Variety Trials

Screening of New Mexico Autumn-sown Onions for Black Mold Disease

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ADDITIONAL INDEX WORDS. *Allium cepa*, *Aspergillus niger*, disease incidence, severity rating, sporulated area

SUMMARY. Black mold, caused by the fungus *Aspergillus niger*, is one of the major postharvest onion (*Allium cepa*) diseases causing qualitative and quantitative losses. To screen autumn-sown onion cultivars for black mold resistance, 12 cultivars were sown in 2004 and 2005 in Las Cruces, NM. Percent sporulated area, disease severity, and disease incidence were recorded after 2 and 4 weeks of storage. 'Texas Early White' exhibited less disease symptoms than other cultivars tested. For all cultivars, disease symptoms in terms of severity and incidence increased as bulbs were stored for longer periods of time.

New Mexico provides around 30% of the bulk demand for onion in the United States during the months of June and July (U.S. Department of Agriculture, 2012). Abundant sunshine, high temperatures, and a relatively dry climate during summer months make New Mexico an ideal environment for

onion bulb production. However, sporadic periods of rain at the time of maturity aggravate bulb decay because of various diseases (Corgan, 2002).

Black mold, caused by *Aspergillus niger*, is a frequent onion disease in the southwestern United States (Wall and Corgan, 1994). Every year, this disease causes yield and quality losses in the field and during storage (Wall and Corgan, 1994). Bulbs with black mold exhibit shallow lesions on dry outer scales and streaks of mycelial growth and black-colored conidia under dry outer scales (Ko et al., 2002a; Royal Botanic Gardens and Domain Trust, 2012). Eventually, the entire bulb

surface turns black, shrivels, and loses quality (Royal Botanic Gardens and Domain Trust, 2012).

In nature, *A. niger* can be saprophytic and can reside as an endophyte until infection occurs and symptoms become apparent at harvest or later during storage (Lorbeer et al., 2002). The fungus survives in soil on decaying organic matter and infects onion bulbs via wounds (University of California, 2012). Black mold is generally a postharvest disease but can be seen on mature bulbs in fields before harvest. Onions are harvested when they are physiologically mature at 80% tops down (Wall and Corgan, 1994).

In New Mexico, onion harvesting often coincides with rainfall and higher temperatures, conducive for development of black mold. Disease incidence can vary from 11% to 50% for short-day cultivars. No resistance to black mold has been described, however (Ko et al., 2002a). This variation for disease incidence among onion cultivars indicates cultivars can be identified for lower disease incidence (Ko et al., 2002a, 2002b). New Mexico State University (NMSU) onion cultivars have not been studied for black mold resistance. The objective of this study was to screen autumn-sown NMSU onion cultivars for resistance to *A. niger*.

Materials and methods

Twelve autumn-sown onion cultivars were sown on 23 Sept. 2004 and 26 Sept. 2005 at the Fabian Garcia Research Center in Las Cruces, NM. Of the 12 cultivars, six were early maturing cultivars (NuMex Camino, NuMex Chaco, NuMex Crispy, NuMex Mesa, NuMex Sweetpak, and Texas Early White), three were intermediate-maturing cultivars (NuMex Dulce, NuMex Starlite, and NuMex Vado), and the remaining three cultivars (NuMex Freedom, NuMex Luna, and NuMex Solano) were late maturing. Early maturing, autumn-sown cultivars

This research was funded by the NMSU Agricultural Experiment Station and the New Mexico Dry Onion Commission.

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	kg-ha ⁻¹	0.8922
28.3495	oz	g	0.0353
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

often mature the second to third week of May. Intermediate-maturing cultivars often mature 7–10 d later than early maturing cultivars, and late-maturing cultivars often mature 10–14 d later than intermediate-maturing cultivars. The experiment was conducted in a randomized complete block design with four replications. Plots were 8 ft long, with 2-ft alleys between plots. Two rows were planted on 40-inch-wide beds. For each plot, 1.5 g seed was sown and divided equally between both planted rows. Seedlings were thinned to 4 inches between plants in the first week of January in 2005 and 2006 to achieve a plant density of 40–50 plants per plot at maturity.

