Evaluation of Disease Resistance among 57 Cultivars of Zinnia

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SUMMARY. Fifty-seven cultivars of zinnia (*Zinnia elegans* Jacq.) were studied for 17 weeks to determine their resistance to alternaria blight (*Alternaria zinniae* Pape), powdery mildew (*Erysiphe cichoracearum* DC ex Merat) and bacterial leaf & flower spot [*Xanthomonas campestris* pv. *zinniae* (syn. *X. nigromaculans* f. sp. *zinniae* Hopkins & Dowson)]. A disease severity scale was used to determine acceptability for landscape use. At week 4, all cultivars were acceptable. At week 10, eleven cultivars were acceptable. At week 17, all cultivars were unacceptable. Ten cultivars had been killed by one or more pathogens by week 17. Only two cultivars showed any tolerance to any disease (powdery mildew) at week 17.

Considerable economic loss can occur to growers and landscape contractors using zinnia because of the diseases alternaria blight, powdery mildew and bacterial

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leaf & flower spot. During warm, rainy or humid weather, these organisms spread rapidly through the crop, leaving plants unsightly and of little ornamental value (Spooner et al., 1991; Stimart et al., 1987; Terry-Lewandowski and Stimart, 1983). Disease problems are so prevalent that many greenhouse growers will not produce zinnias and landscape contractors no longer select them for landscape use in the southeastern U.S.

While the epidemiology of these three pathogens has been extensively studied, little research has been done to determine which cultivars of zinnia are less susceptible to these pathogens. The overall objective of this research was to determine whether cultivar selection can affect the development and suppression of three diseases: alternaria blight, powdery mildew, and bacterial leaf and flower spot on the bedding plant and cutflower, *Z. elegans*.

Materials and methods

Seed of 57 zinnia cultivars were obtained from various commercial seed suppliers in the spring of 1997. Seeds were sown on 3 and 5 June 1997 in flats (TLC Polyform, Plymouth, Minn.) in a commercial germination mix (Berger's BM2 Germination Mix, Que., Canada) and placed under intermittent mist on bench-bottom heat in the University of Tennessee research greenhouses. When seedlings had produced one set of true leaves (16 June), they were transplanted into 70 ml, 1803 cell-pack inserts (T.O. Plastics, Minneapolis, Minn.) containing a soilless growing medium (Pro-Mix BX, Premier Horticulture, Inc., Red Hill, Pa.) and grown, using standard commercial practices (Ball, 1991) until they had several sets of true leaves (30 June). Plants were pinched to two nodes and transplanted into field plots. The experimental plots were irrigated with sub-irrigation soaker hoses as needed. Based on soil test results, adequate nutrient levels were present in the field soil, and therefore no additional fertilizer was applied. Natural inoculum was relied upon to infect the plants with all three pathogens.

The cultivar trials were divided into three height categories: tall cutflower types [76 cm or taller (30 inches)], medium height [38 to 76 cm (15 to 30 inches)], and short bedding plant types (under 38 cm (15 inches)) (Table 1) and randomized within a complete block within their respective height categories. Four blocks, each containing three plants of all cultivars, were used for each cultivar.

All plants were planted on 30.5 cm (12 inches) centers with each replication being planted three plants in a row in the center of the 1.83 m (6 ft) wide beds.

Plants were evaluated at 4 (26 July), 10 (3 Sept.) and 17 weeks (22 Oct.) after transplanting into the field for incidence and severity of alternaria blight, powdery mildew and bacterial leaf and flower spot. Data were collected on the center plant; the two outer plants served as guard plants. The following disease severity rating scale was used to evaluate each disease: 0 = no disease apparent; 1 = <2% affected by disease; 2 = >2% and <10% affected by disease; 3 = >10% and <25% affected by disease; 4 = >25% and <50% affected by disease; 5 = >50% affected by disease; 6 = plant dead (killed by disease).

Data were analyzed using mixed model analysis of variance (SAS Institute, Cary, N.C.). The model tested the factorial effects of cultivar and had repeated measures over weeks. The statistical mean for the foliage damage rating for each cultivar was used to determine its resistance or susceptibility to each of the three pathogens. Cultivars having a disease severity rating of <2 (10% of plant foliage showing signs and/or symptoms of disease) were judged acceptable in a landscape situation while those having a disease severity rating >2 were judged unacceptable.

Results

Alternaria blight

WEEK 4. On 25 July, incidence of alternaria blight was significantly differ-

ent among cultivars and ranged from 0% to 83%. Severity ratings differed significantly among cultivars and ranged from 0 to 1.3. Incidence was significantly different among series and ranged from 24% to 83%. Severity ratings ranged from 0.2 to 1.0. Disease severity was not significantly different among series. All cultivars and all series were rated acceptable.

