Hybrid Performance from Male-Sterile and Pollinator Inbred Onion Lines

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CONTENTS

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During June and July, New Mexico supplies more than 50% of the onions (*Allium cepa* L.) consumed in the United States (U.S. Dept. Agr., 2000). Each year, New Mexico grows 7,000 to 8,000 acres of onions with a total of 160,000 to 180,000 tons produced at a value of $43 to $55 million. The yield averages 920, 50 lb sacks per acre. Acreage, total production, and total value for the New Mexico onion crop have increased during the last 20 years. The continued growth of the New Mexico onion industry requires well-adapted, high-yielding, high-quality cultivars. During the past 17 years, 20 onion cultivars have been released from New Mexico State University's onion breeding program (Cramer et al., 1998). These cultivars were open-pollinated populations adapted to New Mexico growing conditions and produced high yields of high-quality bulbs. Since 1985, the goals have included the development of male-sterile, maintainer, and pollinator inbred lines for hybrid cultivars. Commercial onion cultivars are predominantly hybrids, and commercial seed companies are interested in developing inbred lines with good hybrid performance. This study's objective was to identify promising inbred lines that could be released from the program for use in hybrid production. The inbred lines were evaluated by measuring the performance of the hybrids they made.

MATERIALS AND METHODS

Five short-day, inbred lines (NMSU 97-19-2, 97-28-2, 97-46-2, 97-88-2, 97-109-2) were crossed as female parents to four male, short-day inbred lines (NMSU 96-5-1, 96-16-1, 96-17-1, 96-51-1). Six intermediate-day, inbred lines (NMSU 96-24-2, 96-196-2, 96-199-2, 96-237-2, 96-298-2, 96-300-2) were crossed as female parents to seven male, intermediate-day, inbred lines (NMSU 96-160-1, 96-258-1, 96-271-1, 96-274-1, 96-280-1, 96-335-1, 96-395-1). The lines chosen represented the most promising short- and intermediate-day inbred lines in the NMSU breeding program. Bees were used as pollinators in isolation cages that included one pollinator line and all female lines within each group. Mature seed was collected from plants of each female parental line.

Twenty short-day hybrids were seeded on Sept. 15, 1998, and Sept. 15, 1999, and 42 intermediate-day hybrids lines were seeded on Jan. 21, 1999, at the Fabian Garcia Research Center in Las Cruces, N.M. Plots were 8 ft (2.5 m) long and 22 inches (56 cm) wide with two rows equally spaced on a raised, shaped, standard vegetable bed. Plots were separated by 2 ft (0.6 m) alleys within the bed, and 2 ft (0.6 m) furrows between beds. Both studies were arranged as a split plot design with four replications, with the hybrid male parent being whole plot, and the female parent being subplot. Plots of the short-day hybrids were thinned to 10 cm between plants within the row on Nov. 18, 1998, and Nov. 10, 1999, while plots of the intermediate-day hybrids were thinned on March 25, 1999. Plants were grown using standard cultural practices for growing fall- and spring-seeded onions in southern New Mexico (Corgan et al., 2000).

Before harvest, the maturity date (80% of tops down) was estimated for each plot. All four replications of a particular hybrid were harvested when all of the plots exhibited at least 80% of the plants with their tops down. For the fall-seeded hybrids, the number of plants with seedstalks was recorded at harvest. The percentage of seedstalks, a measure of bolting, was calculated by dividing the number of plants with seedstalks by the total number of plants per plot.

Hybrids in the fall-seeded group were harvested on May 25, and June 1, 3, and 7, 1999, and May 11 and 16, 2000, while hybrids in the spring-seeded group were harvested on July 8, 16, and 22, 1999. The total bulb number per plot was recorded at harvest. Twenty-five randomly selected bulbs per plot were rated for pink root incidence, using a subjective rating of 1 (no pink

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roots) to 9 (severely infected roots). For the spring-seeded hybrids, bulbs infected with Fusarium basal rot (FBR) were recorded and expressed as a percentage of the total bulb number per plot. FBR-infected bulbs were discarded and were not included in bulb yield calculations.

Hybrids were evaluated subjectively for bulb firmness, scale color, number of scale layers, scale thickness, scale adherence, bulb defects, bulb shape, shape uniformity, and uniformity of bulb maturity. Bulb tops and roots were clipped, and bulbs were placed in burlap sacks for field curing. Bulbs were cured at field conditions for four days.

