietal information, especially for hay quality characters and relative performance under management system that are less than ideal. This research project is designed to provide a systematic evaluation of commercially available forage varieties in Ontario for specific attributes, namely, tolerance to machine traffic, tolerance to liquid manure application, and stem physical characteristics in hay systems. These characteristics are subject to genotype x environment interaction thus assessment within the province is necessary to provide relative variety performance. This specific research is not being conducted by other groups in the province.

Studies conducted at the University of Wisconsin have indicated that alfalfa yield is depressed due to traffic injury caused by a mechanical harvesting system. A comparison of a silage system (traffic one day after cutting) and a hay system (traffic five days after cutting) revealed that the hay traffic resulted in significant reductions in forage yield and that there were differences among alfalfa varieties to this stress. At the Elora site in 2003, a comparison of varieties and forage species was conducted by S.R. Bowley's research group to determine if there were species and variety differences in tolerance of traffic injury five days following cutting. This "hay traffic" stress was imposed on a series of OFCC trials following first harvest in 2003. For each test, five days after cutting, two replicates were driven on with a John Deere 6420, two replicates were not. This stress was applied to alfalfa (6 tests involving 95 varieties), orchardgrass (7 varieties), timothy (10 varieties), reedcanary (4 varieties), tall fescue (7 varieties), and red clover (8 varieties). On average, the reduction in yield in alfalfa and red clover was 11 and 13%, respectively. Surprisingly, the reduction in second cut yields were significantly greater for the grasses, the yield reduction for tall fescue, orchardgrass, reed canary, and timothy averaged 15%, 16%, 27% and 32%, respectively. Variety differences were also detected in their tolerance to the stress, the range in reduction for alfalfa was 0 to 25%. It was predicted that varieties with more rapid regrowth, higher yield potential would be most susceptible to this traffic injury. However, there was no relationship between yield performance and the susceptibility to traffic injury. This preliminary, one-year study has revealed that there is a significant loss in yield in areas that are driven upon during hay harvest, grasses were more susceptible to the stress, and that there are varieties that have greater tolerance, and varieties that have lower tolerance to this stress. Assessment of the genotype x environment interaction will be necessary in order to determine the stability of the assessment and provide relative performance information to producers.

S.R. Bowley's group at the University of Guelph In collaboration with Nuhn Industries, Sebringville, ON and Precision Metal Fabricating, Rosetown SK, a research size soil aerator was modified to allow precision application of liquid manure to research plots. Through a project financially supported by the AAC, this unit was used in 2004 at the Elora research station to study the effects of soil aeration and liquid manure application to an alfalfa-timothy mixture. In this study, the effects of aeration, manure rate (3000, 4500, 6000 gal/acre), day of application following harvest (2,4,6 days after harvest), and study of the effects following first and following second harvest were measured. This study indicated that the negative effects of the aerator per se could be reduced if it was used close to harvest. The average subsequent yield reduction due to aeration (averaged over all treatments) was 2% if applied 2 days after cutting, 7% if applied 4 days after cutting, and 9 % if applied 6 days after cutting. Without aeration, the optimum level of manure application (based on subsequent regrowth yield) was 4500 gal/acre. However, if aeration was included, the optimum level was higher, at least 6000 gal/acre. Additional seasons of application will be made to confirm the response, reaction findings, and assess the level of variety x manure application.

MATERIALS AND METHODS

Alfalfa maturity and stem diameter.

Trials were seeded in 2005 at two sites in Ontario, one at the University of Guelph Elora Research Station, the other on a private farm site located near Enniskillen. Forty-nine varieties of alfalfa were seeded. The test was arranged as a simple lattice repeated with two replications and two repetitions. Plot size was 1 x 6 m, seeding rate of 13 kg/ha. Trial management corresponded to the Ontario Forage Crop Committee (OFCC) Standard Test Protocols. In 2005, trials were clipped and forage removed early August. Fertilizer was applied in early September as per soil test.

In 2006 three yield harvests were taken for each test. A Haldrup self-propelled sickle bar forage harvester was used at Elora and a Carter self-propelled sickle bar forage harvester used at Enniskillen. In 2007, three harvests were taken at Elora, and one at Enniskellin. Severe drought at the latter site prevented further yield harvests to be taken from that test for 2007. Herbage dry matter yields were computed for each plot and yields of each harvest and total seasonal yields were subjected to variance analyses with a lattice model using the Proc Mixed procedure of SAS.

Prior to harvest, a 9 dm^2 hand clipped sample was removed from two replications. The samples were fractionated into maturity classes and the Mean Stage by Weight (MSW) maturity computed as per the method of Kalu and Fick (1981). The stem diameter of the first full internode above the cut end was measured for all Stage 4 stems using electronic calipers. Stage 4 corresponds to the late bud stage (>2 floral buds with no open flowers). MSW and stem diameter measures were subjected to Proc Mixed variance analyses for individual harvests as well as combined analyses over harvests and locations. Correlations and graphical analyses were used to elucidate relationships and genotype interactions. A Type 1 error rate of 0.05 was set for all statistical comparisons.

Manure, Traffic, and Aeration

Variety Interactions

In 2005, plots of 49 varieties of alfalfa were seeded at the Elora Research Station. The trial arrangement was a split-plot with entries allocated using a balanced lattice randomization. Plot size was 1 x 6 m and alfalfa was seeded at 13 kg/ha. Four treatments, Control, Traffic, Manure, and Manure-Aeration, were the main plots, alfalfa varieties the sub-plot. Treatments were applied after the first and second harvests in 2006 and 2007. The experiment had two replications. The Control treatment was the management treatment as per the OFCC Standard Test protocol. Annual P_2O_5 & K_2O applications were based on soil tests for each treatment regime. The Traffic treatment was applied 3 days after each harvest by systematically driving across the plots using a tractor (John Deere 7000 series with standard tires) so that the entire plot received a single wheel pass over the entire surface. The Manure treatment was 4500 gal/acre liquid dairy manure (obtained from the Elora Dairy Research Facility) and applied using a custom built aerator-precision manure applicator (Nuhn Industries, Sebringville, ON and Precision Metal Fabricating, Rosetown SK) that was mounted on a three-point hitch on a John Deere 7000 series tractor (Figure 1). The custom built unit was equipped with a 500 gallon tank and was designed to operate in any combination of aeration, manure, or aeration + manure treatment mode. Manure was applied with drop-tubes with fan nozzles positioned behind the aeration unit. The aerator is part of the Smart Till product line from HCC Inc. (Hart-Carter Company Inc.), Mendota, Illinois. The Manure + Aeration treatment was 4500 gal/acre of liquid manure along with aeration. The aerator was operated at an angle of 2°.

In 2006 and 2007, three yield harvests were taken for each test using a Haldrup self-propelled sickle bar forage harvester. Herbage dry matter yields were computed for each plot and yields of each harvest and total seasonal yields were subjected to variance analyses using the Proc Mixed procedure of SAS. Yield of the first harvest in 2006 (prior to treatment effects) was used as a covariate.

Treatment Effects.

In 2006 and 2007, a study was superimposed on a field of alfalfa (Pioneer 54V46) established in 2005 at the Elora Research Station. This study was a split-split-plot arrangement with three replications. The main plot was one of three times of application: one after first harvest, one after second harvest, the third had applications after both first and second harvests. The subplot was one of the following treatments: Without aeration: Control, Water (4500 gal/acre), Traffic, nitrogen (85 kg/ha of 34-0-0), 3000, 4500 and 6000 gal/acre liquid manure; and With aeration: Aeration alone, Water (4500 gal/acre), and 3000, 4500, and 6000 gal/acre liquid manure. Annual P_2O_5 & K_2O applications in September were based on soil tests for each treatment regime.

In 2006 and 2007, three yield harvests were taken for each test using a Haldrup self-propelled sickle bar forage harvester. Herbage dry matter yields were computed for each plot and yields of each harvest and total seasonal yields were subjected to variance analyses using the Proc Mixed procedure of SAS. Yield of the first harvest in 2006 (prior to treatment effects) was used as a covariate.

Figure 1. Photos of custom-built aeration-liquid manure application unit. 1A. Refill of the manure reservoir tank. 1B. View from side showing the agitator, metering unit and aerator. 1C, 1D. View of plots immediately following the aeration + manure treatment.

RESULTS

Variety yield performance

Herbage yield was analyzed and the results for the standard management tests at Elora (2006 and 2007) and Enniskillen (2006) were included in the OFCC variety trial database. Due to the drought for second and third harvests at Enniskillen, there was insufficient yield data in 2007 to include this test-year in the OFCC database. Yield summaries are presented (Tables 1-3).

