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EFFECT OF AVAIL AND NUTRISPHERE-N APPLICATION ON ANNUAL RYEGRASS PRODUCTION AND QUALITY

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ABSTRACT

Two important soil reactions are phosphorus (P) fixation and nitrogen (N) volatility in the ammonia form. Phosphorus fixation occurs as a result of P adsorption reactions to clays and aluminum and iron oxide minerals while N loss as ammonia from urea containing fertilizers is related to urease activity. These two types of soil reactions are impediments to nutrient use efficiency and crop uptake in forage crops. Two relatively new products to the forage industry, AVAIL and Nutrisphere-N (N-N) were tested in annual ryegrass forage production and nutrient uptake. AVAIL claims to reduce P fixation and increase plant uptake while N-N claims nitrification and urea volatilization inhibiting properties. A study was conducted during the 2010-2011 growing season at Mississippi State University to evaluate the value of adding AVAIL to a P based fertilizer and Nutrisphere-N to an N based fertilizer when growing annual ryegrass as a forage crop and their effects in forage production, nutrient uptake and forage quality. Marshall annual ryegrass planted at a seeding rate of 30 lb ac^{-1} on a prepared seed bed. Phosphorus was applied at a rate of 30 lb ac^{-1} with or without AVAIL (AV). Urea (46-0-0) was applied at a rate of 0, 80, 100, and 120 lb ac^{-1} in split applications with or without Nutrisphere-N (N-N). There was no evidence that the AVAIL and Nutrisphere-N treatments had an effect on the amount on forage production, N removal or forage quality. Most of the variables measured in the study were greatly affected by harvest date.

INTRODUCTION

Early vigorous growth in fall and late maturity has made annual ryegrass a popular forage crop. In Mississippi, approximately 40 to 50% of warm-season pastures are planted in annual ryegrass to minimize winter feeding (Lemus, 2008). Climatic conditions such as temperature and precipitation play a major role in determining biomass production. Annual ryegrass is best adapted to cool, moist climates, but not to temperatures below 30 ºF. Optimal growth occurs between 50 and 70°F. Thus, annual ryegrass grows well in early spring and fall in Mississippi. Nitrogen is commonly applied to annual ryegrass pastures in the fall and in the spring with rates ranging from 60 to 100 lb N ac^{-1}. With the increase and fluctuation in fertilizer prices over the last 5 years (NASS, 2013), producers have considerably reduced nitrogen applications, affecting forage production and quality.

Commercial fertilizers, such as nitrogen (N) and phosphorous (P), play a major role in plant growth and development. One of the most important roles of nitrogen in grasses is stimulating shoot growth which helps increase yield and promotes recovery from grazing pressure, hay production, and environmental stress (Volenec, Ourry & Joem, 2006). Nitrogen is also needed for synthesis of chlorophyll and amino acids. Amino acids are the building blocks of protein. Phosphorous is a major element required for stimulating early season growth and root formation. Phosphorus is also used by plants to form nucleic acids (DNA and RNA), and is used in storage and energy transfer (ATP and ADP). Phosphorous fertilization benefits cool-season growth and root growth and development (Pant et al. 2004).

Polymer additives such AVAIL and Nutrisphere-N have been studied extensively in row crops to improve nutrient use. AVAIL is a polymer coated phosphate particle (partial sodium salt of maleic–itaconic copolymer) that has been used to inhibit phosphate fertilizer soil fixation (SPF, 2013a). Fixed phosphate is not readily available to plants. Phosphorus fixation can be influenced by factors such as soil type and pH. Acidic soils (low pH) usually contain higher iron and aluminum that react with phosphate and produce iron or aluminum phosphate complexes. Alkaline soils (high pH) contain higher calcium concentrations, which allow for P fixation as calcium phosphate (Havlin et al. 2005). The AVAIL product has shown a large variability of responses in different row crops when banded or broadcasted. Studies in rice using AVAIL and triple phosphate (0-46-0) have shown positive results (Dunn & Stevens, 2008). A bermudagrass study indicated that AVAIL did not consistently improve dry matter yields when compared to di-ammonium phosphate (DAP) alone (Stewart et al. 2009). Studies conducted in corn across eight locations in Delaware and Maryland over three growing season indicated that AVAIL had no effect on crop uptake or response to P and no response in yields (McGrath & Binford, 2012).

