Hindawi Publishing Corporation
International Journal of Agronomy
Volume 2012, Article ID 348754, 7 pages
doi:10.1155/2012/348754

Research Article

Nitrogen Fertilizer and Growth Regulator Impacts on Tuber Deformity, Rot, and Yield for Russet Potatoes

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Received 8 January 2012; Revised 10 April 2012; Accepted 3 May 2012

Academic Editor: H. Allen Torbert

Potatoes (*Solanum tuberosum*) are an important high-value commodity for producers in the Mid-Atlantic Region. Current production recommendations were based on white potatoes, and practices for Russet potatoes have not been researched in this region. The objective of this study was to test impacts of N rate (0, 67, 134, 201, and 268 $\mathrm{kg\,N\,ha^{-1}}$), N application timing (100% applied with planter, 2-way split (30% with planter and 70% band applied approximately 30 days after planting at dragoff), and three-way split (30% with planter, 50% band applied prior to drag-off, and 20% band applied at first sight of bloom)), and additions of the growth regulator maleic hydrazide (MH-30). We tested "Goldrush" and "Norkotah" Russet potato varieties on marketability, total yield, tuber deformity, and tuber soft rot incidence for sandy loam soils in the Mid-Atlantic. Overall, year variations were significant with substantial rots (up to 86.5%) occurring in year 3. Maleic hydrazide and N application timing had little consistent effect on any tested parameter. Nitrogen rate and variety factors had the greatest impacts on deformity, tuber rots, and yields for Russet potatoes in the Mid-Atlantic Region with 134 $\mathrm{kg\,N\,ha^{-1}}$ producing the highest total yields in 2009 and 2010. If tuber rots can be controlled, both "Goldrush" and "Norkotah" are acceptable varieties under the Mid-Atlantic production practices.

1. Introduction

Potatoes are an important crop to Virginia and the rest of the Mid-Atlantic Region that includes Delaware and Maryland, USA. Annually, the Mid-Atlantic states produce 4049 hectares (ha) of potatoes with an average yield of 30,091 kg tubers $\mathrm{ha^{-1}}$ worth $9.97 million (5 year averages) [1]. Sandy loam soils in the Mid-Atlantic Region are favorable for potato production. However, a close proximity to sensitive water bodies, such as the Chesapeake Bay, means that fertilizer use efficiency and reduction of nutrient losses from production fields are more important than ever before.

Intensive fertilizer management is necessary in sandy loam soils in the Mid-Atlantic to ensure proper nutrient supplies to growing crops. Sandy loam soils generally have overall low organic matter, low cation exchange capacities, and low total nitrogen (N) in the upper horizon, which means that little N is mineralized from soil organic N sources and N must be applied with fertilizer to match crop uptake needs [2]. For instance, Stanford and Smith [2] found that a Norfolk fine sandy loam had little initial N mineralized after 4 weeks of incubation (7.3 $\mathrm{mg\,kg^{-1}}$) and this amount gradually fell for the next 30 weeks. Similarly, Van Veen and coworkers [3] found that any organic N applied to sandy loam soils was quickly mineralized into inorganic forms; therefore, soil supplies of N from crop to crop would be minimal in sandy loam crop production systems. Generally, only 1 to 3% of total organic N concentrations in the soil become available to a crop within the growing season in temperate regions of the world [4].

Nitrogen management is one of the most important aspects for potato production. Nitrogen fertilizer recommendations vary widely around the world. In loamy sand soils, Jamaati-E-Somarin and coworkers [5] found that

160 kg N ha^{-1} was sufficient for producing highest yields. Worthington et al. [6] found that 196 to 224 kg N ha^{-1} was necessary for the highest yields in Florida fine sands, with sidedress N applications being important for supplying necessary N fertilizer after leaching rain events. Nitrogen fertilizer recommendations for white potatoes in Virginia vary based on yield potential. For instance, producers yielding approximately 22,000 kg tubers ha^{-1} need 140 to 168 kg N ha^{-1} while higher producing yield goals require more N. For high yielding systems; growers are recommended to multiply yield goals in kg ha^{-1} by 0.006 to find recommended kg N ha^{-1} necessary [7]. Currently, producers in Virginia do not have separate guidelines for Russet potato varieties even though Russet varieties are more prone to deformity and other quality issues than white potatoes. Tuber deformity and secondary growth are historically correlated with moisture; however, other environmental factors that initiate and decrease growth, such as N fertility, may also be a cause [8].

