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Blue Mold (*Penicillium expansum*) Decay Resistance in Apple Cultivars, and Its Association with Fruit Physicochemical Traits

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ABSTRACT

Relative resistance of 43 Iranian as well as introduced apple cultivars to blue mold (*Penicillium expansum*) was studied within years 2010-2011. The fruit physicochemical traits were also evaluated as measures of potential resistance to decay. Local *P. expansum* strains were isolated from decayed apple fruits and the most aggressive isolate (5,000 spores ml^{-1}) used as inoculum. Fruits were wound-inoculated, and after four months stored in cold storage, decay lesion diameter was recorded. Force to break epidermis, cortex firmness, Total Soluble Solids (TSS) and Titratable Acidity (TA) were determined and their correlation with decay severity detected. Based on the obtained, results significant differences were observed in decay diameters in cultivars and for both years of the study priod. Mashhad was rated as the most susceptible cultivar while Granny Smith as the most resistant one. Relatively, 11.3% of cultivars were rated as susceptible, 54.5% as moderately susceptible, 31.8% as moderately resistant, and finally 2.2% resistant. The cultivars were significantly different in all the physicochemical traits studied. Correlation studies indicated weak negative correlations between decay diameter and TSS, TA, cortex firmness as well as epidermal toughness. Cortex firmness was directly correlated with epidermal toughness and is probable to influence blue mold severity.

Keywords: Apple, Blue mold, *Penicillium expansum*, Physicochemical traits.

INTRODUCTION

Postharvest diseases affect a wide variety of crops particularly in developing countries where sophisticated postharvest storage facilities are lacking (Jeffries and Jeger, 1990). Losses in postharvest can be remarkably high and their economic damage proportionately greater than field losses. Some reported figures for disease losses show that approximately 10-30% of harvested fresh horticultural crops are lost to postharvest spoilage in developed countries, whereas losses being even greater, amounting to more than 10-50% in developing countries where sanitation and refrigeration are either lacking or minimal (Eckert and Ogawa, 1985). More than 90 fungal species have been described as causative agents of apple decay during storage (Jones and Aldwinckle, 1990). Blue mold decay caused by *Penicillium expansum* Link. is the most important postharvest disease of apple worldwide (Pierson *et al*., 1971). *P. expansum* has been demonstrated to produce Patulin, a mutagenic, immunoitoxic and neurotoxic mycotoxin, particularly unacceptable to apple juice industry (Bracket and Marth, 1979).

Control of postharvest pathogens relies mainly on the use of synthetic fungicides, but the development of fungicide-resistant pathogens and the public demand to reduce

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pesticide use (Janisiewicz *et al*., 1994; Wilson *et al*., 1993) have already either completely banned or severely restricted postharvest applications of fungicides in many countries (Gullino and Kuijpers, 1994). Various alternatives to synthetic fungicides have been developed during the past decade for protecting pome fruits against postharvest decays, including biological control, sanitation, various physical treatments (heat, ultraviolet), or the use of substances Generally Recognized As Safe (GRAS) (Janisiewicz and Korsten, 2002; Lurie, 1998; Watkins *et al*., 2004; Wilson and Wisniewskim, 1994). Breeding for disease resistance has always been considered an important part of integrated pest management programs, but the focus has been on field production with little attention having been devoted to postharvest disease resistance and to associated decays (Janick *et al*., 1996). Even a slight improvement in fruit resistance to decay could increase the effectiveness of these alternatives resulting in an additive or even synergistic effect. The few reports on the variability of resistance in apple cultivars to postharvest decays indicate some differences in relative susceptibility levels (Cappellini *et al*., 1987; Janisiewicz and Peterson, 2004; Spotts *et al*., 1999; Janisiewicz *et al*., 2008). In a limited number of studies, relatively weak correlations have been established between decay resistance and fruit physicochemical traits (Spotts *et al*., 1999; Janisiewicz *et al*., 2008; Michailides *et al*., 1994; Miller, 1959).

Apple germplasm in Iran benefits from a great diversity of fruits with respect to a range of forms, colors, and taste and could serve as a broad genetic pool of important horticultural traits in breeding programs. The objectives followed in the present study were to evaluate the level of resistance to blue mold decay in several Iranian and introduced apple cultivars when wound-inoculated and as well: (i) force required to break the epidermis, (ii) fruit firmness and (iii) the fruit sugar and acid contents, as measures of potential decay resistance.