Cultural practices were as per general recommendations to produce onions in southern New Mexico (Corgan et al., 2000). Before planting, triple super phosphate (0N–20.1P–0K; Helena Chemical Co., Collierville, TN) was applied at a rate of 200 lb/acre. Subsurface drip irrigation lines (T-tape; T-Systems International, San Diego, CA) were placed 4 inches deep in the centers of each bed to apply water and fertilizers (26N–0P–0K; Western Blend, Las Cruces, NM). Plots were irrigated and fertilized as and when required.

The bulbs were harvested when 80% of the plant had broken over at the neck in a plot. After removing plant leaves and roots with knives, bulbs were placed into mesh sacks and cured for 3–4 d in a greenhouse under high temperatures and low relative humidity (RH) to suppress microbial infection and storage decay. Sacks were placed in a ventilated wooden shed for 2 weeks with average climatic conditions of 19–32 °C, 8% to 77% RH in 2005 and 20–31 °C, 20% to 86% RH in 2006.

At 2 weeks after harvesting, 20 bulbs from each sack were selected arbitrarily; individual bulbs were labeled (1–20) and rated for presence of black mold without removing dry outer scales. Bulbs displaying symptoms of other fungal and bacterial diseases were discarded. Bulbs were examined visually and rated for black mold severity based on the area covered and bulb softness or degree of disease progression (Kamal, 2007). Absence of black mold was rated as “0.” Bulbs were rated from 1 to 6 if black mold was present (1 = area

covered by black mold was $\leq 50\%$ and the bulb surface was dry; 2 = area covered by black mold was $\geq 51\%$ and the bulb surface was dry; 3 = area covered by black mold was $\leq 50\%$ and the bulb surface was $\leq 50\%$ soft; 4 = area covered by black mold was $\geq 51\%$ and the bulb surface was $\leq 50\%$ soft; 5 = area covered by black mold was $\leq 50\%$ and the bulb surface was $\geq 51\%$ soft; 6 = area covered by black mold was $\geq 51\%$ and the bulb surface was $\geq 51\%$ soft). Following bulb rating, they were placed individually in paper bags and placed back inside the sack for 2 weeks more. After 4 weeks in storage, the same bulbs were rated again for presence of black mold after removing dry outer scales, as at the 2-week rating.

Percent bulb area covered with black spores irrespective of bulb softness was also recorded. Percent disease incidence at 2 and 4 weeks after storage was calculated as the numbers of diseased bulbs out of 20 bulbs. Means for severity and percent sporulation area were analyzed using the General Linear Models procedure of SAS (version 9.2; SAS Institute, Cary, NC) for a randomized complete block design. Mean separation among cultivars and treatments were calculated by Fisher's least significant difference test.

Results and discussion

The combined analysis of variance over years indicated the absence of an interaction between cultivars and years for the traits measured of all cultivars; years were analyzed separately because of magnitude differences in performance between years. The early maturing cultivars comprised white cultivars (NuMex Crispy and Texas Early White) and yellow cultivars (NuMex Camino, NuMex Chaco, NuMex Mesa, and NuMex Sweetpak). Among the earliest maturing cultivars in 2005, ‘Texas Early White’ had less black mold disease severity and area covered at 2 and 4 weeks after harvest compared with all yellow cultivars (Table 1). Conversely, bulbs of ‘NuMex Camino’ exhibited a greater amount of black mold disease severity and area covered at 2 and 4 weeks after harvest as compared with bulbs of all other cultivars. The remaining cultivars were intermediate in their response for both characters (Table 1). For disease incidence, there

were no differences at 2 weeks among cultivars while at 4 weeks bulbs of ‘Texas Early White’ exhibited a lower incidence than bulbs of all other cultivars (Table 1). After 4 weeks of storage, ‘NuMex Camino’ and ‘NuMex Sweetpak’ had a higher percent of bulbs exhibiting black mold symptoms than most other cultivars (Table 1).