Nitrogen application timing is one of the most important management techniques that producers can use to increase their fertilizer N use efficiency. For sandy loam and loamy sand soils, Virginia Cooperative Extension recommends two or three N fertilizer application splits to reduce potential N losses due to over irrigation or excessive rainfall. Fertilizer should be split between at planting, at dragoff (approximately 30 days after planting when potato plants are beginning to emerge, are bedded during cultivation, and the bed height is reduced), and immediately prior to bloom [7, 9]. Split N applications are recommended to increase overall yield and fertilizer use efficiency [10, 11]. However, N applications too late in the growing season can significantly delay maturity and decrease tuber quality [12].

Nutrient availability is not only important for overall yield in potato production, but is also important for disease management. Mackenzie [13] studied the relationship between N rate and potato yield in association with potato early blight in silt clay loam soils of Pennsylvania. Mackenzie [13] demonstrated that increasing N rates from 133 to 160 kg N ha^{-1} decreased overall rates of potato early blight infection. Research with potassium fertilizer also demonstrated that fertilizer rate and source impacted disease incidence. Panique and coworkers [14] found that potassium sulfate increased overall yields, but potassium chloride fertilizers decreased *Rhizoctonia solani* incidence. Therefore, fertilizer applications can significantly impact both foliar and tuber disease; however, the role of N fertilizer management in the Mid-Atlantic on tuber rots such as *Erwinia carotovora* ss. *carotovora and Pythium* sp. is not known.

Growth regulators have been researched for decades to help producers manage tuber sugar content, maturity, and sprouting after harvest and during storage [15, 16]. However, results are mixed depending on the factors studied. For instance, Yada et al. [17] found that foliar application of maleic hydrazide (MH-30) at a rate of 3.39 kg ha^{-1} had no significant effect on potato yield or sugar content, but did reduce sprout growth after harvest. Other research by Rex [18] found that foliar applications of chlormequat chloride, ethephon, and a combination of the two products reduced tuber size, increased tuber deformity, and reduced overall yield. Work by Caldiz and coworkers [19] found that MH-30 was safe to use on potato foliage did not cause any phytotoxicity symptoms, and did increase yield in several varieties. However, no yield impact was found in any variety, but in all cases tuber sprouting was reduced. An analysis by Davis and Groskopp [20] found that overall tuber yield was reduced from MH-30 treatments; however, this reduction was mainly from lower numbers of undersized tubers. Overall, growth regulators have demonstrated positive effects on yield and sprouting, but impacts on tuber rot is not known.

Previous studies did not focus on Russet potatoes and most producers in the Mid-Atlantic currently use recommendations for white potatoes. The objectives of this study included finding: (1) impacts of N rate and N application timing and (2) impact of maleic hydrazide growth regulator on tuber yield, deformity, and rot on sandy loam soils in the Mid-Atlantic for Russet potatoes.