MATERIALS AND METHODS

P. expansum Strains

In year 2009, local fruit markets and cold storages in Karaj were surveyed for decayed apple fruits with those showing blue mold symptoms collected. Some *Penicillium* sp. strains were isolated from healthy and whole some margins fruit of the decayed areas and purified on water-agar medium. All the isolates were maintained on acidified Potato Dextrose Agar plates and slants (PDA) (1.5 ml per liter lactic acid) at 25ºC. *P. expansum* was identified using keys presented by Pitt and Hocking (1997). Growth on Czapek Yeast extract Agar (CYA) and Malt Extract Agar (MEA) was examined after 7 days from growth at 25ºC. Production of basic metabolites after acid production from creatine was examined in Creatine Sucrose Agar (CSN) after 10-20 days PAST. Nitrate and nitrite assimilations were assayed in 25% glycerol nitrate agar (G25N) medium after 7 days past. Growth on water agar was evaluated as a negative control.

Patogenicity and Aggressiveness

Pathogenicity of *P. expansum* strains was determined through wound-inoculating apple *cv*. Red Delicious. Spore suspension was prepared from 7-day-old cultures using sterile distilled water containing 0.005% Tween-80, vortexed for 1 minute to break spore chains. Spore concentration was determined employing a haemocytometer and adjusted to obtain 5000 spores per ml. Mature fruits were surface disinfected with 70% ethanol, then rinsed twice with sterile distilled water. Each and every fruit was wounded with a metal device (3 mm in diameter, 3 mm depth) at two opposite locations at the equatorial region. The pores were filled with 25 µl inoculum and placed in separate polyethylene bags. Lesion appearance was recorded in inoculated fruits and as well in control fruits inoculated with

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sterilized distilled water after 15 days past from incubation at 25°C. Aggressiveness of strains was determined through a comparison of lesion diameters 15 days after inoculation utilizing the procedure described. Three repetitions per isolate were carried out.

Apple Cultivars

Forty three apple cultivars (25 local *vs.* 18 introduced) with different ripening habits were studied (Table 1). Fruits were harvested at Apple Collection Orchard of Seed and Plant Improvement Institute at their commercial maturity dates and for each cultivar, during the apple harvesting seasons of years 2010 and 2011. The harvested fruits were left for one overnight period at room temperature, and then transferred to cold room storage at 1°C and 80% of RH until decay resistance assay.

Table 1. List of apple cultivars by their ripening habits.

Early-ripening	Late-ripening
Local	Local
Soltani Shabestar	IRI4
Heydarzade	IRI5
Ardebil1	Dirras Mashhad
Assali	Korsijan
Sheikh Ahmad	Golden Karaj
Mashhad Noori	IRI8
Mashhad	Narsib Mashhad
Ahar1	Akhlemad Mashhad
Sharbati	Introduced
Golbahar	Golden Spur
	Spart
Introduced	Granny Smith
Johnathan1	Golden Holland
	Fuji
Middle-ripening	Red Spur
Local	Ganny Beauty
IRI7	Wealthy
Paeize Mashhad	Red Rome Beauty
IRI6	Golden Delicious
Ardebil2	Geane Hardy
Shafiee	Gluckenapfel
Ghermez Rezaie	Starkan Roge
	Red Delicious
Introduced	Golden Smoothee
Stayman	Red Chief
	Cavil Blank
	Yellow Spur

Decay Resistance

For decay resistance evaluation, early-ripening (1-18 June), middle-ripening (24 June-30 August), and late-ripening (2 September-5 October) fruits were bulked separately and in each bulk, fruits were kept in cold storage until all the cultivars belonging to that group were harvested. The inoculum was prepared from a 7-day-old culture of P2 isolate and its concentration adjusted to 5,000 spores ml^{-1}. The inoculum was then divided into small portions and stored at -80°C until it was needed. Prior to inoculation, fruits were placed overnight at room temperature. Each apple was wound-inoculated and incubated in a cold room with the decay diameter being recorded after four months post. The experiment was conducted in a completely randomized design of 3 replicates and a number of 5 fruits per experimental unit. Control fruits were inoculated with sterilized distilled water.

Assessment of Physicochemical Traits

Quality traits including Total Soluble Solids (TSS) content and Titratable Acidity (TA) were determined in fruit juice extracts in year 2011. Total soluble solids content of juice samples was evaluated using a digital, temperature-compensated refractometer (Shouchit Tangliang JI) at 20ºC and while TA, expressed as Malic acid (Watkins, 2003), determined by titrating 10 ml of juice samples (diluted 10 times) with 0.1M NaOH after adding phenolphthalein. Force required to break the epidermis was found out through an electronic penetrometer (Hounsfield-H5KS) using a 8-mm-diameter flat-headed cylinder probe in 100 mm min^{-1} speed and 9 mm of penetration depth. Fruit cortex firmness was determined making use of a hand penetrometer (ATAGO) with an 11-mm diameter probe following peel removal the experiment was conducted in a completely randomized design of five replicates.

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Statistical Analysis

The data were analyzed through one-way Analysis Of Variance (ANOVA). Mean separations were performed through Duncan's Multiple Range Test making use of SAS software. Differences at $P \leq 0.01$ were considered as significant. The clustering of genotypes was performed using an Unweighted Pair Group Method Analysis (UPGMA) cluster analysis and computed through SPSS software.