WEEK 10. On 3 Sept., plants of all 57 cultivars had alternaria blight, but incidence was not significantly different among cultivars. Disease severity, ranging from 0.3 to 3.3, varied significantly among cultivars (Table 2). Disease severity ratings for 43 cultivars were <2.0 (acceptable). Incidence was not significantly different among series. Disease severity ranged from 0.8 to 2.2 and varied significantly among series. All three cultivars in the Ruffles series had disease severity ratings <2.0, making the Ruffles series the best-performing series for tolerance to alternaria blight. Two series, Dasher and Peter Pan, were rated unacceptable.

WEEK 17. On 22 Oct., incidence of alternaria blight was not significantly different among cultivars nor among series. All plants exhibited severe disease damage. Disease severity ratings for cultivars ranged from 3.3 to 6.0. All plants of ten cultivars were dead, most likely killed by a combination of alternaria blight and bacterial leaf and flower spot. Statistically significant differences in severity of alternaria blight among cultivars and among series were evident; however, all cultivars and series were

Table 1. Height categories of zinnia series used in cultivar trial.

Series	Avg ht (cm) ^y	Ht category
Short Stuff series (6) ^z	23	Short
Thumbilina Mix	23	Short
Dreamland series (7)	27	Short
Dasher series (3)	28	Short
Peter Pan series (9)	28	Short
Pulcino Mix	34	Short
Small World series (2)	41	Medium
Liliput Mix	60	Medium
Pumila Mix	70	Medium
Splendor Pink	70	Medium
Sun series (2)	71	Medium
Ruffles series (3)	73	Medium
Sunbow Mix	73	Medium
State Fair Mix	84	Tall
Oklahoma series (5)	89	Tall
Dahlia Flowered Mix	107	Tall
Giant Dahlia Bluepoint series (12)	114	Tall

^zNumber in parentheses is the number of cultivars in the series.

^y2.54 cm = 1.0 inch.

Table 2. Disease severity ratings for alternaria blight, powdery mildew and bacterial leaf and flower spot at weeks 10 (3 Sept. 1997) and 17 (22 Oct. 1997).