2. Materials and Methods

The trial was conducted on a Bojac sandy loam soil (Coarse-loamy, mixed, semiactive, and thermic Typic Hapludult) (65% sand, 25% silt, and 10% clay; 0.75% organic matter) at Virginia Tech's Eastern Shore Agricultural Research and Extension Center near Painter, VA, USA (37.5845808N, −75.8210421W) [21]. Prior to treatment establishment, soil was sampled per replication to a 15 cm depth, dried, ground, and analyzed using the Dumas method for total N and total carbon (C) analysis using a Vario EL cube (elementar Americas, Mt. Laurel, NJ, USA) [22]. Treatments included a $2 \times 4 \times 3$ factorial combination of treatments of variety × N rate × N application timing. Ammonium nitrate (340 g N kg^{-1}) was applied with total N rates of 67, 134, 201, and 268 kg N ha^{-1} at various application timing intervals. Nitrogen treatments were applied either in a single treatment (100% applied with planter), 2-way split (30% with planter and 70% band applied prior to dragoff (approximately 30 days after planting when potato plants are beginning to emerge and are bedded during cultivation, and the bed height is reduced)), or with the high yielding white potato timing methodology of a three-way split (30% with planter, 50% band applied prior to dragoff, and 20% band applied at first sight of bloom). A 0-N control was also included. At-planting fertilizer treatments were spread evenly across the treatment area and incorporated using a field cultivator; dragoff treatments were surface applied and incorporated with bed shaping, while early bloom treatments were surface band applied. "Goldrush" and "Norkotah" Russet cultivars were seeded into conventionally-tilled land in early April following incorporation of fertility treatments. The growth regulator, maleic hydrazide, was applied at the manufacturer's recommended rate of 3.36 kg active ingredient (ai) ha^{-1} (MH-30; 0.18 kg ai L^{-1}). The MH-30 was broadcast foliar-applied using a CO_2-pressurized sprayer calibrated to deliver 280 L ha^{-1} at three weeks past full bloom in late June. The MH-30 was applied to both cultivars and plots that had combinations of all three N application timing treatments, and total N rates of 0, 134, and 268 kg N ha^{-1}. Comparable plots with identical variety, N rate, and N application timing treatments were maintained with and without MH-30 treatments, so direct comparisons of MH-30 impacts could be observed. Plots were two 7.62 m rows spaced 0.9 m apart and separated by a guard row, which did not receive any N fertilizer or growth regulator treatments. Treatments were replicated four times in a randomized complete block design. During the growing season, recommended practices for disease, weed, and insect control were followed as outlined by Wilson and coworkers [9]. The second row of each plot was mechanically harvested upon maturity in late July. Harvested tubers were sorted in the following categories: deformed (misshapen tubers), rotten, marketable (total of all tubers not rotten = misshapen + size B + size A + chef), and total (marketable + rotten tubers). Means were separated using Fisher's protected least significant difference (LSD) test at $\alpha = 0.10$ that was established *a priori*. The 0-N control plots were not included in the factorial combination PROC ANOVA analysis as only 1 control plot per replication was included per variety; therefore, the design was not balanced for all combinations of treatments if 0-N treatments were included.

3. Results and Discussion

Total N attributed to potato plants from sandy loam soil organic matter mineralization is expected to be low in the Mid-Atlantic due to relatively low total C concentrations (Table 1). Ambient soil total N concentrations ranged from 0.42 to 0.49 g N kg^{-1} (Table 1), which would equate to 864 to 1,008 kg total soil ha^{-1} at an average bulk density of 1.35 g kg^{-1} (2,057,400 kg soil ha^{-1} at 15.24 cm depth) for a Bojac sandy loam on the Eastern Shore of Virginia [23]. Due to these low soil total N concentrations, we would expect only 26 to 30 kg N ha^{-1} to be available to potato tubers in temperate conditions from ambient soil sources via mineralization [4]. Therefore, substantial inorganic N fertilizer sources are necessary for optimal production and are the overall focus of a potato grower's fertilizer program.

In each year, *Erwinia carotovora* ss. *carotovora* and *Pythium* sp. occurred naturally in these trials causing tuber rots in the field. Data were analyzed as a year × treatment effect to test differences of treatments across years. In all cases, year × treatment was significant ($P = 0.0063$, <0.0001, <0.0001, and <0.0001 for percentage of deformed tubers, total yield, marketable yield, and percentage of rots, resp.). Large weather variations are likely responsible for varying yearly effects of N fertilizer, variety, and growth regulator treatments. Total yields were the highest in 2010, followed by 2009, and the lowest in 2011, which was inversely proportion to rots (2011 > 2009 > 2010). Therefore, each year will be discussed separately.

3.1. 2009 Growing Season. Maleic hydrazide had no significant effect on deformed tubers (55.8% of nonrotten tubers), rotten tubers (34.3% of total yield), marketable yield (13517 kg ha^{-1}), or total yield (20040 kg ha^{-1}) ($P = 0.6380$, 0.8236, 0.3860, and 0.2909, resp.) when compared to plots with identical N application timing and total N rate treatments that did not receive MH-30. These yield results are similar to work by Yada et al. [17] and Caldiz and coworkers [19] where no yield advantage was seen on several Russet potato varieties when MH-30 was used.

Table 1: Soil total nitrogen, carbon, and C : N ratio for a sandy loam soil in the Mid-Atlantic by year.

Year	Total nitrogen	Total carbon	C : N ratio
	g kg^{-1}		g C g N^{-1}
2009	0.49 a†	5.26 a	10.72 b
2010	0.46 ab	4.88 a	10.52 b
2011	0.42 b	4.87 a	11.47 a
LSD$_{0.10}$	0.04	0.54	0.40
Pr > F	0.0716	0.3500	0.0081

†Means within each dependent variable with the same letter are not significantly different ($P \geq 0.10$; Fisher's Protected LSD) and can be compared within column.