RESULTS AND DISCUSSION

P. expansum Strains

In total, eight *P. expansum* strains were isolated from decayed fruits. After seven days past of growth at 25°C in CYA medium, *P. expansum* strains produced green-blue spores and agar underneath colony turning red-brown in color. The colors of MEA and GSN media turned yellow-orange and yellow, respectively. In $G_{25}N$, dark yellow-colored mycelia were produced. All the strains were capable of causing blue mold on Red Delicious fruit but the lesion diameters were significantly different (varying from 4.02 to 2.6 cm). Based on the lesion diameter, P2 was identified as the most aggressive strain and used for decay resistance assay.

Decay Resistance

The study as previously stated, was designed to compare decay resistance of local *vs.* introduced apple cultivars. Analysis of variance of decay lesion diameter showed significant differences between and within cultivars. For both of the experimental years Mashhad was rated as the most susceptible while Granny Smith as the most resistant cultivar (Table 2, Figure 1). Depending on year, mean lesion extent values for Mashhad *vs*. Granny Smith were respectively recoeded 4.44 *vs.* 1.96 in the first experimental year and while 4.3 *vs.* 1.04 for the second year. Although the most susceptible and resistant cultivars came out to be the same in either

Table 2. Mean lesion diameter (cm) produced in different apple cultivars in years 2010 and 2011.[a]

Cultivar	2010	2011
Masshad	4.44a	4.3a
Spart	ND	4.2ab
Red Spur	3.88c	3.88abc
Masshad Noori	2.9ij	3.79bcd
Ardebil2	ND	3.72bcde
Assali	3.48def	3.39cdef
Sharbati	3.43efgh	3.36defg
Khorsijan	3.3efgh	ND
Golbahar	ND	3.35defg
Golden Karaj	ND	3.32defgh
Golden Delicious	4.28ab	3.29defghi
IRI8	ND	3.2efghij
Soltani Shabestar	3.52de	3.17fghij
Golab Kohanz	3.02hij	3.15fghijk
Heydarzade	3.11ghij	3.06fghijkl
IRI7	ND	3.02fghikkl
Johnathan1	ND	3.01fghijkl
Paize Mashhad	ND	3.00fghijkl
Yellow Spur	ND	2.99fghijkl
Dirras Masshad	4.03bc	2.99fghijkl
Ardebil 1	ND	2.90fghijklm
IRI4	ND	2.86fghijklm
Sheikh Ahmad	4.06bc	2.85fghijklm
Narsib Masshad	3.17fghi	2.8ghijklm
Shafiee	3.13fghij	ND
Ganny Beauty	ND	2.79ghijklm
Golden Spur	2.79ij	2.75hijklm
Ahar1	ND	2.72ijklm
Fuji	3.5de	2.71ijklm
Ghermez Rezaie	3.79cd	2.70jklmn
Stayman	ND	2.60klmno
IRI5	ND	2.55lmnop
Red chief	ND	2.51lmnopq
Golden Holland	ND	2.50lmnopq
Cavil Blank	ND	2.37mnopq
Gluckenapfel	ND	2.22nopqr
IRI6	ND	2.10nopqr
Starkan Roge	ND	2.16opqr
Akhlemad Mashhad	3.44efg	2.13opqr
Red Rome Beauty	ND	2.13opqr
Red Delicious	ND	2.05pqr
Wealthy	ND	1.98qr
Golden Smoothee	ND	1.78r
Geane Hardy	ND	1.74r
Granny Smith	1.96l	1.04s

[a] Values followed by the same letter within columns are not significantly different ($P \leq 0.01$), ND= Not Determined.

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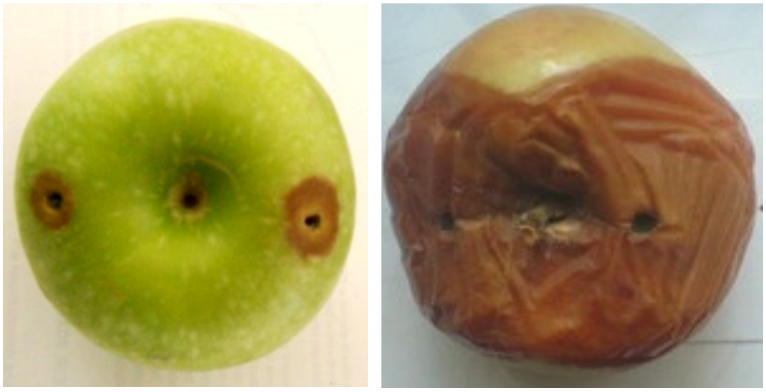