Maturity and Stem Diameter

Genotype differences were detected but there were no genotype by location differences detected. Table 4 provides the summary for first harvest (two locations, two years), and the summary for season weighted MSW (three location-years). The season weighted MSW was computed as the average MSW at each harvest weighted by the herbage yield for the harvest. Season weighted MSW is a measure of the average maturity of all material removed from the plot that season. The varieties in Table 4 have been sorted based on the average MSW across trials, the least mature are at the top and most mature are at the bottom of the list.

At first harvest in 2006, the Elora trial was at a later stage of maturity than the Enniskillen test (trial MSW 3.4 vs 2.9, respectively) but the situation was reversed the following year (trial MSW 3.7 vs 4.6, respectively). Relative maturity ratings of varieties were consistent from trial to trial and cut to cut. First harvest MSW was correlated to the season weighted MSW (r=0.76, P=0.0001).

Combined over trials, the season weighted MSW of the varieties ranged from 3.0 to 3.6. Six varieties (Macon, Amerigraze 401+Z, Steak, Oneida VR, Rhino, and Hybri-Force 400) were significantly less mature than the test mean and six varieties (Starbuck, Reliance, Genoa, Stallion, Exp636, and 4.2) were significantly more mature than the test mean.

There were genotype differences for stem diameter of Stage 4 stems, however, there were no genotype by harvest, or genotype x location differences detected. Thus, the data across trials and harvests could be pooled. Table 5 presents the stem diameter means pooled over harvests and tests. Varieties are sorted in Table 5 from thin stems (top of list) to thicker stems (bottom of list).

Three varieties (Affinity+Z, 53V52, and Rhino) had Stage 4 stems that were significantly smaller in diameter compared to the test mean. Seven varieties (GH700, Stallion, 134, FSG 300LH, WinterGold, OAC Superior, and Renaissance) had Stage 4 stems that were significantly larger in diameter compared to the test mean.

Table 1. Herbage yield of 49 alfalfa varieties seeded 2005 and harvested three times in 2006 under a standard yield test management regime, Elora, Ontario. Design was a simple lattice repeated with two replicates and two repetitions.

		Herbage yield (kg DM / ha)			
code	entry	cut 1	cut 2	cut 3	total
1073	SURPASS	5275	4236	3310	12851
1294	DOMINION	5726	3958	3187	12896
1325	MAGNUM IV	5927	3827	2947	12683
1388	GOLD PLUS MF	5367	3729	2647	11762
1392	AMERIGRAZE 401+Z	5450	4035	3431	12898
1402	GRAZEMASTER	5207	3932	3178	12311
1409	AFFINITY+Z	4953	3510	2696	11192
1410	STALLION	5404	3911	2955	12314
1411	JOLT	5355	3836	2988	12217
1416	RENAISSANCE	5122	3542	2745	11403
1419	54V54	5470	3867	2892	12262
1432	OAC SUPERIOR	5550	3892	2987	12424
1448	PICKSD 8925MF	5618	3618	2709	11953
1462	RHINO	5044	3661	2966	11718
1471	ENHANCER	5920	3810	3000	12751
1474	GENEVA	4984	3835	3109	11943
1479	MARQUIS	5394	3553	2670	11591
1481	APPROVED	4939	3632	2776	11358
1482	WINTERGOLD	4985	3740	3057	11755
1486	AC BRADOR	5455	3583	2690	11714
1498	134	5436	3881	3077	12418
1504	PICKSD 2065MF	5459	3971	2965	12437
1512	WL 327	5641	4161	3110	12948
1521	MAGNUM III-Wet	5458	4162	3282	12895
1524	HYBRI-FORCE 400	5269	3806	2965	12072
1525	FORECAST 1001	5160	3939	2971	12064
1527	MACON	5240	4109	3085	12441
1535	RELIANCE	4989	3825	2912	11772
1537	VALIANT	5020	3963	3063	12057
1541	MULTIPLIER 3	5034	3590	2738	11366
1577	STARBUCK	5166	3696	2907	11731
1579	ASCEND	4913	3924	3130	11967
1580	STEAK	5082	3842	3101	11987
1582	54V46	5090	3856	2971	11891
1584	54H91	5058	3673	2882	11608
1586	Exp586	5179	3660	2990	11842
1599	WL319HQ	5065	3774	3077	11905
1600	4.2	5418	3703	3023	12090
1601	FSG 300LH	4810	4026	3130	11949
1607	GENOA	5275	4099	3071	12391
1609	GH700	5028	3904	3037	11928
1610	Exp610	5202	3942	3148	12289
1613	53V52	5179	3689	2870	11743
1615	STEALTH SF	5240	4102	3038	12377
1624	Exp624	5086	3988	3080	12148
1633	GUARDSMAN II	4921	3559	2716	11151
1635	Exp635	4771	3800	3058	11598
1636	Exp636	5294	4020	2930	12199
9041	ONEIDA VR	5540	4127	3247	12921
se		253.6	187.1	198.9	541.5
mean		5248	3847	2990	12085
CV (%)		7.8	6.9	9.8	6.3

Table 2. Herbage yield of 49 alfalfa varieties seeded 2005 and harvested three times in 2006 under a standard yield test management regime, Enniskillen, Ontario. Design was a simple lattice repeated with two replicates and two repetitions.

		Herbage yield (kg DM / ha)			
code	entry	cut 1	cut 2	cut 3	total
1073	SURPASS	6321	4106	2174	12698
1294	DOMINION	5346	4010	1668	10986
1325	MAGNUM IV	5694	3762	2378	11886
1388	GOLD PLUS MF	6300	4368	2115	12819
1392	AMERIGRAZE 401+Z	5786	3875	2331	11955
1402	GRAZEMASTER	6011	3970	2235	12246
1409	AFFINITY+Z	6572	3616	2131	12309
1410	STALLION	6369	4089	2211	12663
1411	JOLT	6604	4138	2097	12775
1416	RENAISSANCE	6138	4136	1876	12174
1419	54V54	6574	4250	2067	12901
1432	OAC SUPERIOR	7517	3931	2053	13437
1448	PICKSD 8925MF	5779	3654	1843	11279
1462	RHINO	5278	3915	1999	11155
1471	ENHANCER	6120	4094	2096	12383
1474	GENEVA	5990	4350	2263	12617
1479	MARQUIS	6004	4297	2108	12511
1481	APPROVED	7118	4283	2364	13853
1482	WINTERGOLD	5958	4317	2034	12324
1486	AC BRADOR	6350	4016	2189	12636
1498	134	6706	4082	2281	13112
1504	PICKSD 2065MF	6312	4320	2349	12913
1512	WL 327	6118	4055	2272	12393
1521	MAGNUM III-Wet	7153	3778	2208	13177
1524	HYBRI-FORCE 400	7321	4007	2236	13587
1525	FORECAST 1001	5319	4361	2351	11980
1527	MACON	6214	3848	1646	11724
1535	RELIANCE	6943	4899	2242	14060
1537	VALIANT	5852	4631	2391	13055
1541	MULTIPLIER 3	6184	3897	1975	12177
1577	STARBUCK	6776	4022	2009	13017
1579	ASCEND	5973	4439	2894	13501
1580	STEAK	5948	3993	2153	12217
1582	54V46	6428	4146	2143	12905
1584	54H91	5904	3465	1919	11151
1586	Exp586	6916	4091	1980	13135
1599	WL319HQ	6652	4272	2359	13089
1600	4.2	6711	3866	2025	12495
1601	FSG 300LH	6686	3591	1627	11782
1607	GENOA	6163	4511	2581	13060
1609	GH700	7055	3921	1709	12557
1610	Exp610	5498	4141	2410	11882
1613	53V52	6542	4323	2620	13440
1615	STEALTH SF	6345	4578	2288	13106
1624	Exp624	5577	4311	2268	12125
1633	GUARDSMAN II	5209	3898	1964	10967
1635	Exp635	5141	4111	2321	11535
1636	Exp636	6867	4080	1885	12817
9041	ONEIDA VR	5312	3979	2164	11377
Mean		5993	4016	2110	12239
CV		15.7	11.3	18.7	9.3

Table 3. Herbage yield of 49 alfalfa varieties seeded 2005 and harvested three times in 2007 under a standard yield test management regime, Elora, Ontario. Design was a simple lattice repeated with two replicates and two repetitions.