After curing, the total bulb fresh weight was measured for each plot. Bulbs were graded to remove culls (diseased bulbs, bulbs under 1 inch (3.8 cm) in diameter, split or doubled bulbs). The number of culls was subtracted from the total number of bulbs, yielding the number of marketable bulbs per plot. The marketable bulbs per plot were weighed, to measure the marketable fresh weight per plot. The percentage of marketable bulb yield was calculated by dividing the marketable weight per plot by the total weight per plot. The average bulb weight was calculated by dividing total marketable bulb weight by total marketable bulb number per plot. The percentage of bulbs with single growing points (single centers) was determined by counting the number of bulbs with a single growing point or multiple growing points located within 0.5 inches (1.3 cm) from the bulb's center when each bulb was cut transversely at the bulb's vertical center.

The means for each trait were calculated for each hybrid and for the sum of hybrids that pertain to each parent using the Proc Means statement of the SAS statistical software (SAS Institute, Cary, N.C.). For the spring-seeded hybrids, plots with fewer than 11 plants were removed from the data analysis to prevent bias. Differences between male parents and between female parents with respect to the performance of their hybrids were calculated for each trait using the Proc GLM statement of SAS. The total number of plants per plot was used as a covariate in the analysis to reduce any trait variance due to differences in plant density between plots. Since a split-plot arrangement was used, the mean square for replications x male parents was used as the error term for calculating the F value of male parents. In addition, differences between hybrids were calculated for each trait using the Proc GLM statement. A protected Fisher's least significant difference (LSD) mean separation test was calculated at the 5% level for each trait sorted by male parents, female parents, and hybrids using SAS.

RESULTS AND DISCUSSION

Short-Day Inbred Lines

For the female parents, bulb maturity averaged from May 18 (NMSU 97-88-2) to May 23 (97-46-2) (table 1). This maturity time is consistent with commercial cultivars that mature at the same time (Cramer et al., 2000; 2001). For harvest continuity, later-maturing, fall-seeded hybrid lines are desirable to provide onion harvest throughout June.

Hybrids generated by using either NMSU 97-46-2, 97-88-2, or 97-109-2 produced the lowest percentage of seedstalks (table 1). The bolting resistance of hybrids with NMSU 97-19-2 and 97-28-2 was less than desirable. The bolting percentage of hybrid lines will be lower when grown commercially, since most growers seed fall onions from Sept. 25 to Oct. 10, rather than on Sept. 15, as in our study.

All female parents produced hybrids with a low pink root incidence and severity, with NMSU 97-19-2 and 97-46-2 expressing higher levels (table 1). However, the pink root incidence and severity levels observed in these hybrid lines is commercially acceptable and would not reduce bulb size and marketable bulb yield.

The percentage of marketable bulb yield of hybrids was similar among female parents except NMSU 97-88-2, which produced a lower percentage of marketable bulb yield (83.1%) for its hybrids (table 1). Generally, a percentage marketable bulb yield of 90% or greater is desired by growers. All female parents except NMSU 97-88-2 would produce an acceptable percentage marketable bulb yield.

NMSU 97-46-2 produced hybrids with the greatest average bulb yield, except when compared to hybrids using NMSU 97-88-2 (table 1). Bulb yields of hybrids using NMSU 97-19-2, or 97-109-2 were lower. The marketable bulb yields observed for the hybrid lines were comparable to commercial cultivar bulb yields (Cramer et al., 2000; 2001).

The hybrid bulb size was similar among female lines. However, NMSU 97-19-2 and 97-109-2 produced hybrids with slightly smaller bulbs. The average bulb size for hybrid lines would exceed the average bulb size for commercial fall-seeded cultivars (Cramer et al., 2000; 2001).

NMSU 97-19-2 and 97-109-2 produced hybrids with the greatest percentage of bulbs with single centers at 41 and 48%, respectively (table 1). This level of single-centered bulbs is lower than some commercial cultivars and needs to be increased before these inbreds can be used to produce hybrid cultivars.