In 2006, ‘NuMex Camino’ did not exhibit the highest value for black mold disease severity and area covered at 2 and 4 weeks as in 2005 (Table 1). The difference between the two years may have been due to the earlier maturity date of ‘NuMex Camino’ in 2006. In 2006, bulbs of ‘NuMex Sweetpak’ exhibited a greater disease severity and area covered at 2 and 4 weeks after harvest as compared with bulbs of most other cultivars. However, values observed for ‘NuMex Sweetpak’ were less than values observed in 2005 for the same characteristics. In 2006, bulbs of ‘NuMex Crispy’ exhibited a similar disease severity and area covered after 4 weeks as did ‘NuMex Sweetpak’ (Table 1). Unlike in 2005, bulbs of ‘Texas Early White’ were similar to bulbs of ‘NuMex Camino’ and ‘NuMex Mesa’ for disease severity and area covered at 2 and 4 weeks after harvest even though values for ‘Texas Early White’ were similar in both years (Table 1). After 4 weeks of storage, bulbs of ‘NuMex Chaco’ had less area covered by disease than bulbs of all other cultivars. As in 2005, there were no differences among cultivars in disease incidence after 2 weeks of storage. After 4 weeks of storage, ‘NuMex Camino’ and ‘NuMex Sweetpak’ had a higher percentage of bulbs with black mold symptoms than other cultivars (Table 1).

Although a similar number of bulbs developed black mold after 4 weeks of storage in 2005 and 2006, the disease progressed at a slower rate in 2006 than in 2005 as evident by the lower severity rating and less area covered in 2006 than in 2005. This delay in disease development was particularly evident in the earliest maturing cultivars that matured 9–11 d earlier in 2006 than in 2005 (Table 1). Perhaps, the reduced time in the field for these cultivars reduced or delayed disease development as compared with 2005.

The low disease severity and less area covered of ‘Texas Early White’

Table 1. Severity rating, area covered, and incidence of black mold disease at 2 and 4 weeks after harvesting of autumn-sown onion cultivars at the Fabian Garcia Science Center, Las Cruces, NM, during the 2005 and 2006 test years.

Cultivar	Harvest date ^z	Severity rating (0–6 scale)		Area covered (%)		Disease incidence (%)	
		2 wk ^y	4 wk ^x	2 wk ^w	4 wk ^v	2 wk ^u	4 wk ^t
Early maturing cultivars							
2005							
NuMex Camino	22 May	0.95	1.40	14.75	35.31	50.00	84.97
NuMex Chaco	28 May	0.60	0.95	8.26	18.24	36.25	61.65
NuMex Crispy	1 June	0.25	0.52	4.02	15.53	17.64	39.92
NuMex Mesa	27 May	0.35	0.73	4.56	17.61	25.00	45.81
NuMex Sweetpak	25 May	0.64	1.19	9.50	26.20	45.00	75.32
Texas Early White	5 June	0.07	0.39	1.13	8.29	14.26	19.71
LSD (5%) ^s	4 d ^{***}	0.14 ^{***}	0.21 ^{***}	3.21 ^{***}	5.69 ^{***}	NS	25.98 ^{**}
2006							
NuMex Camino	11 May	0.23	0.56	2.63	9.81	20.00	90.00
NuMex Chaco	19 May	0.44	0.41	5.06	4.94	41.25	63.75
NuMex Crispy	29 May	0.24	0.70	4.19	12.94	21.25	52.50
NuMex Mesa	18 May	0.16	0.43	2.25	7.44	16.25	58.75
NuMex Sweetpak	14 May	0.43	0.74	5.95	13.00	42.50	91.25
Texas Early White	21 May	0.21	0.40	2.63	8.50	21.25	56.25
LSD (5%)	4 d ^{***}	0.11 ^{***}	0.14 ^{***}	1.70 ^{***}	2.99 ^{***}	NS	20.08 ^{**}
Intermediate-maturing cultivars							
2005							
NuMex Dulce	1 June	0.19	0.50	2.25	8.32	16.25	33.82
NuMex Starlite	2 June	0.11	0.57	1.88	12.61	11.25	50.66
NuMex Vado	2 June	0.18	0.46	2.94	11.77	17.50	35.36
LSD (5%)	NS	0.05 ^{**}	NS	NS	2.78 ^{**}	NS	NS
2006							
NuMex Dulce	26 May	0.46	0.63	4.56	9.31	41.25	63.75
NuMex Starlite	24 May	0.27	0.57	4.55	9.77	26.25	61.25
NuMex Vado	25 May	0.25	0.39	3.25	7.81	26.25	56.25
LSD (5%)	NS	0.09 ^{***}	0.13 [*]	1.05 [*]	NS	NS	NS
Late-maturing cultivars							
2005							
NuMex Freedom	15 June	0.36	0.83	8.81	22.13	31.25	56.25
NuMex Luna	13 June	0.34	0.69	6.13	18.13	33.75	53.75
NuMex Solano	12 June	0.53	0.89	14.25	29.00	46.25	55.00
LSD (5%)	NS	0.08 ^{***}	0.14 [*]	2.48 ^{***}	4.87 ^{***}	NS	NS
2006							
NuMex Freedom	13 June	0.20	0.60	1.50	12.50	20.00	66.25
NuMex Luna	12 June	0.18	0.43	1.48	5.97	17.18	49.38
NuMex Solano	8 June	0.25	0.70	4.00	19.19	25.00	53.75
LSD (5%)	NS	0.05 [*]	0.16 ^{**}	0.77 ^{***}	4.39 ^{***}	NS	NS