		Herbage yield (kg DM / ha)			
code	entry	cut 1	cut 2	cut 3	total
1073	SURPASS	6779	2269	1468	10387
1294	DOMINION	6467	1851	1063	9371
1325	MAGNUM IV	6719	1844	1109	9655
1388	GOLD PLUS MF	6723	1621	1146	9427
1392	AMERIGRAZE 401+Z	7151	2367	1239	10640
1402	GRAZEMASTER	6535	2014	1281	9766
1409	AFFINITY+Z	6828	1417	985	9177
1410	STALLION	6544	2009	1283	9789
1411	JOLT	6330	1683	1104	9189
1416	RENAISSANCE	6582	1467	921	9035
1419	54V54	6737	1685	1190	9631
1432	OAC SUPERIOR	7120	2124	1171	10380
1448	PICKSD 8925MF	6303	1551	987	8860
1462	RHINO	6664	1679	1059	9432
1471	ENHANCER	6648	1799	1224	9610
1474	GENEVA	6821	2109	1287	10274
1479	MARQUIS	6073	1370	948	8441
1481	APPROVED	6316	1442	1084	8846
1482	WINTERGOLD	6511	2006	1287	9754
1486	AC BRADOR	6755	1379	866	9004
1498	134	6776	2138	1386	10314
1504	PICKSD 2065MF	6733	1979	1270	9954
1512	WL 327	6839	2019	1360	10308
1521	MAGNUM III-Wet	6863	2509	1288	10744
1524	HYBRI-FORCE400	6651	1695	1039	9424
1525	FORECAST 1001	6884	2042	1220	10131
1527	MACON	6982	1827	1093	9940
1535	RELIANCE	6605	1835	1133	9622
1537	VALIANT	6804	1990	1422	10208
1541	MULTIPLIER 3	6221	1510	908	8749
1577	STARBUCK	6988	1806	1152	10049
1579	ASCEND	6683	2177	1331	10248
1580	STEAK	6588	1887	1056	9534
1582	54V46	6966	2138	1366	10527
1584	54H91	6525	1681	1069	9217
1586	Exp586	6873	1798	1072	9812
1599	WL319HQ	6303	1932	1171	9466
1600	4.2	7242	1977	1172	10443
1601	FSG 300LH	6392	1923	1091	9413
1607	GENOA	6809	2128	1524	10415
1609	GH700	6965	2071	1324	10367
1610	Exp610	6497	2211	1216	9941
1613	53V52	6646	1608	1048	9184
1615	STEALTH SF	6679	2445	1590	10715
1624	Exp624	6647	2157	1429	10181
1633	GUARDSMAN II	6512	1756	1158	9322
1635	Exp635	6322	2390	1373	10034
1636	Exp636	5158	2109	1267	8528
9041	ONEIDA VR	6577	2173	1101	9810
Mean		6379	1872	1167	9545
CV		9.6	20.1	13.3	9.4

Table 4. Mean stage by weight (MSW) of 49 alfalfa varieties seeded in 2005 at Elora and Enniskillen and harvested three times in 2006 and 2007.
Design was a simple lattice repeated with two replications and two repetitions. Table sorted based on season weighted MSW.

	Harvest 1, MSW						Season weighted MSW					
		Maturity index	2006		2007			Maturity index		2006		2007
Variety	Mean	relative to mean	Elora	Enniskillen	Elora	Enniskillen	Mean	relative to mean		Elora	Enniskillen	Elora
MACON	3.5	-0.1	3.5	2.6	3.3	4.6	3.0	-0.3	*	3.2	2.5	3.2
Amerigraze_401+Z	3.4	-0.3	3.1	2.6	3.4	4.5	3.0	-0.3	*	3.1	2.6	3.3
Steak	3.3	-0.4	3.0	2.6	3.2	4.3	3.1	-0.2	*	3.1	3.1	3.0
Oneida_VR	3.4	-0.2	3.3	2.7	3.6	4.1	3.1	-0.2	*	3.0	2.8	3.4
Rhino	3.4	-0.3	3.4	2.6	3.2	4.2	3.1	-0.2	*	3.3	2.9	3.2
Hybri-Force 400	3.4	-0.2	3.4	2.6	3.6	4.1	3.1	-0.2	*	3.3	2.8	3.2
Exp586	3.5	-0.2	3.0	2.9	3.3	4.8	3.1	-0.2		3.1	3.1	3.2
Marquis	3.6	-0.1	3.0	3.1	3.4	4.8	3.1	-0.2		3.0	3.1	3.2
Approved	3.4	-0.3	3.4	2.6	3.7	3.7	3.1	-0.2		3.2	2.8	3.4
Magnum_IV	3.5	-0.1	2.8	2.8	3.6	4.9	3.1	-0.2		2.9	2.9	3.6
54V54	3.5	-0.2	3.2	2.8	3.5	4.4	3.2	-0.2		3.2	2.9	3.3
WL319HQ	3.7	0.0	3.3	2.7	3.5	5.0	3.2	-0.1		3.2	2.9	3.4
54H91	3.7	0.1	3.4	3.0	3.4	5.1	3.2	-0.1		3.2	3.2	3.3
Affinity+Z	3.7	0.1	2.9	3.1	3.7	5.1	3.2	-0.1		3.0	3.1	3.6
Exp635	3.3	-0.3	3.1	2.6	3.3	4.2	3.2	-0.1		3.2	3.1	3.5
Dominion	3.6	0.0	3.5	3.5	3.3	4.2	3.2	-0.1		3.4	3.1	3.3
53V52	3.7	0.0	3.3	2.9	3.7	4.7	3.3	-0.1		3.3	3.0	3.4
WL327	3.6	-0.1	3.5	2.6	3.7	4.5	3.3	0.0		3.4	2.9	3.5
Grazemaster	3.5	-0.1	3.5	2.6	3.6	4.4	3.3	0.0		3.5	2.9	3.4
Renaissance	3.5	-0.2	2.9	2.9	3.7	4.5	3.3	0.0		3.2	3.1	3.5
Surpass	3.6	0.0	3.4	3.0	3.8	4.2	3.3	0.0		3.4	3.0	3.5
Exp624	3.7	0.0	3.5	2.4	3.9	4.9	3.3	0.0		3.4	2.9	3.6
PICKSEED_8925MF	3.7	0.1	3.6	2.7	3.5	5.2	3.3	0.0		3.5	2.8	3.6
AC_Brador	3.8	0.1	3.3	3.1	3.7	5.1	3.3	0.0		3.3	3.1	3.5
GH700	3.8	0.2	3.5	3.1	3.9	4.9	3.3	0.0		3.2	3.2	3.6
Ascend	3.8	0.1	3.6	3.0	3.6	4.9	3.3	0.0		3.3	3.1	3.5
VALIANT	3.7	0.0	3.4	2.6	3.8	5.0	3.3	0.0		3.4	2.9	3.7
54V46	3.7	0.0	3.4	3.1	3.6	4.6	3.3	0.0		3.5	3.1	3.3
Stealth_SF	3.8	0.1	3.4	3.0	3.7	5.1	3.3	0.0		3.4	3.0	3.6
PICKSEED_2065MF	3.7	0.0	3.1	2.9	4.0	4.8	3.3	0.0		3.2	3.1	3.7
134	3.6	-0.1	3.4	2.7	3.9	4.4	3.4	0.1		3.4	2.9	3.7
OAC_SUPERIOR	3.7	0.0	3.4	2.9	3.3	5.0	3.4	0.1		3.5	3.1	3.5
Multiplier_3	3.6	0.0	3.2	3.3	3.6	4.4	3.4	0.1		3.3	3.2	3.6
Magnum_III-Wet	3.7	0.0	3.3	3.1	4.0	4.3	3.4	0.1		3.4	3.1	3.6
Geneva	3.6	0.0	3.3	2.9	4.0	4.4	3.4	0.1		3.4	3.0	3.8
Gold_Plus_MF	3.7	0.1	3.7	3.2	3.7	4.4	3.4	0.1		3.5	3.1	3.6
JOLT	3.6	0.0	3.5	2.7	3.7	4.5	3.4	0.1		3.5	3.0	3.7
Guardsman_II	3.7	0.1	3.5	3.0	3.7	4.7	3.4	0.1		3.5	3.3	3.5
Enhancer	3.8	0.1	3.8	2.6	3.7	5.0	3.4	0.1		3.7	2.9	3.6
WinterGold	3.8	0.2	3.3	3.0	3.9	5.0	3.4	0.1		3.3	3.3	3.6
Forecast_1001	4.0	0.3	3.6	3.1	4.0	5.1	3.4	0.1		3.6	2.9	3.8
Exp610	3.9	0.3	3.6	3.4	3.8	5.0	3.5	0.1		3.5	3.1	3.7
FSG 300LH	3.8	0.2	3.5	2.9	3.9	5.0	3.5	0.2		3.4	3.2	3.9
Starbuck	3.9	0.3	3.3	3.0	4.4	5.0	3.5	0.2	*	3.3	3.1	4.1
Reliance	3.9	0.2	4.1	3.3	3.9	4.3	3.6	0.2	*	3.7	3.3	3.6
Genoa	3.7	0.1	3.5	3.0	3.8	4.6	3.6	0.3	*	3.4	3.3	4.0
Stallion	3.9	0.3	3.6	3.2	4.2	4.7	3.6	0.3	*	3.6	3.2	4.0
Exp636	3.8	0.1	3.6	3.2	4.1	4.3	3.6	0.3	*	3.6	3.3	3.8
4.2	4.0	0.3	3.8	3.0	4.4	4.5	3.6	0.3	*	3.5	3.0	4.3
mean	3.7		3.4	2.9	3.7	4.6	3.3			3.3	3.0	3.5
se	0.14		0.27	0.27	0.27	0.27	0.10			0.17	0.17	0.17
LSD (0.05)	0.38		0.75	0.75	0.75	0.75	0.27			0.46	0.46	0.46

* = significantly different from the test mean according to a t-test (P=0.05).