Urease inhibitors slow the conversion of urea to ammonia and they can be of significant agronomic value as fertilizer additives, under certain environmental conditions (high humidity and high temperatures) (Hauck, 1985). Amending urea based fertilizers with urease inhibitors can slow ammonia loss when fertilizer is left on the soil surface (Goos, 2013). Nutrisphere-N (SPF, 2013b) is a fertilizer additive (30-60% maleic-itaconic co-polymer) that has been promoted as a urease and nitrification inhibitor (Goss, 2013). Several studies have indicated that adding Nutrisphere-N to urea had little effect on urease activity or ammonia volatilization (Franzen et al., 2011). A recent study conducted in Minnesota using corn indicated that stabilizer products (Agrotain, Agrotain Plus, Instinct and Nutrisphere-N) and application method did not significantly affected yield or total plant N concentrations and that yield differences were mainly affected by N application rate (Watkins, 2013).

Knowledge of current nutrient management practices (N & P) in annual ryegrass is necessary to provide a basis for identifying opportunities to improve nutrient use efficiency, but detailed evaluation of N fertilizer management practices has not previously been undertaken in Mississippi. This is essential to improve profitability of the livestock-forage enterprise. Recently, the fertilizer additives AVAIL and Nutrisphere-N have been promoted in the south for forage production. AVAIL has been promoted as a product that will increase the plant availability of P fertilizers by reducing P adsorption by iron and aluminum minerals. Nutrisphere-N has been promoted as a product that reduces N losses and increases nitrogen use efficiency in urea and liquid based fertilizers. There have been no reported studies in cool-season forage crops that demonstrate that AVAIL increases fertilizer P availability and Nutrisphere-N reduces N losses. The objective of this study was to evaluate the value of adding AVAIL to a P based fertilizer and Nutrisphere-N to an N based fertilizer when growing annual ryegrass as a forage crop and their effects on forage production, nutrient uptake and forage quality.

MATERIALS AND METHODS

The study was conducted at the Henry H. Leveck Animal Research Farm in Starkville, MS (33º 25' 18" N, 88º 47', 30" W) during the winter of 2010-11. The soil series was a Marietta fine sandy loam (Fine-loamy, siliceous, active, thermic Fluvaquentic Eutrudepts). The experimental design was a randomized complete block design with treatments replicated three times. Glyphosate was applied at rate of 2 pints per acre 3-wk before planting for weed control. Sixteen treatments (Table 1) were applied to Marshall annual ryegrass planted at a seeding rate of 30 lb/ac on a prepared seed bed. Individual plots were 11 ft by 6 ft in size. Plots were planted on October 15, 2010. They were fertilized with 2 tons lime ac^{-1} and 60 lb K ac^{-1} according to soil test recommendations. Soil test phosphorus level was medium. Plots received 100 lb ac^{-1} of 15-5-10 at the time of establishment to aid germination. Phosphorus was applied at a rate of 30 lb ac^{-1} with or without AVAIL (AV) on December 7, 2010. Urea (46-0-0) was applied at a rate of 0, 80, 100, and 120 lb/ac in split applications with or without Nutrisphere-N (N-N) on December 7, 2010 and February 16, 2011. Plots were harvested to a 3-inch stubble height when at least 50% of the plots reached a height of 8 to 12 inches. Plots were harvested using a sensation mower, removing a 42-inch swath from the center of the plot, to minimize border effect. Harvest dates were February 15, March 7, March 21 and April 19, 2011.

Table 1. Fertilizer rates applied to Marshall annual ryegrass.