Series name and cultivar	Disease severity rating ^z					
	Alternaria blight		Powdery mildew		Bacterial leaf and flower spot	
	Week 10	Week 17	Week 10	Week 17	Week 10	Week 17
Dasher series						
Orange	2.3 abcd ^y	4.5 abcd	0.0 b	3.3 a	2.5 a	4.5 ab
Scarlet	2.5 abcd	5.5 abc	0.0 b	4.0 a	3.0 a	5.0 ab
Pink	1.8 abcd	4.3 abcd	0.0 b	2.8 a	2.3 a	4.0 ab
Dreamland series						
Coral	2.0 abcd	5.8 ab	0.3 ab	5.2 a	2.3 a	5.8 ab
Ivory	1.8 abcd	6.0 a	0.0 b	--- ^x	2.0 a	6.0 a
Rose	2.0 abcd	6.0 a	0.0 b	---	2.3 a	6.0 a
Scarlet	2.0 abcd	5.0 abcd	0.0 b	4.4 a	2.0 a	4.8 ab
Pink	2.3 abcd	6.0 a	0.0 b	---	2.3 a	6.0 a
Red	2.5 abcd	6.0 a	0.0 b	---	2.5 a	6.0 a
Yellow	1.3 abcd	6.0 a	0.0 b	---	2.8 a	6.0 a
Giant Dahlia Bluepoint series						
Crimson Monarch	1.3 abcd	5.0 abcd	0.3 ab	4.3 a	2.8 a	4.5 ab
Dream	1.8 abcd	4.8 abcd	0.0 b	5.0 a	2.5 a	5.0 ab
Eldorado	2.0 abcd	5.5 abc	0.0 b	5.0 a	2.0 a	5.3 ab
Exquisite	1.8 abcd	4.5 abcd	0.3 ab	4.8 a	2.3 a	5.0 ab
Golden State	3.3 a	4.5 abcd	0.0 ab	5.0 a	3.5 a	5.0 ab
Hallo	1.3 abcd	4.5 abcd	0.0 b	4.3 a	3.0 a	4.3 ab
Polar Bear	1.0 abcd	4.3 abcd	0.3 ab	4.5 a	2.3 a	4.5 ab
Purple Prince	1.5 abcd	4.5 abcd	0.0 b	4.5 a	2.8 a	4.5 ab
Scarlet Flame	1.8 abcd	5.0 abcd	0.0 b	5.0 a	2.0 a	5.0 ab
Bright Pink	1.3 abcd	4.8 abcd	0.0 b	4.8 a	2.5 a	4.3 ab
Golden Dawn	0.8 bcd	4.8 abcd	0.5 ab	3.0 a	2.3 a	4.3 ab
Meteor	1.5 abcd	5.3 abc	0.0 b	5.1 a	2.5 a	5.3 ab
Oklahoma series						
Salmon	2.0 abcd	4.5 abcd	0.3 ab	4.5 a	2.0 a	4.5 ab
White	1.0 abcd	3.8 cd	0.0 b	4.3 a	2.3 a	3.8 ab
Golden Yellow	2.0 abcd	4.5 abcd	0.3 ab	4.8 a	2.3 a	4.3 ab
Pink	1.5 abcd	4.3 abcd	0.3 ab	4.5 a	2.5 a	4.5 ab
Scarlet	1.8 abcd	4.5 abcd	0.0 b	4.0 a	2.5 a	4.5 ab
Peter Pan series						
Cream	1.0 abcd	6.0 ab	0.0 b	---	3.3 a	6.0 a
Flame	2.3 abcd	6.0 a	0.0 b	---	2.5 a	6.0 a
Orange	2.5 abcd	5.0 abcd	0.5 ab	4.1 a	2.5 a	5.0 ab
Princess	2.8 abc	5.5 abc	0.0 b	3.1 a	3.0 a	4.8 ab
Scarlet	3.0 ab	5.3 abc	0.0 b	4.4 a	2.8 a	4.8 ab
White	1.3 abcd	5.3 abc	0.0 b	2.1 a	2.3 a	5.0 ab
Gold	1.3 abcd	6.0 a	1.5 a	---	2.5 a	6.0 a
Pink	2.5 abcd	5.5 abc	0.0 b	4.9 a	2.8 a	5.5 ab
Plum	2.5 abcd	6.0 a	0.0 b	---	2.5 a	6.0 a
Ruffles series						
Cherry	1.8 abcd	4.3 abcd	0.5 ab	4.3 a	2.8 a	5.3 ab
Pink	0.5 cd	3.3 d	0.3 ab	3.5 a	1.8 a	3.5 b
Yellow	0.3 d	4.3 abcd	0.5 ab	4.8 a	2.0 a	4.5 ab
Short Stuff series						
Coral	2.3 abcd	4.3 abcd	0.0 b	4.1 a	2.8 a	4.5 ab
Deep Red	1.5 abcd	5.5 abc	0.0 b	4.4 a	2.5 a	5.5 ab
Gold	1.3 abcd	6.0 a	0.0 b	---	2.8 a	6.0 a
Orange	1.8 abcd	5.3 abc	0.0 b	2.1 a	3.3 a	4.8 ab
Scarlet	2.0 abcd	5.5 abc	0.0 b	3.0 a	2.8 a	5.5 ab
White	1.0 abcd	5.7 abc	0.0 b	5.2 a	2.3 a	5.8 ab
Small World series						
Cherry	1.8 abcd	5.0 abcd	0.5 ab	4.0 a	2.3 a	5.0 ab
Pink	1.8 abcd	5.0 abcd	0.0 b	4.3 a	2.5 a	4.3 ab
Sun series						
Golden	1.5 abcd	5.3 abc	0.5 ab	5.0 a	2.3 a	5.3 ab
Red	1.5 abcd	5.5 abc	0.5 ab	5.0 a	2.3 a	5.5 ab
Miscellaneous cultivars						
Dahlia Flowered Mix	2.5 abcd	5.5 abc	0.5 ab	5.0 a	2.5 a	5.5 ab
Liliput Mix	0.8 bcd	4.8 abcd	0.8 ab	4.7 a	2.0 a	4.8 ab
Pulcino Mix	1.8 abcd	4.8 abcd	0.0 b	3.8 a	3.0 a	3.5 b
Pumila Mix	2.0 abcd	4.8 abcd	0.3 ab	4.3 a	2.0 a	3.8 ab
Splendor Pink	2.3 abcd	4.8 abcd	0.5 ab	4.5 a	2.3 a	5.0 ab
State Fair Mix	2.0 abcd	4.8 abcd	0.0 b	4.3 a	2.5 a	4.5 ab
Sunbow Mix	2.0 abcd	4.0 bcd	0.5 ab	4.3 a	2.0 a	4.5 ab
Thumbilina Mix	1.8 abcd	4.3 abcd	0.0 b	4.3 a	2.0 a	3.8 ab

^zDisease severity rating scale: 0 = no disease apparent; 1 = < 2% affected by disease; 2 = < 10% affected by disease; 3 = < 25% affected by disease; 4 = < 50% affected by disease; 5 = > 50% affected by disease; 6 = plant dead (killed by disease).

^yMeans followed by the same letters are not significantly different using the Tukey-Kramer adjustment option test of LSD, $P \leq 0.05$.

^xPlant dead from alternaria blight and/or bacterial leaf and flower spot, therefore no disease rating for powdery mildew was possible at this date.

found to be unacceptable.