^zOnions were harvested at 80% tops down.

^ySeverity was rated after 2 weeks of harvest on 0–6 scale on the area covered with disease and bulb softness (Kamal, 2007).

^xSeverity was rated after 4 weeks of harvest on 0–6 scale on the area covered with disease and bulb softness (Kamal, 2007).

^wPercent area covered by black mold was estimated in storage at 2 weeks after harvesting without removing dry outer scales.

^vPercent area covered by black mold was estimated in storage at 4 weeks after harvesting after removing dry outer scales.

^uPercent disease incidence was calculated by dividing number of diseased bulbs by total number of bulbs at 2 weeks after harvesting without removing dry outer scales.

^tPercent disease incidence was calculated by dividing number of diseased bulbs by total number of bulbs at 4 weeks after harvesting after removing dry outer scales.

^sFisher's least significant difference test.

NS, *, **, ***Nonsignificant F test, significant F test at $P = 0.05$, $P = 0.01$, and $P = 0.001$, respectively.

bulbs could be attributed to several factors. Dry matter content of the bulbs could be influencing disease development. Bulbs of 'Texas Early White' tended to have a higher dry matter content (10.7%) than bulbs of the yellow cultivars with a dry matter

content of 8.1% to 8.5% (Kamal, 2007). Ko et al. (2002a, 2002b) and Ardizzi et al. (2008) reported that bulbs with a higher dry matter content showed lower disease incidence than bulbs with a lower dry matter content. Color of the dry outer skin

could also be influencing disease development. 'Texas Early White' produces bulbs with white skins while four out of the five remaining cultivars produce bulbs with yellow skins. Sumner (1995) and Ardizzi et al. (2008) reported that of the different

scale colors of onions, white-scaled onions exhibited the least amount of disease incidence.

The three intermediate-maturing cultivars matured at a similar time in each year with maturity dates in 2006 slightly earlier than those in 2005 (Table 1). In 2005, bulbs of 'NuMex Starlite' exhibited less severe disease symptoms after 2 weeks of storage than bulbs of the other two cultivars (Table 1). By 4 weeks, disease severity was similar among all three cultivars. In 2006, bulbs of 'NuMex Starlite' and 'NuMex Vado' exhibited less severe symptoms at 2 weeks than bulbs of 'NuMex Dulce' (Table 1). By 4 weeks, disease severity increased on bulbs of 'NuMex Starlite' such that severity was similar to that observed on bulbs of 'NuMex Dulce'. After 2 weeks of storage, disease severity was generally lower in 2005 than in 2006; however, by 4 weeks, severity was similar between the years. A similar result occurred for area covered by the disease. After 2 weeks, area covered by the disease was lower in 2005 than in 2006 (Table 1). By 4 weeks, the area covered was similar in both years. In 2005, there were no differences among cultivars in the area covered by the disease after 2 weeks of storage (Table 1). By 4 weeks, the disease had spread in its coverage and bulbs of 'NuMex Dulce' had less area covered by the disease than bulbs of the other two cultivars (Table 1). A different result occurred in 2006. After 2 weeks of storage, bulbs of 'NuMex Vado' had less area covered by disease than bulbs of the other two cultivars (Table 1). By 4 weeks, there was no difference in area covered by disease on bulbs of the three cultivars. Even though there were differences among cultivars in disease severity and area covered by disease, cultivars were similar in number of bulbs exhibiting disease symptoms after 2 and 4 weeks of storage (Table 1). At both measuring times, disease incidence was greater in 2006 than in 2005.