	Application Rate			
Treatment	**Nitrogen**	**P**	**Nutrisphere-N[1]**	**AVAIL[2]**
	---------------- (lb ac^{-1}) ----------------			
1 (Control)	0	0	--	--
2 (80N)	80	-	--	--
3 (80N/P)	80	30	--	--
4 (80N/P+AV)	80	30	--	Yes
5 (80N/P +N-N)	80	30	Yes	--
6 (80N/P+N-N+AV)	80	30	Yes	Yes
7 (100N)	100	-	--	--
8 (100N/P)	100	30	--	--
9 (100N/P+AV)	100	30	--	Yes
10 (100N/P +N-N)	100	30	Yes	--
11 (100N/P+N-N+AV)	100	30	Yes	Yes
12 (120N)	120	--	--	--
13 (120N/P)	120	30	--	--
14 (120N/P+AV)	120	30	--	Yes
15 (120N/P +N-N)	120	30	Yes	--
16 (120N/P+N-N+AV)	120	30	Yes	Yes

[1]Nutrisphere-N was applied at a rate of 1 gallon per ton of nitrogen fertilizer.

[2]Avail was applied to triple-phosphate (0-46-0) at a rate of 1 gallon per ton of phosphorus fertilizer.

Tissue samples were collected at each harvest for dry matter determination. Samples were dried in a forced draft oven at 50°C for 5 to 7-d, and ground in a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass a 2-mm screen. Samples were analyzed for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN) and sugar (total sugar and water soluble carbohydrates) concentrations using the Foss 6500-C nearinfrared reflectance spectroscopy (NIRS) instrument (Foss North America, Eden Prairie, MN). The samples were scanned using the grass hay prediction equation developed by the NIRS Forage and Feed Testing Consortium (Hillsboro, WI). Tissue samples were analyzed by the Mississippi State University Soil Testing Laboratory for P, calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and boron (B). Total N was determined by dry combustion using a Vario EL *III* Elemental Analyzer (Elementar Inc., Mt. Laurel, NJ).

Leaf area index (LAI) and Normalized Difference Vegetative Index (NDVI) readings were taken at each harvest during the 2010-2011 growing season. LAI was measured using a LI-COR 2000 (LI-COR Biosciences, Lincoln, NE) and NDVI was measured using a Green Seeker (NTech -Industries, Ukiah, CA). NDVI was used as an indicator of greenness and plant health status (chlorophyll content). Data was analyzed by using the General Linear Model of SAS (SAS, 2013) and mean separation was done using the least significant difference (LSD) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

CLIMATIC CONDITIONS

Precipitation was below normal for most of the growing season with the exception of November 2010 and April 2011 (Table 2). Average temperature was colder in December and January, but above normal from the rest of the growing season.

Table 2. Monthly precipitation and average temperature during the duration of the study at Starkville, MS (October 2010 to May 2011).

Month	**Precipitation**	**30-yr**		**Temperature**	**30-yr**
	---------------- inches ----------------			----------------- °F -----------------	
October	0.78	3.48		66.3	63.0
November	5.39	3.35		55.2	53.4
December	1.54	4.66		41.6	45.0
January	3.86	5.70		41.8	41.7
February	1.45	4.85		49.9	46.1
March	5.56	6.07		57.5	54.2
April	9.09	5.62		67.8	61.8
May	1.89	4.88		72.0	70.2
Total/Average	29.56	38.61		56.5	54.4

YIELD

There was no significant difference in total seasonal yield among treatments. Seasonal yields had a narrow distribution ranging from 2.4 to 2.6 tons/ac. The treatment combination of 120N/P+N-N+AV had the lowest yield while the treatment combination of 120N/P had the highest yield (Table 3). There was a date effect among harvests (Table 4), but not a treatment effect or interaction. Mean harvest yield was very uniform among all treatments (Table 3). The April 19 harvest had the highest mean yield while the March 21 harvest had the lowest dry matter yield.

NUTRIENT REMOVAL

There were no significant differences in N removal among the treatment combinations (Table 3). Most of the effect was due to a harvest date effect (Table 4). Higher N removal was observed in the April harvest. No significant differences among treatments were observed for calcium and magnesium removal, but there was significant date effect for removal of these two nutrients. Highest Ca and Mg removal were observed in the April harvest. There was a significant treatment x date interaction for phosphorus (Table 5), potassium and sulfur removal (Tables 5, 6, and 7). Most of the interactions on P removal were caused by nutrient removal across harvests within specific treatments. There was not a defined trend among the treatments that suggest a treatment advantage within a specific time of the year. Removal of K and S were influenced by treatments in the early production of annual ryegrass.