Figure 1. Lesions produced in cold storage in apple cv. Granny Smith (left) *vs.* Mashhad (right) four months past of inoculation.

year, differences between the years were varied. Similar variations for different years have also been reported by Spotts *et al.* (1999) and could be attributed to many such uncontrolled factors as different climates and harvest maturity standards pertaining to each year (Valiuŝkaité *et al*., 2006; Torres *et al*., 2003). A comparison of blue mold resistance in Fuji, Granny Smith and Golden Delicious by Spotts *et al*. (1999) indicated that Fuji and Golden Delicious were moderately susceptible while Granny Smith moderately resistant in line with the present study's results. In another study, 83 accessions of Kazak origin showed differences in decay resistance (Janisiewicz *et al.,* 2008), but none of the accessions in that study have been included herein. Many biochemical factors influence resistance of apple cortical tissue to decay, including glycoprotein endopolygalacturonase inhibitors (Brown, 1984), benzoic acid (Seng *et al*., 1985), H_2O_2 and its associated metabolism (Torres *et al*., 2003) as well as peroxidase activity, especially through its action on lignification (Valentines *et al*., 2005).

Based upon lesion diameter, the cultivars were grouped in four relative susceptibility clusters (Figure 2) including susceptible (11.63%), moderately susceptible (53.49%), moderately resistant (32.56%) and the only resistant cultivar being Granny Smith (2.33%). This cultivar has been rated as moderately resistant by Spotts *et al.* (1999) indicating a low relative resistance among the local cultivars and in comparison with commercial cultivars studied therein. In Kazak collection, 5% of the accessions were rated as resistant, 64% intermediate while 29% susceptible. Our intermediate group (moderately resistant+moderately susceptible) accounted for 76% of the cultivars indicating that in either one of Iranian or Kazak collections, most cultivars show intermediate levels of resistance. In Kazak collection, 2 cultivars did not produce any lesion, being rated as immune but there did not exist any record of immune cultivars in our collection.

Fruit Physicochemical Traits

The values of quality indices (TSS and TA) were different among cultivars (Table 3). TSS ranged from 10.5 to 19.0 percent in Iranian cultivars and from 11.5 to 18.0 percent in the introduced cultivars indicating that the TSS range for local cultivars was essentially close to that for the introduced apples. In a number of studies, relatively weak correlations have been found out between decay resistance *vs.* fruit physicochemical traits (Spotts *et al*., 1999; Janisiewicz *et al*., 2008; Michailides *et al*., 1994; Miller, 1959). Janisiewicz *et al.* (2008) found TSS ranging from 9.0 to 20.4 in Kazak apple collection. TA ranged from 0.07 to 1.7 and exhibited similar ranges in both Iranian and introduced cultivars. This range was narrower than that of Kazak

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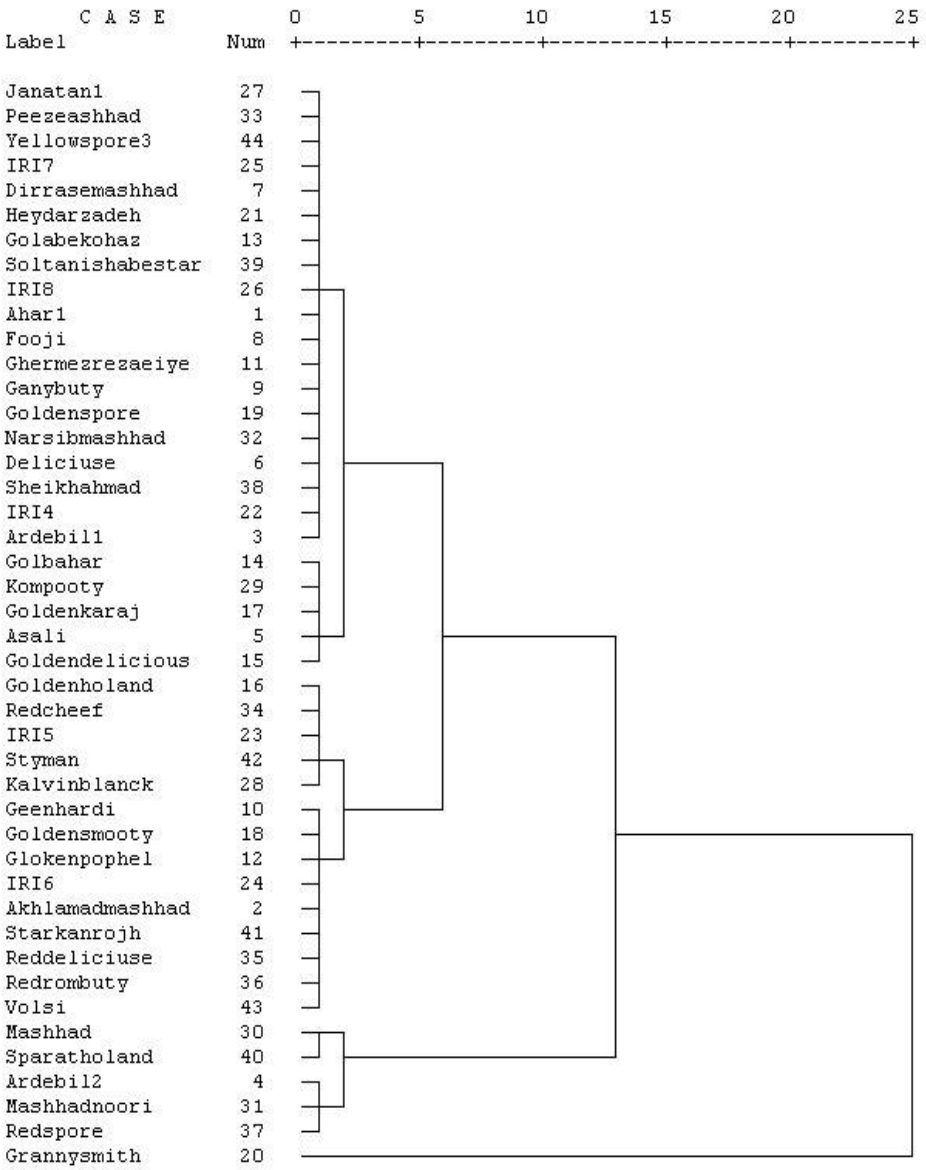

