Fall Applications of Nitrogen and Potassium and their Effect on Winter Hardiness on Annual Bluegrass

Summary:
Fall fertilization can have a significant impact on the ability of plants to acclimate. Recommendations on fall fertilization practices vary widely, and appear to be species specific. A granular fertility research project focused on the response of annual bluegrass to fall applied nitrogen (N) and potassium (K) was implemented to determine the effects of N and K fertilization on cold hardiness, and to determine if there is a relationship between plant cold hardiness, soil nutrient status, and tissue nutrient content. Nitrogen and K were applied at 0, 1.22, 2.44, and 4.88 g m^{-2} in a complete factorial design for a total of 16 fertilizer rates applied biweekly from 15 Aug through 1 Oct in 2014 and 2015. Ammonium sulfate and potassium sulfate were the sources for N and K respectively. Cold tolerance was evaluated 4 times during the acclimation process; however the final testing date in November displayed the highest cold tolerance levels and robust statistical differences. Results showed that a balanced rate of both nutrients provided the highest level of cold tolerance. Optimal cold tolerance levels correlated with tissue tests levels between 2.5 - 3% N and 2.25 - 2.75% K. Excessive amounts of both N and K reduced the cold tolerance of annual bluegrass. Soil N (estimated) and K did not correlate with the cold tolerance, suggesting that when optimizing fertility programs to improve cold tolerance tissue test results are more indicative of the nutritional state of the plant.

Introduction:

Annual bluegrass (*Poa annua* L.) putting greens often experience winter damage due to several factors including: desiccation, anoxia, early crown hydration, overwintering diseases, and direct exposure to extreme cold temperatures. To mitigate these potential problems turfgrass managers will focus their cultural practices on promoting healthy plants that will acclimate to cold temperatures during the autumn, or may implement the use of tarping systems for the prevention of desiccation and direct exposure to cold temperatures.

One of the most important cultural practices used on putting surfaces is the fertility program. Primarily fertility programs are dialed-in to promote a desirable playing surface during the golf season; however, fertility programs' effect with respect to cold tolerance have had varied results. Taulavuori et al. (2014) reviewed 50 papers and found that there is an association between nitrogen (N) applications during the acclimation period and a general improvement of frost hardiness in some plant species. Carroll and Welton (1939) discovered that high applications of N resulted in higher crown weights in Kentucky bluegrass. Potassium (K) research has had variable results. Marklan and Roberts (1967) found that as K applications increased crown hydration levels decreased in creeping bentgrass, and Hurto and Troll (1980) showed tissue K levels were positively correlated with cold tolerance of perennial ryegrass. Ebdon et al (2013) found that when either N or K is limited the nutrient use efficiency of the other is compromised. Recommendations for N and K nutrition has some discrepancies: Hurto and Troll (1980) recommend a 2:1 N: K ratio, while Webster and Ebdon (2005) found that ratios

of 1:4 – 2:1 improved prevention of winter injury when N was applied at (5-15 g m^{-2} yr^{-1}) with medium to high levels of K (24-22 g m^{-2} yr^{-1}).

The objectives of this study were to determine:

1) the effects of fall applied nitrogen and potassium on cold hardiness of *Poa annua* L.
2) the relationship between plant cold hardiness, and plant tissue content
3) if tissue nutrient deficiencies or excesses have an impact on plant cold hardiness

Materials and Methods:

A sand-based USGA spec annual bluegrass putting green established in 2012 was used to set up 1m x 2m plots at the Prairie Turfgrass Research Centre (PTRC) in Olds, AB. All plots were fertilized biweekly throughout the summer to ensure no deficiencies before the onset of the trial. Plots were arranged in a 2-factorial randomized complete block design with 4 replications (total of 64 plots). All plots were fertilized with ammonium sulfate (N) and sulfate of potash (K) based upon their treatment number (Table 1) on: 15 Aug, 1 Sept, 15 Sept, and 1 Oct in 2014 and 2015.