Table 5. Stem diameter (mm) of Stage 4 maturity stems of 49 alfalfa varieties seeded in 2005 at Elora and Enniskillen and harvested three times in 2006 and 2007. Design was a simple lattice repeated with two replications and two repetitions. Table sorted based on mean diameter over tests.

	Harvest 1, Diameter (mm)					Mean over harvests	
		2006		2007		2006 & 2007	
	Mean	Elora	Enniskillen	Elora	Enniskillen	combined	
Affinity+Z	2.8	2.6	2.6	3.3	2.9	2.50	*
53V52	3.1	2.9	2.6	3.6	3.4	2.55	*
Rhino	3.1	3.1	2.8	3.3	3.1	2.57	*
54V54	3.1	3.1	3.1	3.1	3.0	2.62	
Magnum_IV	3.2	3.2	3.5	3.3	3.1	2.65	
Genoa	3.3	3.3	3.5	3.2	3.2	2.65	
Exp624	3.1	3.1	3.2	3.1	3.1	2.66	
Enhancer	3.0	3.1	3.1	3.1	2.7	2.66	
Multiplier_3	3.3	3.4	3.0	3.3	3.3	2.67	
Forecast_1001	3.1	3.1	3.1	3.4	2.8	2.67	
Amerigraze_401+Z	3.1	3.1	3.1	3.4	2.9	2.67	
54V46	3.2	3.2	3.1	3.1	3.3	2.67	
Geneva	3.2	3.2	3.0	3.4	3.1	2.67	
Reliance	3.2	3.1	3.2	3.3	2.9	2.67	
Steak	3.3	3.5	3.0	3.3	3.4	2.67	
WL327	3.1	3.2	3.1	3.2	3.1	2.68	
JOLT	3.2	3.2	2.7	3.9	2.9	2.68	
Oneida_VR	3.4	3.3	4.0	3.2	2.9	2.69	
PICKSEED_2065MF	3.2	3.0	3.3	3.3	3.0	2.69	
Approved	3.2	3.1	3.6	3.2	3.0	2.69	
Dominion	3.2	3.3	3.3	3.0	3.3	2.70	
WL319HQ	3.2	2.9	3.4	3.5	2.9	2.72	
Exp586	3.3	2.9	3.4	3.6	3.4	2.73	
AC_Brador	3.1	3.2	3.3	3.0	2.9	2.74	
VALIANT	3.3	3.4	3.8	3.4	2.7	2.74	
Stealth_SF	3.2	3.2	3.4	3.4	2.8	2.75	
Gold_Plus_MF	3.3	3.4	3.3	3.7	2.9	2.77	
Exp635	3.5	3.5	3.6	3.7	3.3	2.77	
Magnum_III-Wet	3.2	3.4	3.0	3.3	3.2	2.77	
Exp610	3.3	3.6	3.2	3.3	3.1	2.79	
Starbuck	3.4	3.6	3.4	3.0	3.5	2.80	
Guardsman_II	3.3	4.1	3.1	3.2	2.9	2.81	
PICKSEED_8925MF	3.3	3.2	3.6	3.6	3.0	2.81	
Marquis	3.4	3.4	3.9	3.4	3.1	2.81	
54H91	3.2	3.4	3.3	3.3	3.0	2.82	
Hybri-Force 400	3.5	3.5	3.6	3.3	3.5	2.82	
MACON	3.3	3.7	3.4	3.2	2.9	2.83	
Ascend	3.2	3.4	3.2	3.5	2.8	2.84	
Exp636	3.4	3.2	3.6	3.5	3.2	2.85	
Surpass	3.3	3.4	3.4	3.3	3.0	2.86	
4.2	3.4	3.5	3.9	3.4	3.0	2.89	
Grazemaster	3.2	2.8	4.5	3.0	2.6	2.90	
GH700	3.4	3.3	3.5	3.6	3.1	2.91	*
Stallion	3.4	3.4	3.6	3.6	3.1	2.91	*
134	3.6	3.9	3.5	3.8	3.1	2.92	*
FSG 300LH	3.3	3.5	3.4	3.6	2.9	2.94	*
WinterGold	3.6	4.0	3.9	3.4	3.1	2.97	*
OAC_SUPERIOR	3.9	3.2	5.8	3.5	3.3	3.08	*
Renaissance	3.7	3.5	5.1	3.4	2.8	3.10	*
mean	3.2	3.3	3.4	3.3	3.0	2.76	
se	0.14	0.28	0.28	0.28	0.28	0.072	
LSD (0.05)	0.38	0.77	0.77	0.77	0.77	0.198	

* = significantly different from the test mean according to a t-test (P=0.05).

Manure, Traffic, and Aeration Effects
Variety Interactions

Since the treatment applications did not begin until after the first harvest in 2006, total yield of the second and third harvests were analyzed to determine differences among treatments. In the first year of the study, there was no difference between the control and the traffic treatments (Table 6). In contrast, manure applications increased yield over the control. On average, the yield of the manure treatments were 4-6% higher in yield compared to the control treatment.

Differences among treatments became more evident the following year. This was consistent with other studies in that the impact of stresses on alfalfa became more pronounced as the stand ages. In 2007, the traffic stress decreased herbage yield by 5% averaged across varieties (Table 6). Surprisingly, there was a significant increase in total seasonal herbage yield (131%) in 2007 as a result of the application of 4500 gal/acre liquid dairy manure following the first and second harvests in 2006 and 2007 (Table 6). In this study, continued application of manure after harvests increased the differential between the control and the manure treatments. Aeration in combination with the liquid manure application was also much higher than the control. In this test, the aeration treatment *per se* decreased yield by 5%, similar to the effect of traffic injury. This finding is consistent with previous studies we have conducted.

There were differences among varieties in their response to traffic, manure, and manure application in conjunction with aeration. Some varieties were very sensitive to traffic (eg. Jolt) while others were relatively unaffected by traffic (eg. AC Brador). Similarly, some varieties were highly responsive to manure application (eg. Reliance) while others were not as responsive to the manure application (eg. Jolt).

Table 6. Herbage yield (kg DM/ha) of 49 alfalfa varieties seeded in 2005 at Elora and harvested three times in 2006 and 2007.

Following first and second harvest each year, plots were subjected to one of the four following management stresses: control, wheel traffic, manure, and manure + aeration. Design was a split plot with two replications; varieties within a replication were arranged in a lattice design.