CANOPY AND PLANT HEALTH STATUS

Leaf area index (LAI) and normalized difference vegetative index (NDVI) were not affected by treatments applications (Table 3), but by harvest date (Table 4). There was a decline in LAI and NDVI readings with harvest date, which is a typical pattern observed with plant senescence. Annual ryegrass will intercept most sunlight as LAI in the sward increases progressively up to an LAI of 4 to 6. A LAI of 4.3 was commonly observed in the study.

FORAGE QUALITY

Forage quality parameters (CP, ADF, NDF, TDN, WSC and sugar) were mainly affected by harvest date (Table 4) and not by treatment applications. Brix levels, ADF and NDF fluctuated across the harvest dates. Crude protein declined 38 percent from February to April. Total digestible nutrients declined 11 percent during the growing season. Water soluble carbohydrates and sugar levels did not have a defined trend, but had higher concentrations toward the end of the season. This might be expected since plants entering a stress period, such as senescence, tend to increase sugar accumulation since growth is stunted and the dilution effect in minimized (Lemus & Morrison, 2012).

Table 3. 2010-2011 Average harvest yield, seasonal yield, nutrient removal, Leaf Area Index (LAI) and Normalized Difference Vegetative Index (NDVI) of 16 treatments applied to Marshall annual ryegrass in Starkville, MS. Data averaged over harvest dates.

	Yield			Total Nutrient Removal					
Treatment	**Harvest**	**Seasonal**		**N**	**Ca**	**Mg**		**LAI**	**NDVI**
	--------------------------------- lb DM ac^{-1} ------------------------------								
1 (Control)	1197.21	4788.85		44.75	7.92	1.77		3.76	0.84
2 (80N)	1207.28	4829.13		51.68	8.69	1.91		4.30	0.84
3 (80N/P)	1231.02	4924.06		50.76	8.82	1.91		4.13	0.85
4 (80N/P+AV)	1321.97	5287.87		52.86	8.64	2.03		4.28	0.85
5 (80N/P +N-N)	1216.49	4865.95		47.97	7.76	1.82		4.07	0.83
6 (80N/P+N-N+AV)	1176.75	4707.01		46.99	8.04	1.82		4.27	0.86
7 (100N)	1211.94	4847.73		42.85	7.29	1.59		4.30	0.85
8 (100N/P)	1230.14	4920.57		48.67	7.85	1.91		4.22	0.82
9 (100N/P+AV)	1238.99	4955.94		47.90	8.21	1.90		4.09	0.84
10 (100N/P +N-N)	1261.86	5047.43		55.28	9.30	2.05		4.59	0.86
11 (100N/P+N-N+AV)	1263.72	5054.86		56.55	9.10	2.08		4.39	0.85
12 (120N)	1291.33	5165.34		53.63	9.24	2.16		4.41	0.85
13 (120N/P)	1294.90	5179.58		55.77	9.31	2.13		4.41	0.85
14 (120N/P+AV)	1281.02	5124.09		54.65	8.88	2.12		4.70	0.85
15 (120N/P +N-N)	1204.78	4819.12		48.04	8.64	1.87		4.37	0.85
16 (120N/P+N-N+AV)	1161.49	4645.94		44.96	7.83	1.73		4.03	0.86
Mean	**1236.93**	**4947.82**		**50.21**	**8.47**	**1.92**		**4.27**	**0.85**

Note: No significant differences were observed among treatments.

Table 4. Harvest effect on yield, nutrient removal, LAI, NDVI and forage quality of Marshall annual ryegrass at Starkville, MS. Data average over treatments.