Generally, only the N rate and cultivar main effects were significant in 2009. When averaged across N application timing and cultivar, the percentage of deformed tubers and total yield increased as N rate increased (Table 2). The 201 kg ha^{-1} N rate had more deformed tubers than the lower N rate of 67 kg N ha^{-1} (58.3 versus 45.8% of nonrotten tubers, resp.; LSD$_{0.10}$ = 9.5%). For total yield, at least 134 kg N ha^{-1} was necessary to achieve commercially acceptable yields (19267 kg ha^{-1}), which is similar to N rates currently recommended in Virginia for white potato production [7]. However, the Virginia agronomic efficiency is significantly lower than efficiencies for Russet potatoes grown in Oregon and Washington states. Lauer [24] found that Russet Burbank returned 223 kg of tubers per kg N fertilizer applied, while yields in our study returned 144 kg tubers per kg N fertilizer. For the N rate main effect, marketable yield was not significant and averaged 13061 kg tubers ha^{-1} ($P = 0.4200$) (Table 2). For the cultivar main effect, "Goldrush" had significantly higher yields than "Norkotah" albeit higher percentage of deformed tubers, averaged across N rate and N application timing (Table 3). An N rate × N application timing × variety cultivar interaction was significant for rotten tubers ($P = 0.0399$, Table 4). Wide variation was seen in this experiment regarding tuber rots, which resulted in a relatively large LSD$_{0.10}$ (15.9% rotten tubers as a percentage of total yield). Generally, treatments that one would expect to have higher N use efficiency (more N splits) and higher N rates had more tuber rots. For example, "Norkotah" 268 kg N ha^{-1} with 3-splits (41.9% rots) compared to "Norkotah" 67 kg N ha^{-1} with all N applied at planting (24.5% rots) or "Norkotah" 0-N fertilizer treatments (21.8% tuber rots) (Table 4).

3.2. 2010 Growing Season. Maleic hydrazide had no impact on deformity (16.8% deformed tubers as a percentage of nonrotten tubers) or rot (23.4% of total yield) in 2010. An N rate × N application timing × variety × MH-30 interaction in 2010 for total yield was significant ($P = 0.0474$) and is illustrated in Table 5. Generally, "Norkotah" yielded the

Table 2: Nitrogen rate main effect in 2009 for deformed tubers, rotten tubers as a percentage of total yield, marketable tuber yield, and total tuber yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic, averaged across Russet cultivars and N application timing.

Nitrogen rate kg ha^{-1}	Deformed tubers Percentage of tubers	Rotten tubers Percentage of total yield	Marketable yield kg ha^{-1}	Total yield
0[†]	30.0	22.2	12728	15978
67	45.8 b[‡]	33.2 a	12248 a	17360 b
134	54.2 ab	34.0 a	14884 a	21515 a
201	58.3 a	35.5 a	12862 a	19267 ab
268	61.5 a	35.7 a	12248 a	21507 a
LSD$_{0.10}$	9.5	6.5	3053	3208
Pr > F	0.0445	0.8967	0.4200	0.0995

[†] No-fertilizer control plots were not included in Analysis of Variance and are included for informational purposes only.

[‡] Means within each dependent variable with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD) and can be compared within column.

Table 3: Russet potato main effect in 2009 for deformed tubers, rotten tubers as a percentage of total yield, marketable tuber yield, and total tuber yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic, averaged across N rate and N application timing.

Variety	Deformed tubers Percentage of tubers	Rotten tubers Percentage of total yield	Marketable yield kg ha^{-1}	Total yield
Goldrush	66.7 a[†]	34.5 a	16894 a	24549 a
Norkotah	43.2 b	34.6 a	10343 b	15276 b
LSD$_{0.10}$	6.7	4.6	1928	2025
Pr > F	< 0.0001	0.9726	<0.0001	<0.0001

[†] Means within each dependent variable with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD) and can be compared within column.

Table 4: Nitrogen rate × N application timing × variety interaction in 2009 for rotten tubers as a percentage of total yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic.