	2006 Cut 2 & 3 Total yield (kg DM/ha)				2007 Total yield (kg DM/ha)				2007 -as a % of control		
Variety	Control	Traffic	Manure	Manure+ Aeration	Control	Traffic	Manure	Manure+ Aeration	Traffic	Manure	Manure+ Aeration
134	7607	7601	7778	7627	9072	8304	12672	12017	91.5	139.7	132.5
4.2	6863	6881	7839	7693	8811	8601	12178	11645	97.6	138.2	132.2
53V52	7727	7072	7892	7671	10432	8583	12035	11514	82.3	115.4	110.4
54H91	6154	6564	6928	7043	8906	7874	10339	10143	88.4	116.1	113.9
54V46	8071	6931	7721	7449	9907	8643	11932	12258	87.2	120.4	123.7
54V54	6914	6586	7620	7208	8828	7772	11854	10691	88.0	134.3	121.1
AC_BRADOR	7390	6956	7332	6915	8245	8435	10873	10030	102.3	131.9	121.7
AFFINITY+Z	6581	7400	7699	7074	8419	8200	12200	10335	97.4	144.9	122.8
AMERIGRAZE 401+Z	6776	6622	6937	7697	8431	8172	11733	10568	96.9	139.2	125.4
APPROVED	6489	7561	7053	7122	8271	8146	10777	10610	98.5	130.3	128.3
ASCEND	7253	7275	8052	7528	9244	9313	12902	12018	100.7	139.6	130.0
Exp586	7546	6801	7658	7405	8545	8099	10796	11913	94.8	126.3	139.4
Exp636	7659	7364	7590	7654	9518	9145	11725	11430	96.1	123.2	120.1
DOMINION	6387	6919	7234	6980	8677	8352	11310	10565	96.3	130.3	121.8
ENHANCER	7017	7875	7825	7810	8862	9092	12367	11484	102.6	139.5	129.6
FORECAST_1001	7550	7528	7351	7440	9043	8573	11673	11196	94.8	129.1	123.8
FSG 300LH	6872	6628	6957	7201	8841	8052	10686	10641	91.1	120.9	120.4
GENEVA	6513	7672	7739	7148	8782	8131	12560	11454	92.6	143.0	130.4
GENOA	6651	7464	7558	7897	9209	9421	13417	13447	102.3	145.7	146.0
GH700	7154	7439	7875	7677	9179	8643	12265	11770	94.2	133.6	128.2
GOLD_PLUS_MF	7726	7923	8247	7440	8917	8687	11890	10460	97.4	133.3	117.3
GRAZEMASTER	7129	7516	7471	7508	9022	9532	12645	11372	105.7	140.2	126.1
GUARDSMAN_II	6298	7187	7413	7788	8680	9009	11168	11191	103.8	128.7	128.9
HYBRI-FORCE 400	6451	8150	7959	7525	8428	9060	12438	11554	107.5	147.6	137.1
JOLT	7876	7150	7540	7407	9753	8554	10701	10522	87.7	109.7	107.9
MACON	7699	7082	7608	6932	8338	8574	11162	9070	102.8	133.9	108.8
MAGNUM III-Wet	6892	7047	7625	7583	9132	7792	12045	11749	85.3	131.9	128.7
MAGNUM_IV	6735	7231	7344	7139	8529	8393	12221	11510	98.4	143.3	135.0
MARQUIS	7216	6321	7423	7165	8153	8200	10828	10282	100.6	132.8	126.1
MULTIPLIER_3	6289	7424	7242	6831	7949	7452	9638	9590	93.7	121.3	120.6
OAC_SUPERIOR	7520	7055	7458	7212	9287	8355	12631	10880	90.0	136.0	117.1
ONEIDA_VR	6755	6318	7326	7018	9040	8016	11706	10472	88.7	129.5	115.8
PICKSD 2065MF	7206	7333	7484	7246	8867	8495	12120	11496	95.8	136.7	129.6
PICKSD 8925MF	6879	6728	6863	7063	8354	7738	10455	10475	92.6	125.1	125.4
Exp624	7525	7218	7946	8187	9406	9572	13265	12879	101.8	141.0	136.9
RELIANCE	6498	6582	7572	7069	8485	7721	12594	11635	91.0	148.4	137.1
RENAISSANCE	7454	7563	7686	7256	8910	8013	11753	10803	89.9	131.9	121.3
RHINO	6931	6803	7447	6963	8767	8369	11561	10031	95.5	131.9	114.4
Exp635	7819	6982	7471	8147	9634	9202	12471	12633	95.5	129.4	131.1
Exp610	7029	7002	6763	7192	9442	9332	11021	11754	98.8	116.7	124.5
STALLION	7135	7846	7212	7235	9485	8935	10986	10912	94.2	115.8	115.0
STARBUCK	6329	6862	7378	7207	8739	8244	12702	12152	94.3	145.4	139.1
STEAK	7622	7766	7029	6891	9168	8245	10605	10770	89.9	115.7	117.5
STEALTH SF	7602	7389	8286	8178	10090	10195	14502	13188	101.0	143.7	130.7
SURPASS	8261	7550	8238	7806	9125	8424	11968	12419	92.3	131.2	136.1
VALIANT	7843	7948	7812	7745	9945	9374	12595	13100	94.3	126.6	131.7
WINTERGOLD	6780	6379	7296	7699	9532	8340	11838	11927	87.5	124.2	125.1
WL319HQ	7032	7722	7365	7601	9137	9741	12495	12533	106.6	136.8	137.2
WL_327	7670	6974	7560	7340	9027	8090	11172	11842	89.6	123.8	131.2
Mean	7093	7151	7527	7403	8979	8543	11834	11333	95.3	131.7	126.0
Mean as % of control	100.0	100.8	106.1	104.4	100.0	95.1	131.8	126.2			
se -trt x entry	370.2				285.34						
se -trt means	154.7				163.08						

DISCUSSION

Maturity and Stem Diameter

There were variety differences for herbage yield, for maturity, as well as stem diameter (Stage 4 stems). These attributes are, in general, not related. Herbage yield was not correlated with season weighted MSW (r=0.17 P=0.2383) and not correlated with Stage 4 diameter (r=0.05 P=0.7538). Furthermore, maturity was not correlated to Stage 4 stem diameter (r=0.26 P=0.0650).

The absence of strong correlation revels that if either maturity or stem diameter is an issue for producers, then both management (harvest timing) and variety selection are factors that should be considered in designing a system to produce the desired harvested product. For example, harvesting at an earlier stage of development will result in a forage that has a greater proportion of finer stemmed, less mature material. In the present study, the varieties were all harvested on the same date with the finding that varieties differed not only in their maturity but also in their diameter of Stage 4 stems. Thus, one could leave harvest date unchanged but modify the maturity/diameter profile by changing the variety.

The absence of correlation among the three attributes (yield, maturity, and diameter) provides the opportunity to mix and match desirable traits but increases the complexity of selecting a variety that has an optimal combination. Of these three traits, herbage yield is probably the attribute of greatest importance. So, a method of selecting varieties would be to choose from among varieties with greater than average yield and, from among those varieties, select the ones with the desired performance for maturity, diameter, or both.

Figure 1 illustrates a scatterplot of average yield and average maturity of the 49 varieties. These values combine all first year and second year data. The graph has been bisected with lines marking the average yield and the average maturity of the trial. Varieties on the right side are varieties that had greater than average yield. Those in the upper right quadrant are varieties that were more mature on average, those in the lower right quadrant are varieties that were less mature on average.

A similar bi-plot could also be constructed for yield by diameter and for maturity by diameter, however, it was desired to present all three variables in a single graph. The stem diameter results have been incorporated into Figure 1 by using different symbols to plot the variety means. Varieties that had Stage 4 stems that were smaller in diameter than average are indicated using an asterisk (*), those that were larger in diameter are plotted with a plus (+) sign.

Figure 2 is the same plot as Figure 1 but only presents the varieties that had an average Stage 4 stem diameters that were less than the test mean. Varieties in the lower right quadrant are varieties that had a mean yield higher than the test mean, a maturity index lower than the test mean, and had Stage 4 stems that were smaller in diameter than the test mean.