		Harvest Date				
Parameter	**Unit**	**14-Feb**	**7-Mar**	**21-Mar**	**19-Apr**	**$LSD_{0.05}$[1]**
Harvest Yield	lb ac^{-1}	1013.82	1491.22	681.24	1761.44	123.17
Nutrient Removal						
N		45.33	63.47	28.24	63.78	8.10
Ca	lb ac^{-1}	4.01	9.69	4.62	15.57	1.32
Mg		1.11	2.53	1.08	2.96	0.31
Canopy						
LAI		5.18	5.38	3.39	3.13	0.28

Plant Health Status						
NDVI		0.89	0.93	0.82	0.75	0.02
Forage Quality[2]						
CP	%	24.26	22.08	19.09	14.91	0.91
ADF		24.27	31.02	33.13	30.86	0.91
NDF		46.36	51.30	52.19	47.70	1.28
TDN		81.68	75.48	72.90	72.31	0.82
WSC		13.24	10.20	11.24	16.08	1.06
Sugar		9.47	7.38	8.12	11.63	0.78

1 Least Significant Difference.

2 CP = Crude Protein; ADF = Acid Detergent Fiber; NDF = Neutral Detergent Fiber; TDN = Total Digestible Nutrients; WSC = Water Soluble Carbohydrates.

Table 5. Influence of treatment and harvest on phosphorous removal by Marshall annual ryegrass at Starkville, MS.

	Harvest Date					
Treatment	**14-Feb**	**7-Mar**	**21-Mar**	**19-Apr**	**Mean**	**$LSD_{0.05}$**[1]
	----------------------------------- lb ac^{-1} -----------------------------------					
1 (Control)	2.20	2.50	2.75	6.87	3.58	2.20
2 (80N)	3.11	7.34	3.18	4.29	4.48	1.47
3 (80N/P)	3.69	8.47	2.87	5.70	5.18	NS
4 (80N/P+AV)	2.70	9.49	3.63	4.14	4.99	NS
5 (80N/P +N-N)	3.54	6.64	3.88	5.29	4.84	NS
6 (80N/P+N-N+AV)	1.28	6.50	3.17	6.59	4.38	2.31
7 (100N)	1.87	5.36	3.36	5.07	3.91	NS
8 (100N/P)	4.66	6.83	3.45	4.48	4.85	NS
9 (100N/P+AV)	4.26	8.83	3.99	4.46	5.38	NS
10 (100N/P +N-N)	3.01	5.56	4.65	7.01	5.06	NS
11 (100N/P+N-N+AV)	2.49	7.99	3.46	6.82	5.19	2.89
12 (120N)	1.41	9.63	3.34	7.35	5.43	1.05
13 (120N/P)	2.33	7.96	3.38	7.78	5.36	3.55
14 (120N/P+AV)	2.68	7.00	3.77	4.68	4.53	2.68
15 (120N/P +N-N)	2.26	5.91	4.02	6.76	4.74	2.42
16 (120N/P+N-N+AV)	1.54	5.00	3.48	6.15	4.04	3.08
Mean	2.69	6.94	3.52	5.84	4.75	0.65
$LSD_{0.05}$[2]	NS	NS	NS	NS	1.30	--

1 Least Significant Difference for comparison of harvest dates within a treatment.

2 Least Significant Difference for comparison of treatments within a harvest date.

Table 6. Influence of treatment and harvest on potassium removal by Marshall annual ryegrass at Starkville, MS.

	Harvest Date					
Treatment	**14-Feb**	**7-Mar**	**21-Mar**	**19-Apr**	**Mean**	**$LSD_{0.05}$[1]**
	------------------------------------ lb ac-1 ------------------------------------					
1 (Control)	23.06	34.07	25.30	67.17	37.40	NS
2 (80N)	30.78	70.90	23.71	45.87	42.81	NS
3 (80N/P)	35.18	71.06	24.53	46.77	44.38	24.44
4 (80N/P+AV)	35.12	81.22	25.52	37.43	44.82	17.99
5 (80N/P +N-N)	33.59	66.89	28.22	47.04	43.93	24.28
6 (80N/P+N-N+AV)	13.21	55.42	26.92	67.08	40.66	16.00
7 (100N)	23.09	59.27	28.56	45.76	39.17	NS
8 (100N/P)	46.29	72.54	23.14	42.64	46.15	16.39
9 (100N/P+AV)	32.77	71.54	26.64	43.71	43.66	26.08
10 (100N/P +N-N)	31.99	47.07	29.74	54.61	40.85	NS
11 (100N/P+N-N+AV)	24.42	64.94	25.52	58.51	43.34	29.89
12 (120N)	16.17	79.30	26.92	68.69	47.77	37.65
13 (120N/P)	28.92	65.25	26.41	62.77	45.83	NS
14 (120N/P+AV)	30.66	75.68	28.94	49.61	46.22	26.06
15 (120N/P +N-N)	22.54	51.64	30.70	53.94	39.70	22.76
16 (120N/P+N-N+AV)	14.94	54.29	26.70	64.72	40.16	25.56
Mean	27.67	63.81	26.72	53.52	42.93	5.61
$LSD_{0.05}$[2]	14.56	24.99	NS	NS	NS	--

