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BORON FERTILIZATION EFFECTS ON NUTRITIVE PARAMETERS OF ALFALFA[1]

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Abstract

With early pre-plant incorporation of limestone to raise soil pH to 6.8 to 7.0, alfalfa (*Medicago sativa* L.) may be grown successfully on acid, Coastal Plain, sandy loam soils. Fertility and forage quality for hay and/or grazing require alternative management of alfalfa on these Coastal Plain soils. A two-year experiment evaluated alfalfa fertilized with three rates of boron to quantify effects on nutritive entities, especially fiber components. On a whole-plant basis in year 1, only crude protein was increased ($P<.05$) at one of six harvest dates. In year 2, chemical analyses of leaf-stem components indicated consistent increases in crude protein of leaf fractions at each harvest ($P<.05$), reduction in neutral detergent fiber at three harvest dates ($P<.06$), and reduced lignin ($P<.07$) at the final harvest. Stem sections were affected by rate of boron at only the June harvest with an increase in crude protein ($P<.05$). Rate of boron fertilization had indirect effects on nutritive value (crude protein) by either delaying physiological maturity or enhancing nitrogen fixation in leaves, and had a direct negative effect on certain fiber components.

Keywords: Alfalfa, boron, nutritive entity, cell wall, forage quality

Acronyms: Boron (B), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CEL), lignin (LIG), crude protein (CP), *In vitro* dry matter digestibility (IVDMD)

Introduction

Of the micronutrients essential for plant growth, boron (B) is likely to be most limiting. Soil levels of B are usually inadequate for many crop species, and applications of this element are often necessary for optimum yields. Among its functions in plants, B is involved in lignin synthesis and control of phenolic concentrations. The involvement of B in the synthesis of phenolic compounds and in enzyme activity may account for its impact on cell division and enlargement (Gupta et al., 1985). With B deficiency, phenolic acids accumulate, stimulating the activity of polyphenol oxidase, which is responsible for the production of highly reactive phenolic compounds such as caffeic quinone in plant tissues. It is possible that the negative effects of these phenolic compounds are the direct cause of restricted meristematic activity rather than a response to auxin levels in the tissue as has been proposed (Parr and Loughman, 1983).

Alfalfa is the premier forage legume in the US for hay, silage, and/or grazing. Fertilization with B is frequently required to enhance alfalfa production. The objective of this research was to evaluate the effects of B application on nutritive parameters, and especially fiber composition, of ‘Alfagraze’ alfalfa.

Material and Methods

A well-established stand (3 yrs) of Alfagraze alfalfa growing on a Darco loamy fine sand (loamy, siliceous, thermic Grossarenic Paleudult), which was previously limed pre-planting to pH 7.2, was fertilized each spring and autumn with 0-140-179-74-37 kg ha $^{-1}$, respectively of N-P_2O_5-K_2O-S-Mg. In each of 2 consecutive years, B was applied to alfalfa during the previous autumn at rates of 0, 2.24, and 4.48 kg ha $^{-1}$ in a randomized complete block with four replications of each rate. Monthly harvests were made with a Hege 211-B self-propelled, sickle-bar plot harvester from April 11 to September 19 (n = 6 dates) in year 1 and from May 15 to August 14 (n = 4 dates) in year 2. Physiological maturity at time of harvest ranged from early bud (stage 3) to early flower (stage 5) (Kalu and Fick, 1983; Fick and Mueller, 1989). At each harvest date, B rate plots were sampled for forage mass and the following nutritive parameters were chemically analyzed: neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CEL), lignin (LIG), *in vitro* dry matter digestibility (IVDMD), and crude protein (CP) (Goering and Van Soest, 1970). In year 1, the entire plant was chemically analyzed; whereas, in year 2, alfalfa leaf and stem components were analyzed separately. Statistical analyses for each nutritive entity were assessed for sources of variation attributed to B rate, harvest date, and plant part.

Results and Discussion

In year 1 (Table 1), alfalfa fiber components, especially CEL and LIG, increased with chronological age (harvest date) as expected. Likewise, IVDMD and CP decreased with time. Although for the August harvest there was a tendency for B rate to negatively affect LIG, there was no consistent effect of B on any other fiber constituent for the other dates. Also at the August date, B rate appeared to be positively related to CP. This influence on CP may be associated with increased forage mass and reduced physiological maturity, and/or an enhanced N-fixation process.

In year 2 (Table 2), each fiber component (NDF, ADF, CEL, LIG) was lower for leaves compared to stems ($P<.05$). A key characteristic of B that contributes to its importance in several processes is the ability of boric acid (H_3BO_3) to form stable mono- and diesters with cis-diols (Marschner, 1986). Boric acid forms these esters with polyhydroxyl compounds that have the adjacent cis-diol configuration. Some of the sugars and sugar derivatives that form these complexes include mannitol, mannan, and polymannuronic acid, which are constituents of hemicellulose in plant cell walls. Grass lignin has a lower proportion of these o-dihydroxy units than lignin from dicots (Lewis, 1980). In addition, legume forage is generally much higher in lignin than grass forage (Collins, 1988). Both of these characteristics are consistent with the recognized higher B requirement of dicots. Further, IVDMD and CP were higher for leaves compared to stems ($P<.05$) at every harvest date in year 2. Rate of B affected only CP of stems at the June harvest ($P<.05$). No other nutritive entity of stem sections was influenced by B at any other harvest date. Crude protein of alfalfa leaves was increased by B rate at each harvest ($P<.01$ for May, $P<.06$ for June, $P<.03$ for July, and $P<.05$ for August). At the June and August dates, B rate increased IVDMD ($P<.10$). For June, July, and August, B rate reduced NDF at $P<.06$, $P<.05$, and $P<.10$, respectively. Leaf LIG was lower ($P<.07$) at the August harvest. Marschner (1986) reported that B plays a role in the condensation of phenolic acids during LIG synthesis.