Treatment #	Nitrogen (g*m^{-2})	Potassium (g*m^{-2})
1	0	0
2	0	1.22
3	0	2.44
4	0	4.88
5	1.22	0
6	1.22	1.22
7	1.22	2.44
8	1.22	4.88
9	2.44	0
10	2.44	1.22
11	2.44	2.44
12	2.44	4.88
13	4.88	0
14	4.88	1.22
15	4.88	2.44
16	4.88	4.88

Soil and tissue samples were harvested at the onset of the trial (Aug. 15) and on Sept. 15th and October 15th of each year. Samples were sent to Brookside Laboratories (Ohio, USA) where Mechlich III was used for determination of soil P and K.

Whole plant samples were taken using a 2 cm diameter soil probe for determining crown weight and the lethal temperature (LT50) on the weeks of Oct. 6, Oct 20, Nov 3, and Nov 24th, 2014 and the weeks of Oct. 20, Nov.3, and Nov. 24th, 2015. Eight of the soil probe samples were placed into test tubes for the determination of cold tolerance following a methodology like that described by Tompkins et al. (2004). One additional plug was taken from the Mason jar samples and maintained at 4C until transplanting to potting media (Sunshine Mix no. 1) for

regrowth analysis to serve as an untreated control for the LT_{50} tests. Test tubes were placed in a circulating bath (Model LT50, Neslab Instruments) and plants were allowed to equilibrate overnight at −2C. The temperature was then decreased by 2C h^{-1} in a stepwise fashion. When the temperature reached the targeted temperatures as determined by Tompkins et al. (2000), a test tube with plants from each treatment was removed and the temperature of the bath was further decreased by 2C. Plants were removed at −4, −6, −8, −10, −12, −14, −16, and −18C. Following the cold-hardiness test, plugs were held at 4C overnight. Plugs were then placed in 5cm diam. seed wells in a soilless potting media and allowed to regrow in the greenhouse at 23/18C day/night temperatures. After 4 wk, individual living plants were isolated and counted to determine the cold-hardiness level of each treatment. These levels are presented as an LT_{50} value, which represents the lowest temperature at which 50% of the plants survived.

Percent crown moisture was determined using a methodology similar to Tompkins et al. (2000) with the following modifications: two soil probe samples were used to isolate 25 crowns. The verdure was clipped off to leave 5mm of tissue above the base of the crown, and the roots were cut off to leave the bottom 5mm below the base of the crown. Crowns were patted dry with paper towel and wet weight was determined. The crowns were placed in a number 1 coin envelope and into the drying oven at 70 C for 24 hours. After the dry weights for each sample was weighed, the percent crown moisture content was determined for each plot.

Spring recovery or green-up was visually rated on a 1-9 scale: 1= dormant/dead turf and 9 = ideal green dense turf (NTEP, 2016). Each individual plot was rated 4 times from the last week of March through the last week of April in 2014 and 2015.

All data was analyzed using JMP 11 for determination of ANOVA. Tukey's HSD was used for means comparison when appropriate. Summary statistics are presented when the N:K interaction prevented main effects investigations.

Results and Discussion:

Percent Crown Moisture:

There was no year interaction for the crown moisture data therefore 2 years of data were analyzed using Tukey's HSD (Table 2). Potassium did not affect the crown moisture levels of AB, while N applications did. As N application levels increased the crown moisture levels increased. Carroll and Welton's (1939) also found that as N levels increased, crown moisture levels increased in Kentucky bluegrass. Marklan and Roberts (1967) and Hurto and Troll (1980) found contrasting results in creeping bentgrass and perennial ryegrass respectively; in general, they found that as K application levels increased the crown moisture levels decreased. The conflicting results suggest that bluegrasses respond to N and K applications during the acclimation period differently than the other two grass species mentioned.

Cold Tolerance:

A significant year by treatment interaction was seen for LT_{50}; therefore, year 1 and 2 data are presented separately. This was unsurprising as the fall weather varied between 2014 and 2015. Both years had mild autumnal weather such that optimal sampling dates for determining cold tolerance were 24 Nov 2014 and 20 Nov 2015. In year one, the greatest cold tolerance (-15C) was seen in the 1.22 and 2.44 g N m^{-2} rates with K at 1.22 and 2.44 g K m^{-2}. The

best cold tolerance was seen in plots treated with 1.22 g N m^{-2} x 1.22 g K m^{-2} (Table 3a). In year two, the greatest cold tolerance (-15°C) occurred at the 2.44 g N m^{-2} x 1.22 g K m^{-2}. The optimal fertilizer rates for cold hardiness were 1.22 -2.44 g N m^{-2} x 1.22 g K m^{-2} (Table 3b).