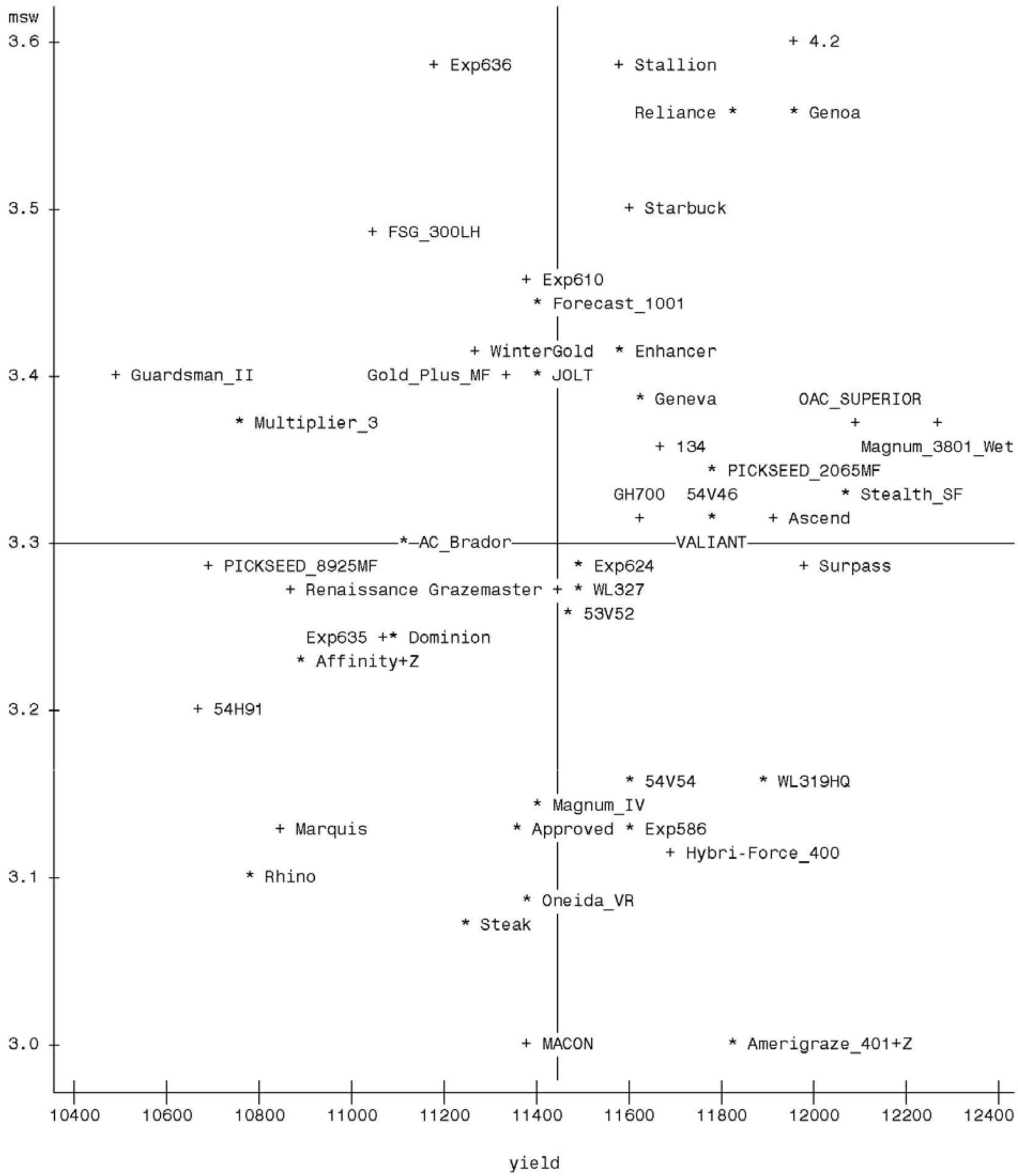

Figure 1. Scatterplot of mean seasonal herbage yield (kg DM / ha) and season weighted mean stage by weight (MSW) of 49 varieties of alfalfa seeded in 2005 and evaluated over a three harvest management in 2006 and 2007, Elora and Enniskillen, Ontario. Design was a simple lattice repeated with two replications and two repetitions. The graph has been bisected with plots showing the test mean for mean yield and mean MSW. Varieties that had Stage 4 stems that were smaller in diameter than the test mean were plotted with the symbol * and those with stems larger in diameter than the test mean were plotted with the symbol +.

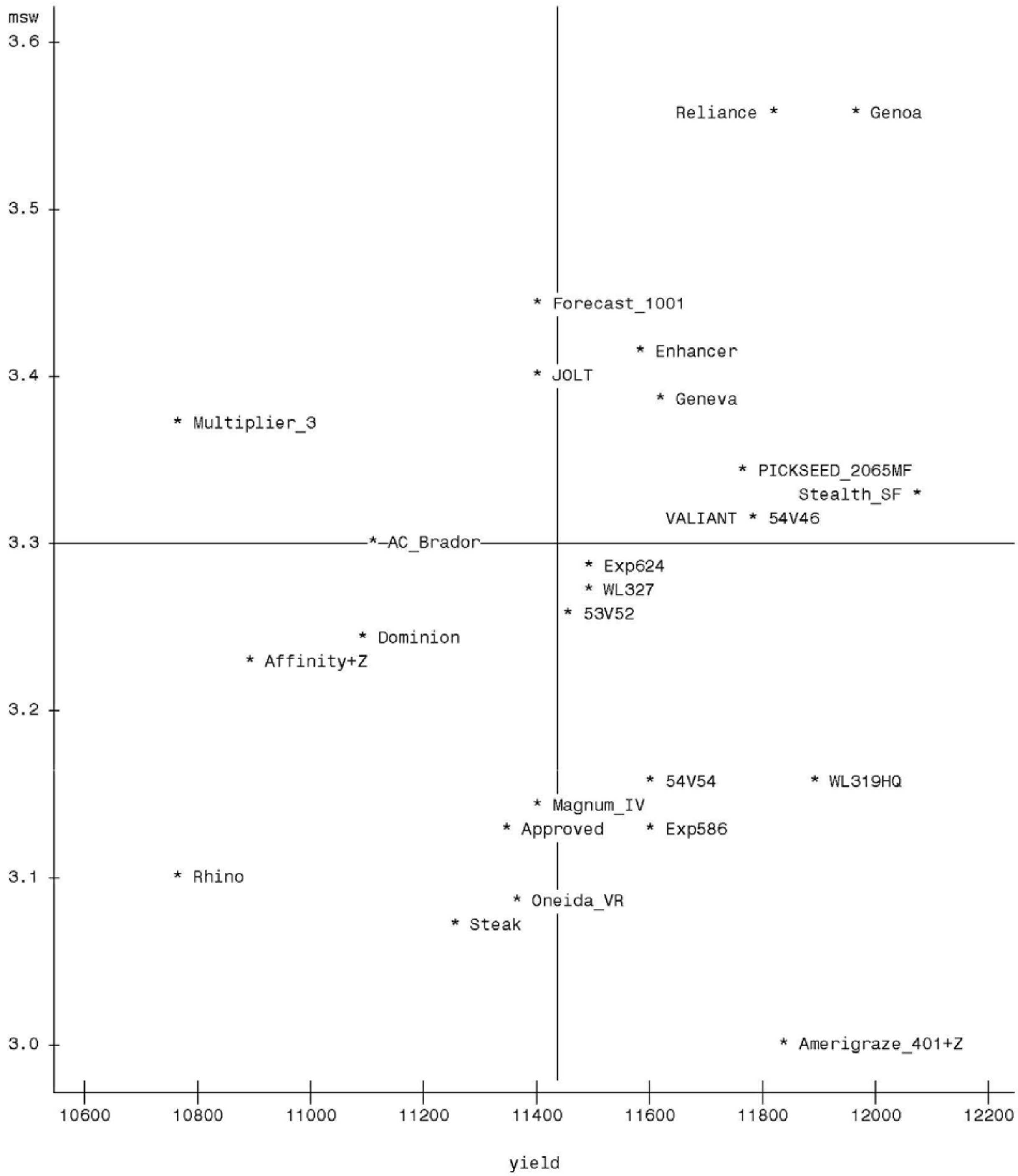

Figure 2. Scatterplot of mean seasonal herbage yield (kg DM / ha) and season weighted mean stage by weight (MSW) of 49 varieties of alfalfa seeded in 2005 and evaluated over a three harvest management in 2006 and 2007, Elora and Enniskillen, Ontario. Design was a simple lattice repeated with two replications and two repetitions. The graph has been bisected with plots showing the test mean for mean yield and mean MSW. Varieties plotted were only those that had Stage 4 stems that were smaller in diameter than the test mean.

Traffic and Manure

There were differences among varieties in their response to the application of traffic and manure, either with or without aeration. In general, there was a positive correlation between herbage yield of the control treatment and yield under the various stresses (r ranged from 0.54 to 0.59, P=0.0001). Nonetheless, there were interactions detected in the responses of the varieties.

Bi-plots were constructed to present the differences in variety response in the second production year (2007). Figure 3 is a scatterplot of the control yield of the 49 varieties and the yields when 4500 gal/acre liquid manure application was applied after first and second harvest in 2006 and 2007. The graph has been bisected with lines marking the average yield for each treatment. Those on the right side are varieties that had greater than average control yield. Those in the upper right quadrant are varieties that had greater than average yield under manure application, those in the lower right quadrant are varieties that yielded less than average under manure application.

A similar bi-plot could also be constructed for control yield and yield under traffic stress (or yield under manure plus aeration treatement), however, it was desired to combine all three variables in a single graph. The traffic stress results have been incorporated into Figure 3 by using different symbols to plot the variety means. Varieties that had higher yields than average under traffic stress are indicated using an asterisk (*), those that were lower than average yield under traffic stress are plotted with a plus (+) sign.

Figure 4 is the same plot as Figure 3 but only presents the varieties that had an average yield under traffic stress that was higher than the test mean. Varieties in the upper right quadrant are varieties that had a mean yield higher than the test mean under the control treatment, a yield higher than the mean under the manure treatment, and had a yield higher than the mean of the trial under the traffic stress treatment.