Nitrogen rate	Goldrush			Norkotah		
	All at planting	2-splits	3-splits	All at planting	2-splits	3-splits
kg ha^{-1}	% of total yield					
0[†]		11.8			21.8	
67	47.2 ab[‡]	29.3 cdef	34.6 bcdef	24.5 ef	29.6 cdef	33.7 bcdef
134	31.2 cdef	31.9 bcdef	35.4 abcdef	35.3 abcdef	26.7 def	43.4 abc
201	23.2 f	50.8 a	33.0 bcdef	39.8 abcde	29.7 cdef	36.6 abcdef
268	36.4 abcdef	26.3 def	35.2 abcdef	31.6 bcdef	42.9 abc	41.9 abcd
LSD$_{0.10}$	15.9					
Pr > F	0.0399					

[†] No-fertilizer control plots were not included in Analysis of Variance and are included for informational purposes only.

[‡] Means with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD) and any mean can be compared within the table.

Table 5: Nitrogen rate × N application timing × variety × MH-30 interaction in 2010 for marketable yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic.

Nitrogen rate and MH-30	Goldrush			Norkotah		
	All at planting	2-splits	3-splits	All at planting	2-splits	3-splits
kg ha^{-1}	kg ha^{-1}					
134 no MH-30	9148 j[†]	13325 hij	19556 efgh	28348 abcd	32261 abc	29262 abcd
134 with MH-30	17187 fghi	17035 ghi	12237 hij	28337 abcd	32789 ab	31356 abc
268 no MH-30	24800 cdef	22615 defg	22513 defg	28601 abcd	27707 abcd	28277 abcd
268 with MH-30	17696 fghi	10815 ij	26833 cde	27239 abcde	34883 a	32250 abc
LSD$_{0.10}$	7724					
Pr > F	0.0474					

[†] Means with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD) and any mean can be compared within the table.

Table 6: Nitrogen rate × N application timing × MH-30 interaction in 2010 for total yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic.

Nitrogen rate	No MH-30			MH-30		
	All at planting	2-splits	3-splits	All at planting	2-splits	3-splits
kg ha^{-1}	kg ha^{-1}					
134	15185 c[†]	19144 bc	19378 bc	19200 bc	20211 abc	17756 c
268	24216 ab	20719 abc	20231 abc	18241 c	18204 c	25256 a
LSD$_{0.10}$	5766					
Pr > F	0.0588					

[†] Means with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD) and any mean can be compared within the table.

Table 7: Nitrogen rate × variety interaction in 2010 for rotten tubers as a percentage of total yield, marketable tuber yield, and total tuber yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic, averaged across N application timing.

Nitrogen rate	Rotten tubers		Marketable yield		Total yield	
	Goldrush	Norkotah	Goldrush	Norkotah	Goldrush	Norkotah
kg ha^{-1}	Percentage of total yield		kg ha^{-1}		kg ha^{-1}	
0[†]	18.8	14.0	8507	7735	9839	8792
67	43.0 a[‡]	12.2 bc	9239 c	21266 b	13593 d	23777 bc
134	48.2 a	8.6 c	8396 c	27409 a	14009 d	29957 a
201	21.7 b	11.6 bc	21100 b	26972 a	26121 abc	30360 a
268	20.4 b	13.2 bc	19000 b	2444 c	23309 c	28195 ab
LSD$_{0.10}$	10.6		4744		4812	
Pr > F	0.0009		0.0033		0.0184	

[†] No-fertilizer control plots were not included in Analysis of Variance and are included for informational purposes only.

[‡] Means within each dependent variable with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD).

Table 8: Growth regulator (MH-30) × variety interaction in 2011 for rotten tubers as a percentage of total yield and marketable tuber yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic, averaged across Nrates and N application timing.

Russet cultivar	Rotten tubers		Marketable yield	
	With MH-30	No MH-30	With MH-30	No MH-30
	Percentage of total yield		kg ha^{-1}	
Goldrush	52.3 b[†]	39.2 c	7157 b	9423 a
Norkotah	86.4 a	86.5 a	2815 c	2573 c
LSD$_{0.10}$	6.5		1705	
Pr > F	0.0177		0.0873	

[†] Means within each dependent variable with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD).

Table 9: Nitrogen application timing × variety interaction in 2011 for rotten tubers as a percentage of total yield, marketable tuber yield, and total tuber yield for Russet potatoes grown on sandy loam soils in the Mid-Atlantic, averaged across N rates.