Figure 2. Unweighted Pair-Group Method Analysis (UPGMA) dendrogram for the 43 apple genotypes evaluated in the study for their clustering based upon lesion diameter.

collection which was 0.2 to 2.4 with some accessions bearing up to twice the acidity of the acidic cultivated varieties (e.g., 'Granny Smith', 'Gold-Rush') (Corrigan *et al*., 1997; Lau, 1985, Miller *et al*., 2004). High-acid containing apples may not be acceptable in the marketplace unless suitably balanced with a high TSS content (Janisiewicz *et al.*, 2008).

The force required to break epidermis was also different ranging from 73.17 to 11.17 Newton and was distributed evenly among Iranian *vs.* commercial cultivars. The forces of 38.95, 58.25 and 67.47 Newton were required to break the epidermal layers in Golden Delicious, Granny Smith and Fuji, respectively. Spotts *et al*. (1999) reported that among some 12 cultivars studied, the epidermis of Golden Delicious was more easily broken than those in other cultivars with a mean force of 51.4 Newton being required to break the epidermis of this

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Table 3. Physicochemical traits evaluated for susceptibility to blue mold.[a]

Cultivar	Total soluble solids (%)	Titratable acidity (%)	Force to break epidermis (N)	Cortex firmness (N)
Paize Mashhad	19.00	0.31jkl	38.4fghijkl	3.37jkl
Red Delicious	18.00ab	0.34ijk	36.42fghijklm	4.95bcdefgh
Wealthy	18.00ab	0.88e	12.73no	6.4abc
Golden Delicious	17.00bc	0.74f	38.95efghijk	4.79cdefgh
Granny Smith	17.00bc	0.97kl	58.25abcd	5.08abcdef
Narsib Masshad	16.5c	0.5h	30.28ghijklmn	3.93efghijkl
Golden Holland	16.5c	0.67fg	51.27bcdef	4.00defghijkl
Red Rome Beauty	16.0cd	0.7g	62.98abc	4.83bcdefgh
IRI4	16.0cd	0.37ij	56.5abcde	6.13ab
Heydarzade	16.0cd	0.69fg	47.2cdefg	3.69ghijkl
Cavil Blank	16.0cd	1.7a	59.52abcd	4.87bcdefgh
Golab Kohanz	15.0cd	0.25l	13.58no	3.29klm
Ardebil1	15.0cd	0.07m	25.08hijklmno	4.83bcdefgh
Ganny Beauty	15.0de	1.02d	50.55bcdef	3.4ijkl
Yellow Spur	15.0de	0.5h	50.55bcdef	3.4ijkl
Starkan Roge	15.0de	1.4b	48.57cdef	4.53defghijk
Spart	15.0de	0.51h	42.42defghi	4.62defghij
Assali	14.5de	0.37ij	33.27fghijklmn	4.25defghijkl
Golden Karaj	14.0ef	0.51h	47.15cdefg	5.29abcd
Golden Spur	14.0ef	0.51h	51.47bcdef	3.12lm
Sheikh Ahmad	14.0efg	0.31jkl	45.38cdefgh	3.9efghijkl
Mashhad Noori	14.0efg	0.27kl	17.24mno	3.8fghijkl
Arbebil2	14.0efg	0.67fg	47.73cdefg	6.29a
IRI6	14.0efg	0.7g	36.92fghijkl	4.25defghijkl
Styman	14.0efg	0.69fg	44.35cdefgh	3.98defghijkl
Geane Hardy	14.0efg	1.7a	46.53cdefg	4.83bcdefgh
Gluckenapfel	14.0efg	0.07m	51.79bcdef	4.53defghijk
Fuji	14.0efg	1.2c	67.47ab	5.04abcdefg
Red Spur	14.0efg	0.1m	52.25bcdef	4.98bcdefg
Dirres Mashhad	13.5fgh	0.37hj	73.17a	5.00abcdefg
Solatni Shabestar	13.5fgh	0.24l	11.17o	3.62hijkl
IRI7	13.5fgh	0.24l	23.32jklmno	3.08lm
Golden Smoothee	13.0ghi	1.02d	41.4defghij	5.08abcde
IRI5	13.0ghi	1.7a	45.35cdefgh	4.62defghij
IRI8	13.0ghi	0.7g	21.97klmno	4.53defghijk
Golbahar	13.0ghi	0.27kl	21.18klmno	3.08lm
Sharbati	12.5hij	0.37jkl	20.15mno	2.13m
Red Chief	12.5hij	0.31jkl	34.77fghijklmn	4.36defghijkl
Akhlemad	12.0ijk	0.88e	57.1abcde	5.2abcde
Johnathan1	11.5jkl	1.3c	37.1fghijkl	4.91bcdefgh
Ghermez Rezaie	11.0kl	1.7a	13.47no	4.7defghi
Ahar1	10.5l	0.4i	44.23cdefgh	5.04abcdefg
Mashhad	10.5l	0.3jkl	26.88hijklmno	3.08lm