In addition to disease resistance and bulb yields, hybrids were evaluated for bulb quality, which included bulb firmness, defects, and shape, scale color, thickness, and adherence, number of scale layers, shape uniformity, and uniformity of bulb maturity. Hybrids of NMSU 97-28-2 generally possessed high bulb quality.

Among the female parents tested, NMSU 97-28-2 combined well with all pollinator lines to produce hybrids with excellent bulb yield and quality. This line should be crossed with other pollinator lines to develop additional hybrids. With improvement in marketable bulb yield and bulb size, NMSU 97-19-2 and 97-109-2 would produce desirable hybrids. With an improvement in percentage of single centers, NMSU 97-46-2 and 97-88-2 would produce more desirable hybrids.

Among the male parent lines, maturity ranged from May 19 (NMSU 96-16-1) to May 23 (96-51-1) (table 1). This maturity time is ideal for producing early maturing hybrids from fall seeding. However, later-maturing hybrids need to be developed for onion harvest in June.

NMSU 96-17-1 and 96-51-1 produced hybrids with the lowest percentage of seedstalks, greatest marketable bulb yield, and greatest percentage of single-centered bulbs. NMSU 96-5-1 and 96-16-1 produced hybrids with a high percentage of seedstalks and a low incidence of pink root (table 1). The high percentage of seedstalks is unacceptable commercially. A later planting date, as is used commercially, would reduce seedstalk percentage. The pink root incidence and severity was generally low for all male parents, and commercial hybrids from these parents would express acceptable levels of pink root incidence and severity without a reduction in bulb size or marketable bulb yield. The pink root incidence and severity levels are comparable to fall-seeded commercial cultivars (Cramer et al., 2000; 2001). All parents produced a commercially acceptable percentage of marketable bulbs, with only NMSU 96-5-1 producing a less than desirable percentage.

The marketable bulb yields observed for the hybrid lines was comparable to commercial cultivar bulb yields, while the average bulb size would exceed the average bulb size for commercial fall-seeded cultivars (Cramer et al., 2000; 2001). The percentage of single-centered bulbs is lower than that of some commercial cultivars (Cramer et al., 2000; 2001) and needs to be increased before these inbreds can be used to produce hybrid cultivars. With regard to bulb quality, NMSU 96-17-1 and 96-51-1 produced high-quality bulbs that are comparable to the quality of commercial cultivars.

Among the male parent lines tested, NMSU 96-17-1 and 96-51-1 combined well with all short-day, male-sterile lines tested to produce hybrids with excellent bulb yield and quality. These pollinator lines should be crossed with additional male-sterile lines to develop additional hybrids.

Short-Day Hybrids

The bulb maturity of hybrids tested varied by 8 days (May 16-24) (table 2). Later-maturing hybrids are needed to provide continual harvest through the end of June.

The percentage of seedstalks produced varied greatly and ranged from 0.0% for NMSU 97-19-2 x 96-17-1 to 32% for NMSU 97-19-2 x 96-5-1. Numerous hybrids possessed high bolting resistance, while NMSU 97-19-2 x 96-5-1 and 97-28-2 x 96-16-1 had the least bolting resistance. A bolting percentage of 10% or less is desirable. Bolting will vary from year to year depending upon environmental conditions, such as time of low temperatures, duration of low temperatures, warm fall season, etc.

The severity of pink root was generally low (1.8) among hybrids. NMSU 97-28-2 x 96-5-1, 97-28-2 x 96-16-1, 97-28-2 x 96-17-1, 97-88-2 x 96-5-1, 97-88-2 x 96-16-1, 97-109-2 x 96-5-1, and 97-109-2 x 96-16-1 exhibited the lowest incidence of pink root disease. As stated with the parents, the pink root incidence and severity observed for the hybrids are comparable to commercial cultivars (Cramer et al., 2000; 2001) and are acceptable commercially.

The percentage of marketable bulb yield among hybrids varied from 78.5% (NMSU 97-88-2 x 96-5-1) to 94.2% (NMSU 97-28-2 x 96-17-1) with an average of 88.3% (table 2). A percentage marketable bulb yield of 90% or greater is considered highly desirable. Several of the hybrids meet this level.