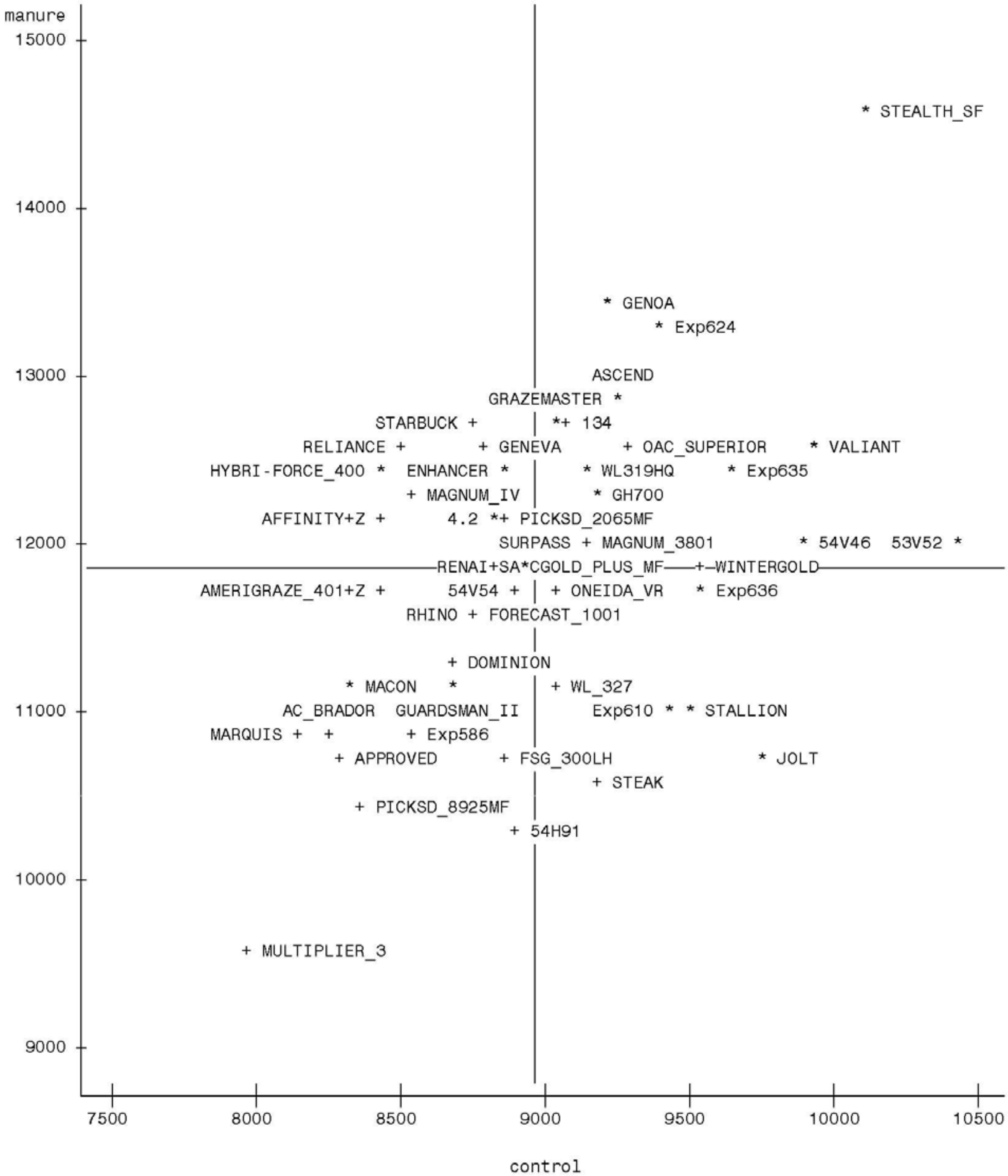

Figure 3. Scatterplot of mean total herbage yield (kg DM / ha) in 2007 for the control treatment and a liquid manure application (3500 gal/acre) applied after first and second harvest in years 2006 and 2007 of 49 varieties of alfalfa seeded in 2005 and evaluated over a three harvest management in 2006 and 2007 at Elora, Ontario. The trial arrangement was a split-plot with two replicates with entries allocated using a balanced lattice randomization. The graph has been bisected with plots indicating the mean for the two treatments. Varieties that had mean yields higher than the mean under the traffic stress treatment were plotted with the symbol * and those with yield lower than the traffic stress treatment mean were plotted with the symbol +.

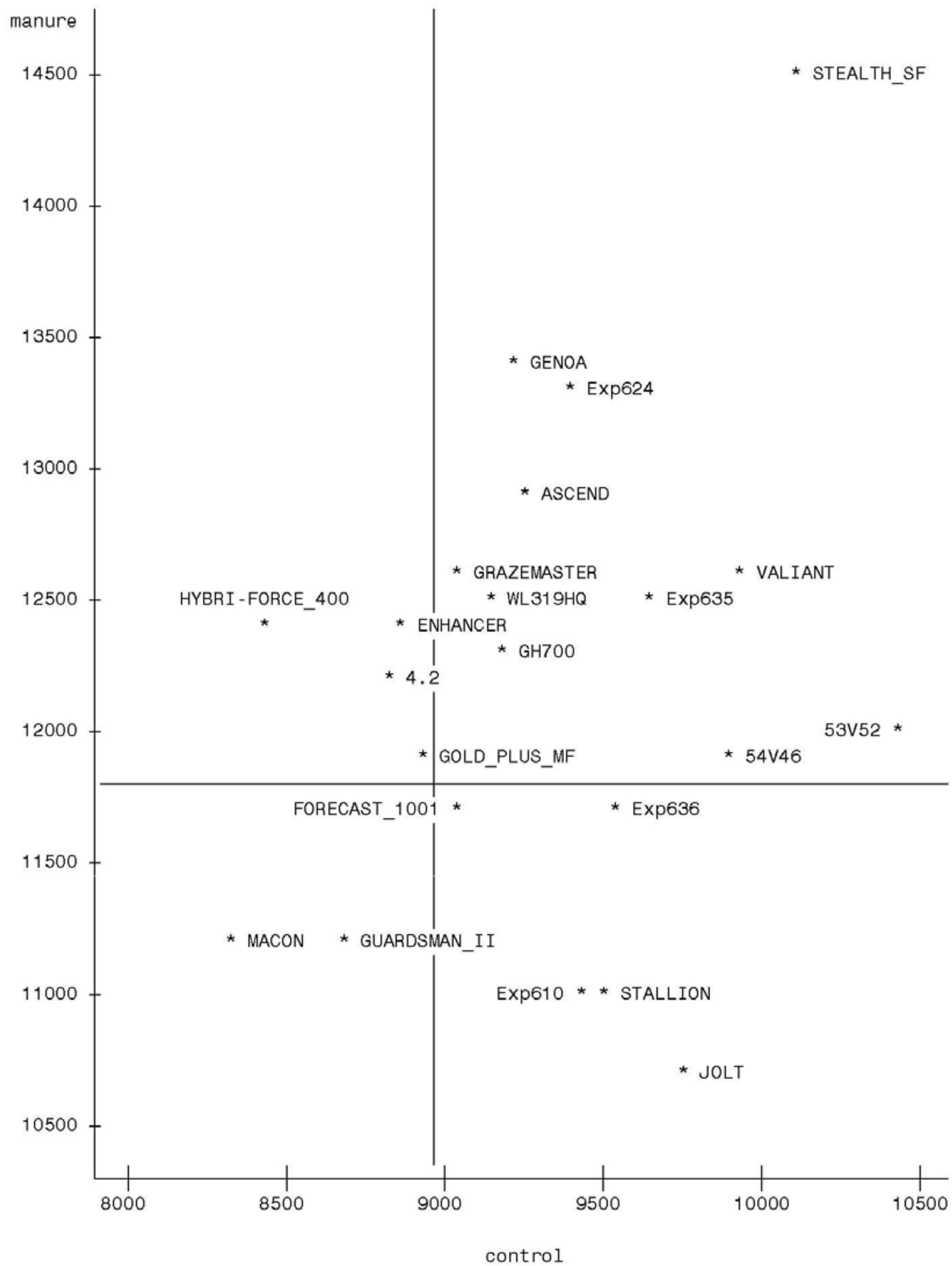

Figure 4. Scatterplot of mean total herbage yield (kg DM / ha) in 2007 for the control treatment and a liquid manure application (3500 gal/acre) applied after first and second harvest in years 2006 and 2007 of 49 varieties of alfalfa seeded in 2005 and evaluated over a three harvest management in 2006 and 2007 at Elora, Ontario. The trial arrangement was a split-plot with two replicates with entries allocated using a balanced lattice randomization. The graph has been bisected with plots indicating the mean for the two treatments. Varieties plotted are only those that had mean yields higher than the mean under the traffic stress treatment.

Manure, Traffic, and Aeration Effects

A. Within-year Treatment Interactions-2006

The preceding studies focused on variety responses under a specific manure rate application: 4500 gal/acre applied after first and second harvest each season. A parallel study was conducted to measure the effects of different management treatments *per se*. This study involved comparing rates of manure application, water and other control treatments, and comparison of the effect of application for a one-time application (either after the first or second harvest) in addition to an application following both harvests.

Table 7. Third harvest herbage yield as a percent of the control treatment of the alfalfa manure management study at Elora, 2006. Design was a split-split-split plot with three replications with time of treatment application as the main-plot, treatment as a sub-plot, and aeration as a sub-sub-plot.

		Treatments applied after 1st harvest		Treatments applied after 1st & 2nd		Treatments applied after 2nd harvest	
		Aeration		Aeration		Aeration	
		Without	With	Without	With	Without	With
Control		100.0		100.0		100.0	
Traffic no aeration		91.2		100.8		113.5	
Aeration			91.8		108.5		126.6
Water (4500 gal/acre)		103.5	108.5	114.4	125.9	121.9	113.8
Nitrogen		109.3		122.1		132.6	
Manure (gal/acre)							
	3000	89.1	102.8	114.6	122.7	120.0	119.5
	4500	92.8	99.6	128.1	124.8	109.4	135.3
	6000	137.2	123.3	154.7	138.0	140.5	162.3

Table 7 presents the third harvest yields following the various treatment applications in 2006. Analysis of third harvest data enables a comparison of the effects of all possible treatment combinations in the test. Significant interactions among the treatment combinations were detected.