Except for B rate effects on CP at only one harvest date, there was no statistically detectable impact of B rate on fiber components of the vegetative portion of the alfalfa plant. However, the consistent enhanced nutritive value of alfalfa leaves via increased CP at each harvest date, reduced NDF at the last three harvest dates, and reduced LIG at the August date, suggests a potential, positive involvement of B in enhancing nutritive value of alfalfa. We concluded that these effects might be both indirect through delayed maturation or enhanced N fixation, and direct through involvement with

LIG synthesis and control of phenolic concentrations. We also speculate that with the controlled stage of harvests incorporated in this experiment, the potential effects of B may be greater on more mature (stage 6-8) alfalfa plants.

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Table 1 - Nutritive entities of alfalfa with three rates of boron at each of six harvest dates.

B rate (kg ha^{-1})	Harvest Date	Nutritive Entity (g kg^{-1})					
		NDF	ADF	CEL	LIG	IVDMD	CP
0	April 11	.282	.244	.188	.035	.686	.249
2.24		.293	.273	.217	.035	.707	.277
4.48		.307	.285	.225	.030	.722	.270
	AVG	**.294**	**.268**	**.210**	**.033**	**.705**	**.265**
	SE[1]	.010	.017	.016	.002	.015	.012
0	May 5	.288	.279	.216	.047	.651	.300
2.24		.323	.327	.259	.044	.564	.282
4.48		.296	.299	.237	.046	.652	.296
	AVG	**.302**	**.302**	**.237**	**.046**	**.623**	**.293**
	SE	.015	.020	.018	.001	.042	.008
0	June 8	.324	.294	.231	.046	.581	.252
2.24		.359	.355	.281	.063	.709	.245
4.48		.365	.359	.279	.035	.612	.237
	AVG	**.349**	**.336**	**.263**	**.048**	**.634**	**.245**
	SE	.018	.030	.023	.011	.055	.006
0	July 13	.331	.298	.232	.052	.542	.214
2.24		.347	.308	.238	.061	.545	.215
4.48		.330	.307	.247	.048	.525	.214
	AVG	**.336**	**.304**	**.239**	**.054**	**.537**	**.214**
	SE	.008	.005	.006	.005	.009	.001
0	August 11	.320	.268	.215	.045	.560	.229
2.24		.275	.235	.192	.034	.684	.258
4.48		.301	.258	.208	.026	.655	.251
	AVG	**.299**	**.254**	**.205**	**.035**	**.633**	**.246**
	SE	.018	.014	.010	.008	.053	.012
0	Sept. 19	.313	.264	.209	.052	.602	.253
2.24		.340	.290	.224	.059	.499	.225
4.48		.352	.325	.259	.057	.588	.227
	AVG	**.335**	**.293**	**.231**	**.056**	**.563**	**.235**
	SE	.016	.025	.021	.003	.046	.013

[1]Standard error

Table 2 - Nutritive entities of alfalfa leaf and stem sections with three rates of boron at each of four harvest dates.

B rate kg ha^{-1}	Harvest Date	Plant Part	Nutritive Entity (g kg^{-1}) NDF[1]	ADF[1]	CEL[1]	LIG[1]	IVDMD[2]	CP[2,3]
0	May 15	Leaf	.148	.148	.115	.032	.668	.370
0	May 15	Stem	.493	.451	.362	.088	.504	.168
2.24	May 15	Leaf	.134	.140	.108	.032	.667	.390
2.24	May 15	Stem	.461	.435	.351	.081	.524	.177
4.48	May 15	Leaf	.130	.147	.115	.030	.683	.385
4.48	May 15	Stem	.454	.433	.350	.077	.492	.187
0	Jun 12	Leaf	.181	.151	.121	.031	.652	.291
0	Jun 12	Stem	.494	.432	.342	.088	.483	.135
2.24	Jun 12	Leaf	.162	.147	.120	.028	.695	.315
2.24	Jun 12	Stem	.490	.439	.347	.090	.474	.127
4.48	Jun 12	Leaf	.173	.145	.118	.029	.689	.317
4.48	Jun 12	Stem	.487	.434	.346	.084	.474	.144
0	Jul 12	Leaf	.207	.128	.103	.026	.630	.289
0	Jul 12	Stem	.535	.423	.335	.088	.436	.135
2.24	Jul 12	Leaf	.179	.126	.102	.025	.620	.333
2.24	Jul 12	Stem	.578	.472	.372	.096	.428	.130
4.48	Jul 12	Leaf	.183	.124	.102	.023	.658	.322
4.48	Jul 12	Stem	.568	.451	.356	.096	.457	.128
0	Aug 14	Leaf	.194	.131	.106	.026	.657	.287
0	Aug 14	Stem	.531	.436	.338	.095	.418	.139
2.24	Aug 14	Leaf	.171	.124	.098	.024	.630	.302
2.24	Aug 14	Stem	.529	.424	.325	.093	.445	.137
4.48	Aug 14	Leaf	.170	.118	.096	.019	.672	.291
4.48	Aug 14	Stem	.514	.421	.323	.093	.448	.137

[1]At each harvest, NDF, ADF, CEL, and LIG were lower ($P<.05$) for leaves vs. stems.
[2]At each harvest, IVDMD and CP were higher ($P<.05$) for leaves vs. stems.
[3]CP of leaves was increased by B rate at each harvest.