The marketable bulb yield also varied greatly among hybrids from a low of 880 sacks/acre (49.3 t/ha) for NMSU 97-19-2 x 96-17-1 to a high of 1,757 sacks/acre (98.4 t/ha) for NMSU 97-28-2 x 96-17-1 (table 2). The marketable bulb yield of NMSU 97-28-2 x 96-17-1, 97-46-2 x 96-17-1, and 97-46-2 x 96-51-1 exceeded the yield of other hybrids and is comparable to the highest-yielding, open-pollinated cultivars (Cramer et al., 2000; 2001).

The average bulb weight was large, less than 12.0 oz (482 g) for all hybrids (table 2). But NMSU 97-46-2 x 96-17-1 and 97-46-2 x 96-51-1 produced bulbs that were generally larger than bulbs from other hybrids. The average bulb size was generally larger than the bulb size of commercial cultivars (Cramer et al., 2000; 2001).

The percentage of bulbs with single centers generally was low among hybrids (34.0%) (Table 2). However, NMSU 97-19-2 x 96-17-1 produced a high percentage (78.4%) of bulbs with single centers. The percentage of bulbs with single centers for these hybrids is lower than the percentage for open-pollinated cultivars currently grown in New Mexico (Cramer et al., 2000; 2001). Of the hybrids tested, NMSU 97-28-2 x 96-17-1, 97-46-2 x 96-17-1, and 97-46-2 x 96-51-1 are the best because of their high bulb yield, high percentage of marketable bulb yield, large bulb size, high bolting resistance, and high pink root resistance (table 2).

In addition to disease resistance and bulb yield traits, hybrids were evaluated subjectively for bulb quality traits. Of the hybrids tested, NMSU 97-28-2 x 96-17-1 possessed a deep globe shape with some taper to deep grano shape, uniform shape within the line, multiple scale layers, good scale retention, and firm to hard bulbs. The hybrid possessed excellent bulb quality, except for a few scale splits caused by overmaturity. NMSU 97-88-2 x 96-17-1 also possessed excellent bulb quality. Bulbs from this hybrid were uniform, globe to deep globe in shape, and firm to hard. They also possessed excellent scale quality with good color, multiple layers, and good retention.

Intermediate-Day Inbred Lines

For the female parent lines, maturity dates (July 11) and pink root incidence of hybrids were similar (table 3). Later-maturing female parents are desirable for producing later-maturing hybrids. The pink root incidence levels are comparable to those for spring-seeded cultivars (Cramer et al., 2000). NMSU 96-24-2 produced hybrids with a lower pink root severity than all other parental lines except NMSU 96-237-2, while hybrids generated using NMSU 96-300-2 exhibited higher pink root severity. The range of pink root severity observed in the hybrids is acceptable for commercial hybrids and is comparable to commercial cultivars (Cramer et al., 2000).

NMSU 96-199-2 and 96-300-2 conferred the most FBR resistance to their hybrid progeny. The FBR incidence levels were generally low and comparable to commercial cultivars (Cramer et al., 2000). The FBR levels observed by growers are lower.

NMSU 96-237-2 and 96-300-2 produced hybrids with greater percentage marketable bulb yields than other female parents, except NMSU 96-298-2. A higher percentage of marketable bulbs is desirable. The current percentages are lower than those of commercial cultivars (Cramer et al., 2000). The marketable bulb yield of hybrids was not influenced significantly by the parental line. Marketable bulb yield for these parents was greatly influenced by plant density and the interaction between male and female parents. In addition, a higher marketable bulb yield is desirable in order to compete with commercial hybrids (Cramer et al., 2000).

Among parental lines, NMSU 96-196-2 produced hybrids with the largest bulb size. The bulb size was generally larger when compared with commercial cultivars (Cramer et al., 2000). NMSU 96-196-2 and 96-300-2 produced hybrids with the greatest percentage of bulbs with single growing points. The percentage of single-centered bulbs is generally higher in commercial cultivars (Cramer et al., 2000). The percentage would need to be increased for these parents before commercial hybrids can be released. NMSU 96-196-2 and 96-300-2 are the best lines for generating hybrids with the best performance.

For male parents, three distinct maturity groups existed. Hybrids generated using NMSU 96-160-1, 96-258-1, 96-271-1, and 96-280-1 matured at about July 7, while hybrids using NMSU 96-274-1 and 96-335-1 matured one week later (table 3). Using NMSU 96-395-1 as a male parent produced hybrids, which matured at about July 21. These separate male parents could be used to generate hybrids, which mature at various dates throughout July.