Traffic and Aeration

When applied after first harvest, traffic stress decreased the third harvest yield by 8.8%. However, when traffic was applied after both first and second harvest, this resulted in a negligible effect on yield. This was due to a yield enhancement (ca 13%) when the stress treatment was applied after the second harvest. When applied to both harvests, the traffic stress effect (negative if applied after first, positive if applied after second) was negated.

Third harvest yields under the aeration treatment mirrored the same pattern as the traffic stress treatment. When aeration was applied after first harvest this resulted in a 8.2% third harvest yield decrease, when applied after second harvest (only) resulted in a 26% increase, and when applied after both first and second, there was a 8.5% increase in third harvest yields.

Water

A 4500 gal/acre water treatment was included in this study to measure any possible ‘water’ effect from the liquid manure treatment applications. In this study, there was an enhancement to this small application of water, a third harvest yield increase of 3-22% depending on the application timing;

application after second harvest was the most beneficial treatment. In combination with aeration treatment, however, the third harvest yield was enhanced for both the 1st and the 1st+2nd application time treatments.

Nitrogen
Although the stand was not old, 90%+ alfalfa, and nodulated, there was a 9-32% increase in third harvest yields from application of nitrogen fertilizer. The application was equivalent to the nitrogen supplied by the 6000 gal/acre liquid manure application. Normally, applications of nitrogen fertilizer do not result in yield increases in alfalfa. These findings indicate that in this trial the third growth cycle in this trial had less than optimal nitrogen, either through N2-fixation or supply from the soil ecosystem.

Manure
Herbage yields increased as manure rates increased. Third harvest yields increased as much as 50% with the application of 6000 gal/acre of liquid manure. In comparing the response to the water and to the nitrogen controls, this yield increase could be attributed to the nutrients (ie. Nitrogen) in the liquid manure, not the water per se.

The interaction between manure application and aeration was quite variable and no consistent pattern could be visualized from this particular set of data. In five of the nine cases, aeration in combination with the manure application resulted in a higher third harvest yield. On average, the third harvest yield in 2006 was similar whether the manure was applied on the surface or onto a stand that had received an aeration treatment.

B. Within-year Treatment Interactions-2007

Table 8. Third harvest herbage yield as a percent of the control treatment of the alfalfa manure management study at Elora, 2007. Design was a split-split-split plot with three replications with time of treatment application as the main-plot, treatment as a sub-plot, and aeration as a sub-sub-plot.

		Treatment applied after 1st		Treatments applied after 1st & 2nd		Treatments applied after 2nd	
		Aeration		Aeration		Aeration	
		Without	With	Without	With	Without	With
Control		100.0		100.0		100.0	
Traffic no aeration		92.3		127.2		94.4	
Aeration			95.8		129.6		99.1
Water (4500 Gal/acre		96.4	113.2	100.8	118.9	100.5	112.0
Nitrogen		113.0		128.7		105.7	
Manure (gal/acre)							
	3000	109.4	96.8	116.3	127.7	107.3	105.9
	4500	100.0	110.0	103.0	148.0	120.6	108.0
	6000	129.4	127.7	128.4	152.8	140.1	115.8

Table 8 presents the third harvest yields following the various treatment applications in 2007. As for the previous season, significant interactions among the treatment combinations were detected. Moreover, the responses among treatments were similar in magnitude, and, in the main, a similar pattern among treatments was found.

Traffic and aeration stress was detrimental when applied after first harvest, but not when applied after first and second. In 2007, the water treatment did not affect third harvest yield except when applied in conjunction with aeration. Application of nitrogen fertilizer was also a benefit in that this treatment increased the third harvest yield.

As in 2006, herbage yields in 2007 increased as manure rates increased. Comparison of the manure treatments to their respective water and nitrogen controls revealed that this yield increase could be attributed to the nutrients (ie. Nitrogen) in the liquid manure and was not a result of the water *per se*.

As in the previous year, the effect of manure in combination with aeration was variable. In four of nine cases, aeration increased the third harvest yield under manure treatments, in the remainder; however, it decreased the yield.

C. Subsequent year effects

The 2006 trial was harvested in 2007 to measure carry-over effects and determine if the treatments had any effect on persistence. Table 9 presents the first harvest data for 2007.

Table 9. First harvest herbage yield in 2007 as a percent of the control treatment of the alfalfa manure management study at Elora. Treatments were applied in 2006. Design was a split-split-split plot with three replications with time of treatment application as the main-plot, treatment as a sub-plot, and aeration as a sub-sub-plot.

	Treatments applied after 1st harvest		Treatments applied after 1st & 2nd		Treatments applied after 2nd harvest	
	Aeration		Aeration		Aeration	
	Without	With	Without	With	Without	With
Control	100.0		100.0		100.0	
Traffic no aeration	96.3		100.0		99.6	
Aeration		103.8		109.5		111.4
Water (4500 Gal/acre	100.1	99.7	100.2	107.0	104.0	106.1
Nitrogen	101.2		104.7		112.4	
Manure (gal/acre)						
3000	99.7	101.8	107.8	108.5	107.1	106.1
4500	105.5	100.3	106.4	105.2	100.0	100.3
6000	99.9	97.0	106.2	101.9	105.4	111.5

The negative effect of traffic for the application after first harvest was also detected, a decrease in yield of 3.7%. However, for plots that received traffic after second harvest, as well as those that received traffic after both first and second, there was no impact on yield.

The aeration treatment resulted in an increase in first harvest yield, a range of 3.8-11.4%. The effect of water application was negligible for two of three cases. The yield increases that were detected among the water treatments were most evident when it was in combination with aeration. The aeration response was always greater than the response of the combined water and aeration treatment. This indicates that it was the aeration component, not water, that resulted in an increase in first harvest yield the following year for the combined aeration-water treatment.

The application of nitrogen fertilizer also increased first harvest yield, especially when the treatment was applied after the second harvest. The enhanced growth of the third growth (in 2006), and presumably during the fall period (not measured), contributed to better growth and acclimation of the plants prior to winter. These effects of nitrogen application resulted in the yield improvement in 2007.

The impact of manure treatments ranged from 0-7% improvement in yield the following year. The rate of manure application did not affect the response the following year. The greatest yield improvement following manure application was for the plots that received applications after both first and second harvests the previous year.

Manure in combination with aeration, however, revealed a significant interaction. The yield enhancement of the aeration treatment was reduced when combined with manure. Moreover, the greater the application rate of manure, the greater was the reduction in yield performance, especially if the manure-aeration treatment had been applied following first harvest of the previous season.

Analyses of forage quality, nitrogen dynamics, and nutrient profile are in process (A. Bowman, MSc Thesis research). These will provide additional parameters to help understand the impact of these treatments.

Discussion

The results of this study have provided additional information regarding alternate management systems for alfalfa. The most notable result is that liquid manure applications after first and second harvests can be included in alfalfa production systems with no apparent detrimental effect on persistence or herbage yield. Indeed, herbage yields were improved in this study. The responses to liquid manure application were a result of the nutrients, not the water per se.

Use of an aerator also enhanced the yield performance of alfalfa stands. This may relate to changes in aeration in the upper root zone. However when combined with manure application, the effect of aeration was reduced, and at high manure applications, negated. It is possible that aeration increased root-manure contact which may be detrimental to the alfalfa stand.

In this particular study, an application of 4500 gal/acre of liquid manure after first and second harvest , in conjunction with aeration, increased third harvest yield on the order of 24-48% and first harvest yield in the subsequent year by 5%. In another independent trial involving 49 varieties of alfalfa (see Table 6), seasonal yields under this same treatment were increased by 26% averaged over all varieties. The variety test results also indicated that the yield response was cumulative. Combining the information from the various trials, reveals that incorporation of liquid manure into an alfalfa production system is of benefit for forage yield production. For producers, this provides for two additional times of the year (late May/early June and Mid-late July) for application/disposal of liquid manure for livestock farms. These application times may also have less nutrient losses compared to late fall or late winter applications. However, the impact of these applications of liquid manure on the nutritional composition of the feed also needs to be assessed.

Reports and Presentations

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Hancock, D. and Bowley, S.R. 2007. Summary of forage varieties under test. Ontario Forage Crops Committee.
Hancock, D. and Madill, J. (Eds) 2006 Ontario Forage Crop Variety Performance. OFCC brochure.
Hancock, D. and Madill, J. (Eds) 2007 Ontario Forage Crop Variety Performance. OFCC brochure.

Training of **Highly Qualified Personnel** (**HQP**)

Bowman, A. MSc thesis, University of Guelph (in process).