Powdery mildew

WEEK 4. Powdery mildew was not observed on 25 July. All cultivars and series were acceptable.

WEEK 10. Powdery mildew incidence was minimal on 3 Sept. and was not significantly different among either cultivars or series. Disease severity ratings for cultivars ranged from 0 to 1.5 (Table 2). All cultivars and all series were therefore rated acceptable.

WEEK 17. Powdery mildew was widespread on 22 Oct. Despite the significant differences in incidence and severity among cultivars and series, all surviving plants were severely damaged by the pathogen. Disease severity ratings for the 47 surviving cultivars ranged from 2.1 to 5.2. The best-performing cultivars were 'Peter Pan White' and 'Short Stuff Orange.' Both of these cultivars had a mean disease severity rating of 2.1. Mean disease severity ratings for series ranged from 3.3 to 5.

Bacterial leaf and flower spot

WEEK 4. Incidence of bacterial leaf and flower spot on 25 July was not significantly different among cultivars and series. Incidence among cultivars ranged from 50% to 100%. Severity was also not significantly different among cultivars and series. Disease severity ratings among cultivars ranged from 0.5 to 2. Disease severity ratings among series ranged from 0.5 to 1.5. All cultivars and series were rated acceptable at week 4 when evaluated for susceptibility to bacterial leaf and flower spot.

WEEK 10. All cultivars were affected by bacterial leaf and flower spot on 3 Sept. Disease severity ratings ranged from 1.8 to 3.5 (Table 2). Eleven cultivars had disease severity ratings <2. 'Ruffles Pink,' with a disease severity rating of 1.8, showed the least severe disease damage. All series were rated unacceptable. Disease severity ratings for series ranged from 2.2 to 2.7. The Ruffles series, with a disease severity rating of 2.2 was the best-performing series for tolerance to bacterial leaf and flower spot.

WEEK 17. All cultivars showed serious disease damage on 22 Oct. Disease severity ratings ranged from 3.5 to 6. Ten cultivars were dead, most likely from a combination of bacterial leaf and flower spot and alternaria blight. Disease severity ratings for series ranged from 4.3 to 5.8 and were unacceptable.

Discussion

In the mid-southern area, zinnias are often planted in the landscape in early- to mid-May with the expectation that they will flower and remain attractive until late October. None of the cultivars tested in this study proved acceptable for season-long color. However, some of those cultivars that remained resistant to the pathogens for 10 weeks may be acceptable for cut-flower crops. In cut-flower production, plants are regularly pruned back and new growth is continually emerging. Of the eleven cultivars judged resistant to all three pathogens at week 10, eight could potentially be used in cut-flower production (Table 2).

While all cultivars proved to be susceptible to all three pathogens, the summer of 1997 manifested atypically high disease levels. While a normal bedding plant crop would be planted during the first two weeks of May, the plants in this study were not planted until the last week of June due to excessive rainfall, by which time daily high temperatures were high enough to cause significant metabolic stress to the young plants, possibly resulting in higher incidence and severity of disease than might have occurred had the crop been established by this date. Additionally, warm weather enhances development of these diseases (Andersen, 1971; Jones, 1977; Lipschutz, 1965).

The sources of the initial inoculants in this study were not determined. Once the crop was planted, plants were quickly attacked by the pathogens. Once a pathogen had infected one (or a few) individual host(s), it multiplied rapidly due to environmental conditions conducive to its development, spreading quickly throughout the experimental crop. Monocultures such as this cultivar trial provide ideal conditions for dissemination of pathogens between plants. Had the crop been divided into several separate, smaller plots or alternated with blocks of non-host plants, disease pressure may have been lower. Further research is needed in this area.

By week 17, all 57 cultivars tested were susceptible to alternaria blight and bacterial leaf and flower spot. Ten cultivars had been killed by either one or a combination of both pathogens. Powdery mildew was not rated on these cultivars because they died before powdery mildew became severe. For 45 of the remaining 47 cultivars, powdery mildew was severe by week 17. However, two cultivars, 'Peter Pan White' and 'Short Stuff Orange,' had some resistance to powdery mildew. While it is tempting to tout the powdery mildew

resistance of these two cultivars, both cultivars were severely affected by the other two pathogens.

Conclusion

This study shows that cultivar selection does not affect the incidence or severity of the three diseases, alternaria blight, bacterial leaf, and flower spot and powdery mildew. Therefore, for the landscape industry, zinnia is not suitable for season long color display where these diseases are prevalent. However, for short-term color (10 to 12 weeks), zinnia appears to be an acceptable choice. Few plants flower as reliably or as soon after planting as zinnia. These traits also make zinnia a good choice for cut flower production. Therefore, marketing zinnia towards cut flower producers is recommended. It is also recommended that plant breeders work on developing disease resistant cultivars.

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