Nitrogen application timing	Rotten tubers		Marketable yield		Total yield	
	Goldrush	Norkotah	Goldrush	Norkotah	Goldrush	Norkotah
	Percentage of total yield		kg ha^{-1}			
No nitrogen[†]	35.5	82.9	7871	1773	11603	9400
At planting	34.8 c[‡]	85.2 a	7874 b	2811 c	11947 c	15698 ab
2-split	42.6 c	86.4 a	10396 a	2696 c	17354 a	16200 ab
3-split	48.0 bc	79.7 ab	8303 b	3970 c	15729 ab	14284 bc
LSD$_{0.10}$	32.1		1835		2710	
Pr > F	0.0131		0.0823		0.0458	

[†] No-fertilizer control plots were not included in Analysis of Variance and are included for informational purposes only.

[‡] Means within each dependent variable with the same letter are not significantly different ($P \geq 0.10$, Fisher's Protected LSD).

higher than "Goldrush" with only isolated effects of N application timing and MH-30 application. An N rate × N application timing × MH-30 interaction, averaged across variety, was significant for marketable yields in 2010 ($P = 0.0588$) (Table 6). Similar to total yield, significant effects were isolated but at high N rates with MH-30 the 3-split application timing yielded highest.

An N rate × variety interaction was significant in 2010 for rotten tubers, marketable yield, and total yield (Table 7). Overall, "Goldrush" tubers had more rot incidence than "Norkotah" tubers at 67 and 134 kg N ha^{-1}. Tuber rot generally mirrored marketable yield with 134 and 201 kg N ha^{-1} providing the highest marketable yields for "Norkotah," while "Goldrush" tuber yield was lower at similar N rates (Table 7). Compared to white potato recommendations [4], a yield of 29957 kg tuber ha^{-1} would suggest a need of 180 kg N ha^{-1} based on the yield × 0.006 factor for "Norkotah," while only 134 kg N ha^{-1} was necessary in both 2009 and 2010.

3.3. 2011 Growing Season. The 2011 growing season resulted in low yields compared to 2009 and 2010. Generally, yields were only 25 to 50% of yield expectations for potatoes in Virginia. A wet Spring coupled with excessive heat and drought likely contributed to low yields. In 2011, there was an MH-30 × variety interaction for rotten tubers and marketable yield (Table 8). For rotten tubers, "Norkotah" had no impact if MH-30 was included; however, "Goldrush" with MH-30 had more rotten tubers than treatments with no MH-30 (52.3 versus 39.2, resp., $\text{LSD}_{0.10} = 6.5$) (Table 8). Marketable yield followed an inversely proportional trend to rotten tubers with "Goldrush" with no MH-30 treatments having the highest marketable yields (9423 kg tubers ha^{-1}) (Table 8). A main effect was significant for deformed tubers with MH-30 treatments having 38.2% of nonrotten tubers being deformed with 27.6% being irregular if no MH-30 was used ($\text{LSD}_{0.10} = 6.3\%$), averaged across variety, N rate, and N application timing.

Nitrogen rate generally had no significant impacts on deformity, rot, or yield in 2011. However, N application timing × variety interactions, averaged over N rate, indicated that "Norkotah" tubers rotted twice as much as "Goldrush"; which resulted in significantly higher marketable yields for "Goldrush" (Table 9). A two-way N split (at planting and dragoff) was sufficient for providing the highest marketable and total tuber yields for "Goldrush" (10396 and 17354 kg ha^{-1}, resp.). A 3-split application timing decreased yield for "Goldrush," possibly due to reduced tuber formation and delayed maturity due to excessive N late in season as demonstrated by Ojala and coworkers [12]. Interestingly, total yield indicated that "Norkotah" generally yielded similar to "Goldrush" for total yield, so any management to reduce tuber rots would be beneficial.

4. Conclusions

In conclusion, N rate and variety factors had the greatest impacts on deformity, tuber rots, and yields for Russet potatoes in the Mid-Atlantic Region. Generally, findings indicate that 134 kg N ha^{-1} were adequate for producing the highest yields. If tuber rots can be controlled, both "Goldrush" and "Norkotah" are acceptable varieties under the Mid-Atlantic production practices. Neither maleic hydrazide nor application timing had a consistent impact on tuber rot, deformity, or yield.