[a] Values followed by the same letter within columns are not significantly different ($P \leq 0.01$).

cultivar. They reported that the epidermal tissues of Fuji and Granny Smith were more resistant to puncture, requiring averages of 81.5 and 87.0 Newton, respectively. The force required to break epidermis of these three cultivars are recorded as lower in the present study than those reported by Spotts *et al*. (1999), but Granny Smith and Fuji were similarly found being more resistant to puncture than Golden Delicious. Because

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most decay pathogens penetrate through wounds, resistance of the epidermis to breakage may be an important factor in resistance of apple cultivars to decay. The toughness of the epidermis of Fuji and Granny Smith should reduce the probability of puncture wounds, resulting in less decay than in cultivars with more easily broken epidermal layers (Spotts *et al*., 1999). Such crops as apples and pears with well-developed cuticle and epidermis, tolerate lower Relative Humidity (RH) levels that help prevent storage decay (Spotts and Peters, 1981). Cortex firmness was also different among cultivars ranging from 2.13 to 6.29 Newton and distributed evenly among Iranian and introduced cultivars.

Correlation studies on second year data indicated weak negative correlations between decay diameter and the values of TSS and TA (r= -0.24 and -0.35, respectively) (Table 4). TSS was weakly correlated with decay severity as reported by Janisiewicz *et al.* (2008) who concluded that high sugar content might contribute to the susceptibility of fruit to decay. But the present study's results revealed a weak negative correlation between decay diameter and TSS. Similar to the present results, Janisiewicz *et al.* (2008) found TA negatively correlated with decay severity indicating that the more acidic the fruit, the more resistant to decay. Because TA generally decreases in time with apple maturation and ripening (Baile and Young, 1981), the negative correlations between TA and decay support the general observation that less mature apples are more resistant to decay (Janisiewicz *et al.*, 2008).

Weak negative correlations were also observed between decay diameter and cortex firmness and as well epidermal toughness (r= -0.26) (Table 4), cortex firmness being positively correlated with epidermal toughness (r= 0.29). Spotts *et al.* (1999) did not find any significant correlations between decay severity and epidermal toughness but according to the present results, it is suggested that overall fruit toughness (cortex+epidermis) might slow down pathogen penetration and distribution and fruits with more dense and tough tissue might turn out to be more resistant to decay pathogens.

The study's results finally indicate a great diversity among Iranian apple cultivars in the context of resistance to blue mold decay which should serve as a potential source of genetic material in postharvest fruit resistance breeding programs. However, since there was not any strong correlation found between decay resistance and physicochemical traits, therefore they cannot be thought of as decay resistance measures. This research is ongoing to determine the biochemical mechanisms of resistance and to test additional local cultivars, not included in the current study.

Table 4. Pearson's correlation coefficients and probability level for data means of Iranian and introduced apple cultivars.[a]

	Cortex firmness	Force to break epidermis	TA	TSS
Decay diameter	-0.2607	-0.2639	-0.3519	-0.2418
	0.0028	0.0025	<0.0001	0.0058
Cortex firmness		0.2905	0.2760	0.1443
		0.0008	0.0015	0.1029
Force to break epidermis			0.1545	0.1012
			0.0803	0.2540
TA				0.1219
				0.1687

[a] TSS= Total Soluble Solids; TA= Titratable Acidity, For each characteristic: The upper value represents correlation coefficient and the lower, probability level.