[1]Least Significant Difference for comparison of harvest dates within a treatment.

[2]Least Significant Difference for comparison of treatments within a harvest date.

Table 7. Influence of treatment and harvest on sulfur removal by Marshall annual ryegrass at Starkville, MS.

	Harvest Date					
Treatment	**14-Feb**	**7-Mar**	**21-Mar**	**19-Apr**	**Mean**	**$LSD_{0.05}$[1]**
	------------------------------------ lb ac-1 ------------------------------------					
1 (Control)	1.26	1.39	0.95	3.31	1.72	NS
2 (80N)	1.72	3.39	1.13	2.24	2.12	1.45
3 (80N/P)	1.93	3.02	1.16	2.23	2.08	NS
4 (80N/P+AV)	1.98	3.66	1.20	2.08	2.23	1.55
5 (80N/P +N-N)	1.96	2.87	1.31	2.46	2.15	NS
6 (80N/P+N-N+AV)	0.74	2.20	1.06	3.49	1.87	0.89
7 (100N)	1.26	2.34	1.11	2.44	1.79	NS
8 (100N/P)	2.30	3.05	1.04	1.88	2.07	0.75
9 (100N/P+AV)	1.84	3.25	1.33	2.22	2.16	NS

10 (100N/P +N-N)	1.83	2.30	1.43	3.20	2.19	NS
11 (100N/P+N-N+AV)	1.47	3.05	1.21	3.17	2.22	0.69
12 (120N)	1.13	3.50	1.19	3.48	2.32	1.30
13 (120N/P)	1.83	2.76	1.19	3.19	2.24	NS
14 (120N/P+AV)	1.99	3.27	1.38	2.42	2.26	0.60
15 (120N/P +N-N)	1.26	2.24	1.35	2.93	1.94	NS
16 (120N/P+N-N+AV)	0.84	2.08	1.17	2.93	1.75	1.00
Mean	1.58	2.77	1.20	2.73	2.07	0.24
$LSD_{0.05}$[1]	0.87	1.05	NS	NS	NS	--

[1]Least Significant Difference for comparison of harvest dates within a treatment.

[2]Least Significant Difference for comparison of treatments within a harvest date.

CONCLUSIONS

Climatic conditions - temperature and precipitation - play a major role in determining annual ryegrass yield. Since temperature is a major regulator of growth and development of this cool-season grass, early and rapid growth may have affected days of sustainable production by inducing plants to senescence earlier. Despite of soils having a medium P level, there was no evidence that the Avail, Nutrisphere-N or fertilizer treatments had an effect on the amount on forage production, N removal or forage quality. Most of the variables measured in the study were greatly affected by harvest date. Although these products might have a place in forage production, the efficacy of Nutrisphere-N might be suited for conditions where higher temperatures might pose an issue due to N loss. Avail might be more well-suited for use with organic fertilizer sources (such as poultry litter) where there is a need to increase phosphorus availability or in soils with low to medium testing values (especially with reduced P rates and if other nutrients are not out of balance). Further studies will be needed to determine the place of these products in forage production systems. It is important to remember that the implementation of a complete, balanced, and well-timed fertility program is important in getting the most production of annual cool-season grasses. Soil testing is a very important part of developing an environmentally nutrient management plan.

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