Table 2(a). Response of crown moisture based upon N rates applied during the acclimation period. **(b)** Response of crown moisture based upon K rates applied during the acclimation period.

2a: Nitrogen's role:

N (g/m^2)	% Moisture	
4.88	74.03	A*
2.44	69.41	B
1.22	69.27	B
0	65.65	C

2b: Potassium's role:

K (g/m^2)	% Moisture	
2.44	70.34	A*
1.22	70.15	A
4.88	69.36	A
0	68.51	A

*% moisture levels with varying letters are statistically different at the p>0.05 level using Tukey's HSD

Table 3. **(a)** LS means and summary statistics for year 1 results. **(b)** LS means and summary statistics for year 2 results.

3a: Year one results for cold tolerance, tissue nutritional status, and mean spring recovery

N (gm^{-2})	K (gm^{-2})	LT50 (^0C)	% N Tissue	% K Tissue	Spring Recovery
0	0	-11.25_{c}	1.86	2.06	1.50
0	1.22	-11.25_{c}	2.14	3.14	1.50
0	2.44	-12.25_{b}	1.51	2.95	1.66
0	4.88	-10.88_{d}	1.71	3.89	1.38
1.22	0	-12.00_{bc}	3.53	2.05	2.94
1.22	1.22	-13.25_{a}	2.86	2.50	3.19
1.22	2.44	-12.25_{b}	2.96	3.30	2.91
1.22	4.88	-11.25_{c}	2.29	3.22	2.13
2.44	0	-10.75_{d}	3.33	1.95	4.31
2.44	1.22	-12.25_{b}	3.01	2.83	3.44
2.44	2.44	-12.75_{ab}	3.09	3.28	3.06
2.44	4.88	-11.00_{cd}	2.98	3.96	2.94
4.88	0	-10.75_{d}	3.95	1.71	5.00
4.88	1.22	-11.25_{c}	3.96	2.89	5.19
4.88	2.44	-10.50_{d}	4.29	4.17	4.25
4.88	4.88	-11.63_{bc}	3.19	4.02	3.44

3b: Year two results for cold tolerance, tissue nutritional status, and mean spring recovery

N (gm^{-2})	K (gm^{-2})	LT50 (^0C)	% N Tissue	% K Tissue	Spring Recovery
0	0	-7.00_{g}	1.20	1.54	1.81
0	1.22	-9.50_{defg}	2.62	1.72	1.25
0	2.44	-9.25_{efg}	1.97	1.38	2.00
0	4.88	-10.25_{cde}	3.54	2.08	2.00
1.22	0	-11.25_{cd}	2.88	1.93	3.38
1.22	1.22	-13.50_{ab}	2.72	1.92	3.69
1.22	2.44	-11.50_{bcd}	3.46	2.52	3.75
1.22	4.88	-10.25_{cde}	2.55	2.07	2.56
2.44	0	-11.25_{cd}	2.70	2.00	4.81
2.44	1.22	-14.25_{a}	3.05	2.45	4.38
2.44	2.44	-13.25_{ab}	3.44	2.45	3.44
2.44	4.88	-12.00_{bc}	2.62	2.86	3.13
4.88	0	-10.00_{def}	3.09	2.94	5.00
4.88	1.22	-10.25_{cde}	3.02	2.27	5.38
4.88	2.44	-10.75_{cde}	2.53	1.95	4.50
4.88	4.88	-9.50_{defg}	3.35	1.94	4.19

*% moisture levels with varying letters are statistically different at the p≤0.05 level using Tukey's HSD
† Summary statistic of mean performance at the respective treatment level

Tissue Analysis, Soil Status, and LT_{50} Performance:

The soil test results did not correlate with the cold tolerance. This is unsurprising due to the fluid nature of the Nitrogen cycle and the crude estimate results that can be determined with lab testing. The crown moisture results highlight the importance of the N application rate and its effect on improving or hindering winter performance.