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REFERENCES

1. Baile, J. B. and Young, R. E. 1981. Respiration and Ripening in Fruits-retrospect and Prospect. In: "*Recent Advances in the Biochemistry of Fruits and Vegetables*", (Eds): Friend, J. and Rhodes, M. J. C.. Academic Press, New York, PP.**275.**
2. Bracket. R. E. and Marth, E. H. 1979. Patulin in Apple Juice form Roadside Stands in Wisconsin. *J. Food Prot.,* **42:** 862-3.
3. Brown, A. E. 1984. Relatioship of Endopolygalacturonase Inhibitor to the Rate of Fungal Rot Development in Apple Fruits. *Phytopathol. Z.,* **111:** 122-132.
4. Cappellini, R. A., Ceponis, M. J. and Lightner, G. W. 1987. Disorders in Apple and Pear Shipments to the New York Market, 1972-1984. *Plant Dis.,* **71:** 852-856.
5. Corrigan, V. K., Hurst, P. L. and Boulton, G. B. 1997. Sensory Characteristics and Consumer Evaluations of 'Pink Lady' and Other Late-season Apples. *N. Z. J. Crop Hort. Sci.,* **25:** 375-383.
6. Gullino, M. L. and Kuijpers, L. A. M. 1994. Social and Political Implications of Managing Plant Diseases with Restricted Fungicides in Europe. *Ann. Rev. Phytopathol.,* **32:** 559-57
7. Janick, J., Cummins, J. N., Brown, S. K. and Hemmat, M. 1996. Apples. I. Tree and Tropical Fruits. In: "*Fruit Breeding*", (Eds.): Janick, J. and Moore, J. N.. John Wiley and Sons, New York, PP.632.
8. Janiisiewicz, W. J. and Peterson, D. L. 2004. Susceptibility of Stem Pull Area of Mechanically Harvested Apples to Blue Mold Decay and Its Control with Biocontrol Agent. *Plant Dis.,* **88:** 662-664.
9. Janiisiewicz, W. J., Saftner, R. A., Conway, W. S. and Forsline, P. L. 2008. Preliminary Evaluation of Apple Germplasm from Kazakhstan for Resistance to Postharvest Blue Mold in Fruit by *Penicilluim expansum*. *HortSci.,* **43:** 420-426.
10. Janisiewicz, W. J., Petterson, D. L. and Bors, R. 1994. Control of Storage Decay of Apples with *Sporobolomyces roseus*. *Plant Dis.,* **78:** 466-470.
11. Janisiewicz, W. J. and Korsten, L. 2002. Biological Control of Postharvest Diseases of Fruits. *Ann. Rev. Phytopathol.,* **40:** 411-441.
12. Jeffries, P. and Jeger, M. J. 1990. The Biological Control of Postharvest Diseases of Fruit. *Biocontrol News Info.,* **11:** 333-336.
13. Jones, A.L., and Aldwinckle, H.S. 1990. *Compendium of Apple and Pear Diseases*. American Phytopathological Society Press, St. Paul, MN, PP.100.
14. Eckert, J. W. and Ogawa, J. M. 1985. The Chemical Control of Postharvest Diseases: Subtropical and Tropical Fruits. *Ann. Rev. Phytopathol.,* **23:** 421-454.
15. Lau, O. L. 1985. Harvest Guide for BC Apples. *British Columbia Horticulturists,* **7:** 1A-20A.
16. Lurie, S. 1998. Postharvest Heat Treatments of Horticultural Crops. *Hort. Rev.,* **22:** 91-121.
17. Michailides, T. J., Morgan, D. P., Mitchum, E. and Crisosto, C. H. 1994. Occurrence of Moldy Core and Core Rot of Fungi Apple in California. *KAC Plant Prot. Quart.,* **3:** 5-7.
18. Miller, P. M. 1959. Open Calyx Tubes as a Factor Contributing to Carpel Discoloration and Decay of Apples. *Phytopathol.,* **49:** 520-523.
19. Miller, S., McNew, R., Belding, R., Berkett, L., Brown, S., Clements, J., Cline, J., Cowgill, W., Crassweller, R., Garcia, E., Greene, D., Greene, G., Hampson, C., Merwin, L., Moran, R., Roper, T., Schupp, J. and Stover, E.. 2004. Performance of Apple Cultivars in the 1995 NE-183 Regional Project Planting. II. Fruit Quality Characteristics. *J. Amer. Pomol. Soc.,* **58:** 65–77.
20. Pierson, C. F., Ceponis, M. J. and McColloch, L. P. 1971. *Market Diseases of Apples, Pears, and Quinces*. Agricultural Handbook, US Department of Agriculture, 376 PP.
21. Pitt, J. I. and Hocking, A. D. 1997. *Fungi and Food Spoilage*. 2nd Edition, Aspen Publications, 593 PP.
22. Seng, J. M., Saindrenan, P. and Bompeix, G. 1985. Indution of *Nectria galligena* Mutants Resistant to Benzoic Acid and Study of Their Aggressiveness towards Immature Apples. *J. Gen. Microbiol.,* **131:** 1863-1866.
23. Spotts, R. A. and Peters, B. B. 1981. The Effect of Relative Humidity on Spore Germination of Pear Decay Fungi and 'd'Anjou' Pear Decay. *Acta Hort.,* **124:** 75-78.
24. Spotts, R. A., Cervantes, L. A. and Mielke, E. A. 1999. Variability in Postharvest Decay