Abbreviations

ai:	Active ingredient
C:	Carbon
ha:	Hectare
kg:	Kilogram
LSD:	Least significant difference
MH-30:	Maleic hydrazide
m:	Meter
N:	Nitrogen.

Acknowledgments

The authors gratefully acknowledge staff stationed at the Virginia Tech Eastern Shore Agricultural Research and Extension Center for assistance with plot establishment, maintenance, and data collection. They also thank the Virginia Irish Potato Board for funding this paper.

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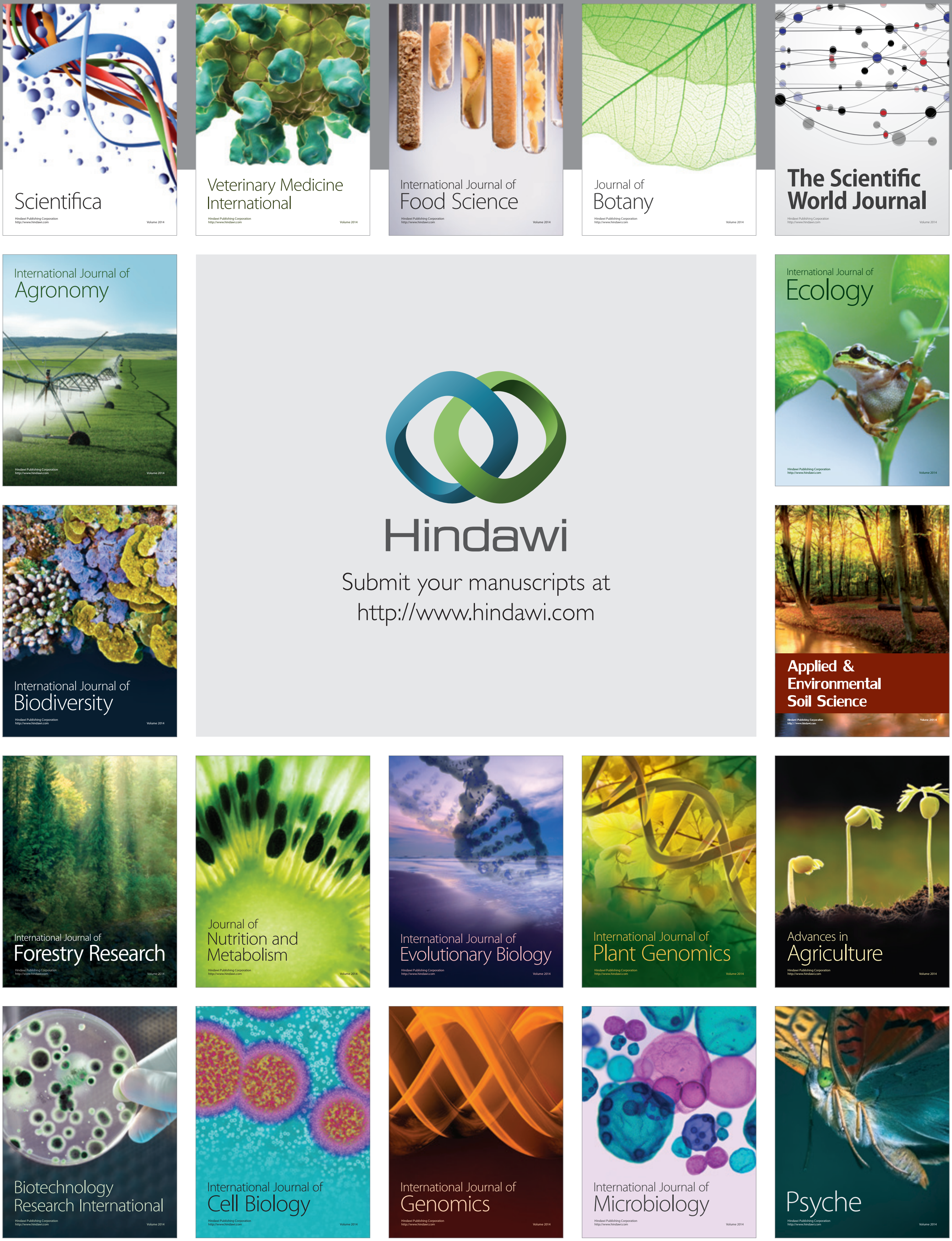
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