The tissue results showed that when tissue N levels were between 2.5 – 3% and tissue K levels were between 2.5 – 3.3% (Table 3a). In year two, the greatest cold tolerance levels were observed when tissue N levels were between 2.7 – 3.05% and tissue K levels were 1.92 – 2.45% (Table 3b).

Spring Recovery:

In general, N drove the spring recovery of the turf plots, whereas K did not appear to have an influence on spring recovery. Wehner et al. (1988) found that late fall applications of urea increased spring quality ratings in Kentucky bluegrass, and Munshaw et al. (2005) found that judicious N applications during the fall promoted colour retention on bermudagrass. The annual bluegrass in Olds, AB that received 2.44 and 4.88 g N m^{-2} retained their green colour during the winter season and had higher spring recovery ratings.

Conclusions:

Fertility levels during the acclimation period play an important role for improving cold tolerance at the onset of winter. Very high N (4.88 g N m^{-2}) and no N applications, and very high K (4.88 g N m^{-2}) applied during the acclimation period negatively affected annual bluegrass' ability to withstand direct exposure to cold temperatures. These results are akin Tompkins et al. (2000) observations. Tissue N levels between 2.5 and 3% with tissue K levels between 2.25 and 3% resulted in the highest cold tolerance values observed. The best overall performance with respect to cold tolerance and spring recovery was when N and K were applied in 1:1, 2:1, or 1:2 ratios. Fall fertility programs on annual bluegrass putting greens will affect the ability of the green to survive direct cold exposure during open cold winters; however, they will not eliminate the need to apply fertilizers in the spring to promote faster recovery (Wehner et al., 1988).

Due to the restrictions of using a granular approach, the applications rates were applied at coarse rates that may not truly represent the methodologies currently being implemented by most practicing superintendents. A foliar approach on the same annual bluegrass putting green is currently being implemented to determine if fine-tuning the fertility program will allow for a more definitive N:K ratio to be recommended.

References:

Carroll, J.C. and F.A. Welton. 1939. Effects of heavy and late applications of nitrogenous fertilizer on the cold resistance of Kentucky bluegrass. Plant Physiol. 18:19-36.

Ebdon, J.S., M. DaCosta, J. Spargo, and W.M. Dest. 2013. Long-term Effects of Nitrogen and Potassium Fertilizaton on Perennial ryegrass Turf. Crop Sci. 53:1750-1761.

Hurto, K.A. and J. Troll. 1980. The influence of nitrogen:potassium ratios on nutrient content and low temperature hardiness of perennial ryegrass, p 114. In: Agronomy abstracts. Amer. Soc. Agron., Madison, WI.

Markland, F.E. and E.C. Roberts. 1967. Influence of varying nitrogen and potassium levels on growth and mineral composition of *Agrostis palustris.* Huds, p.53. In: Agronomy abstracts. Amer. Soc. Agron., Madison, WI.

Munshaw, G.C., E.H. Ervina, C. Shang, S.D. Askew, X. Zhang, and R.W. Lemus. 2005. Influence of Late-Season Iron, Nitrogen and seaweed extract on Fall Color Retention and Cold tolerance of Four Bermudagrass Cultivars. Crop Sci. 46:273-283.

National Turfgrass Evaluation Program. 2016. A Guide to NTEP ratings. [Online] available at: http://www.ntep.org/reports/ratings.htm#quality verified: November 4, 2016

Taulavuori, K., E. Taulavuori, and L.J. Sheppard. 2014. Truths or myths, fact or fiction, setting the record straight concerning nitrogen effects on levels of frost hardiness. Env. And Exp. Botany. 106:132-137.

Tompkins D.K., J.B. Ross, and D.L. Moroz. 2000. Dehardening of annual bluegrass and creeping bentgrass during late winter and early spring. Agron. J. 92:5-9.

Webster D.E. and J.S. Ebdon. 2005. Effects of Nitrogen and Potassium Fertilization on Perennial Ryegrass Cold tolerance During Deacclimation in Late Winter and Early Spring.

Wehner, D.J., J.E. Haley, and D.L. Martin. 1988. Late Fall Fertilization of Kentucky bluegrass. Agron. J. 80:466-471.