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among Apple Cultivars. *Plant Dis.,* **83:** 1051- 1054.
25. Torres, R., Valentines, M. C., Usall, J., Viňas, I. and Larrigaudiere, C. 2003. Possible Involvement of Hydrogen Peroxide in the Development of Resistance Mechanisms in 'Golden Delicious' Apple Fruit. *Postharvest Biol. Technol.,* **27:** 235-242.
26. Valentines, M. C., Vilaplana, R., Torres, R., Usall, J. and Larriagaudière, C. 2005. Specific Roles of Enzymatic Browning and Lignification in Apple Disease Resistance. *Postharvest Biol. Technol.,* 36: 227-234
27. Valiuŝkaité, A., Kvikliené, N., Kviklys, D. and Lanauskas, J. 2006. Post-harvest Rot Incidence Depending on Apple Maturity. *Agr. Res.,* **4(Special Issue):** 427-431.
28. Watkins, C. B., Kupferman, E. and Rosenberger, D. A. 2004. *Apple*. 10 December 2006. <http:// www. ba.ars. usda.gov/hb66/027apple.pdf/>.
29. Watkins, C. B. 2003. Principles and Practices of Postharvest Handling and Stress. In: "*Apples: Botany, Production and Uses",* (Eds.): Ferrec D. C. and Warrington, I. J.. CABI Publishing, PP.660.
30. Wilson, C. L. and Wisniewskim M. E. 1994. Biological Control of Postharvest Disease of Fruit and Vegetables: Theory and Practice. CRC Press, Boca Raton, FL, USA, PP.182.
31. Wilson, C.L., Wisniewski, M.E., Droby, S., Chalutz, E. 1993. A selection strategy for microbial antagonists to control postharvest diseases of fruits and vegetables. Sci. Hortic. 53:183-189.

مقاومت ارقام سیب به کپک آبی و ارتباط آن با خصوصیات فیزیکوشیمیایی میوه

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چکیده

در این تحقیق، مقاومت نسبی ۴۳ رقم ایرانی و خارجی سیب به کپک آبی (*Penicillium expansum*) در سال های ۱۳۸۹ و ۱۳۹۰ بررسی شد. پتانسیل خواص فیزیکوشیمیایی میوه به عنوان معیار تعیین مقاومت نسبی به کپک آبی نیز اندازه گیری شدند. سویه های بومی قارچ از میوه های پوسیده جداسازی شده و مهاجم ترین سویه با غلظت ۵۰۰۰ اسپور/میلی لیتر به عنوان مایه تلقیح به کار برده شد. میوه ها از طریق زخم تلقیح شدند و قطر زخم پس از ۴ ماه نگهداری در سردخانه اندازه گیری شد. ضخامت پوست، سفتی بافت، مواد جامد محلول و اسیدیته قابل تیتر اندازه گیری شدند و ارتباط آن ها با سطوح مقاومت بررسی شد. بر اساس نتایج، تفاوت آشکاری در مقاومت ارقام به کپک آبی مشاهده شد و در هر دو سال، مشهد حساس ترین و گرانی اسمیت مقاوم ترین بود. به طور نسبی، ۱۱/۳٪ ارقام حساس، ۵۴/۵٪ نسبتاً حساس، ۳۱/۸٪ نسبتاً مقاوم و ۲.۲٪ مقاوم رده بندی شدند. ارقام از نظر خصوصیات فیزیکوشیمیایی میوه نیز متفاوت بودند. مطالعه ارتباط صفات با هم نشان داد که رابطه معکوس ضعیفی بین قطر زخم و درصد مواد جامد محلول، اسیدیته قابل تیتر، ضخامت پوست و سفتی بافت وجود دارد. سفتی بافت به طور مستقیم با ضخامت پوست ارتباط داشت و ممکن است شدت آلودگی کپک آبی با آن ارتباط داشته باشد.

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