For late-maturing cultivars, all three cultivars had similar maturity dates in both years (Table 1). Bulbs of 'NuMex Solano' exhibited a greater disease severity after 2 weeks of storage than bulbs of the other two cultivars in both years (Table 1). By 4 weeks, disease symptoms increased for all cultivars such that bulbs of 'NuMex Freedom' were similar to bulbs of

'NuMex Solano' in symptom severity (Table 1). In both years, bulbs of 'NuMex Luna' exhibited less severe symptoms after 4 weeks than bulbs of the other two cultivars. For both years, bulbs of 'NuMex Solano' had more tissue colonized by disease after 2 and 4 weeks of storage than bulbs of the other cultivars (Table 1). In 2006, bulbs of 'NuMex Luna' had less area covered by disease after 4 weeks than bulbs of the other two cultivars. For all cultivars, area covered by disease at 2 and 4 weeks was greater in 2005 than in 2006. As with intermediate-maturing cultivars, there were no differences in disease incidence at 2 and 4 weeks among cultivars tested in either year (Table 1). After 2 weeks of storage, disease incidence was greater in 2005 than in 2006, but by 4 weeks, yearly differences did not exist.

In each of the maturity groups of cultivars tested, disease severity, area on the bulb covered by disease, and number of bulbs exhibiting disease symptoms increased as bulbs were stored for longer periods of time. In New Mexico, it is unlikely that onion bulbs would be stored for 4 weeks after harvest before being sold and shipped as bulbs are usually shipped within a week of harvest (Corgan et al., 2000). However, in other onion producing states, onion bulbs may be stored for 3–6 months before shipment. In these areas, black mold could become a problem in storage given conducive environmental conditions. If onion germplasm screened for black mold resistance is destined for these areas, longer storage times in the evaluation process may be warranted. Even with high levels of disease incidence observed, some bulbs of each cultivar tested did not develop black mold symptoms. Sources of black mold resistance may be present in some germplasm and resistant cultivars could be developed from this material. Ko et al. (2002a) observed variation among short-day cultivars suggesting that resistance may be present. For bulbs that became infected with disease, rate of disease development and spread of disease throughout the bulb varied between cultivars. There could be genetic differences among cultivars with respect to black mold disease development, and these differences could be used in development of resistant cultivars.

Another observation made from this study is the yearly variation of disease expression with respect to evaluation of bulbs for selection. If evaluation of naturally infected mature bulbs stored under ambient conditions is desired in development of resistant cultivars, then several steps must be undertaken to ensure efficiency in the selection process. In field and storage evaluations, a cultivar that is highly susceptible to black mold should be included in the evaluation to ascertain ideal evaluation conditions and to observe yearly variations in disease development. Bulb selections for resistance should be made in years of high disease pressure as observed through disease expression in the highly susceptible control. Evaluations to measure selection progress should be conducted over multiple years as yearly variation in disease development can occur.

'Texas Early White' was the most promising cultivar in terms of resistance based upon disease incidence, disease severity, disease development, and rate of disease development. Breeding efforts to develop short-day, black-mold-resistant cultivars should start with this cultivar. Initially, black mold resistance breeding may strive to reduce the number of bulbs that develop disease, but also reduce severity and delay disease development for bulbs that do develop disease. Screening methods that may include artificial inoculation of whole bulbs should be developed before proceeding with breeding efforts. In addition, controlled atmosphere conditions of consistent temperature and humidity would be helpful when examining the rate of disease development. The dry outer scale tissue should remain on harvested, matured inoculated bulbs throughout the evaluation process. Onion germplasm should be grown in fields without prior history of onion cultivation so as not to introduce additional *A. niger* inoculum.

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