The resistance to pink root varied among hybrids depending upon the male parent used. NMSU 96-271-1 possessed the lowest incidence of pink root and a low pink root severity. In addition, NMSU 96-258-1 and 96-280-1 conferred a low pink root incidence and severity when compared with other male parents. Hybrids using NMSU 96-274-1 or 96-335-1 as male parents require higher levels of pink root resistance. The low levels of pink root incidence and severity are highly desirable in commercial hybrids, since most commercial cultivars express high pink root incidence and severity (Cramer et al., 2000).

FBR resistance also varied greatly among the male parents used. NMSU 96-160-1 conferred the most FBR resistance to its progeny. Later-maturing hybrids tended to exhibit a higher FBR incidence than earlier-maturing hybrids. Hybrids that possessed a high pink root incidence also possessed a high FBR incidence. Strong, positive correlations between pink root and FBR resistance have been reported (Villanueva-Mosqueda, 1996).

The percentage marketable bulb yield of hybrids was similar among male parent lines (table 3) . A higher percentage of marketable bulbs is desirable. The current percentages are lower than those of commercial cultivars (Cramer et al., 2000). NMSU 96-274-1 produced hybrids with a greater marketable bulb yield than all other parents, except NMSU 96-280-1 and 96-395-1. The marketable bulb yield of hybrids generated using NMSU 96-160-1 as a male parent was less than desirable.

The average bulb size ranged from 14.1 oz (NMSU 96-335-1) to 18.4 oz. (NMSU 96-395-1). NMSU 96-160-1, 96-274-1, and 96-395-1 generally produced hybrids with the largest bulbs. The bulb size was generally larger when compared with commercial cultivars (Cramer et al., 2000). Hybrids using NMSU 96-280-1 as a male parent possessed the highest percentage of bulbs with single centers (48.0%). The percentage of single-centered bulbs was generally higher in commercial cultivars (Cramer et al., 2000). The percentage needs to be increased for these parents before commercial hybrids can be released.

For the earliest-maturing group of male parent lines, NMSU 96-280-1 produced hybrids with the best overall performance. Among the later-maturing male parents, NMSU 96-274-1 and 96-395-1 produced comparable hybrids.

Intermediate-Day Hybrids

Maturity dates of the intermediate-day hybrids closely followed the maturity dates of the male parent and ranged from July 4 (NMSU 96-237-2 x 96-160-1) to July 23 (NMSU 96-199-2 x 96-395-1) (table 4). This range of maturity dates is highly desirable for harvest continuity.

The pink root severity of hybrids ranged from 2.0 (NMSU 96-196-2 x 96-258-1) to 5.8 (NMSU 96-300-2 x 96-274-1). Numerous hybrids possessed excellent pink root resistance (pink root rating < 3.0). The low levels of pink root severity are highly desirable in commercial hybrids, since most commercial cultivars express high pink root severity (Cramer et al., 2000).

FBR incidence was variable among hybrids with a low of 0% (NMSU 96-196-2 x 96-160-1, 96-196-2 x 96-258-1, and 96-199-2 x 96-160-1) to a high of 40.1% (NMSU 96-237-2 x 96-274-1). Other hybrids also exhibited a low FBR incidence. However, all of these hybrids matured before July 9. NMSU 96-160-1 may confer some resistance to FBR; all hybrids using NMSU 96-160-1 as a male parent exhibited low FBR incidence levels. However, these hybrids also were the earliest-maturing lines and may have avoided the pathogen causing FBR.

The percentage of marketable bulb yield for hybrids ranged from 64.1% (NMSU 96-298-2 x 96-160-1) to 93.9% (NMSU 96-300-2 x 96-271-1) (table 4). Several hybrids exhibited a marketable bulb yield above 90%, and percentage of marketable bulb yield was generally high for all hybrids (83.3%). A percentage marketable yield of 90% or greater is commercially desirable. The marketable bulb yield varied greatly among hybrids with some difference in yield attributable to differences in plant stand. Some hybrid combinations produced few seeds making it difficult to test for yield. The marketable bulb yield ranged from 352 (NMSU 96-196-2 x 96-258-1) to 1,293 sacks/acre (NMSU 96-300-2 x 96-274-1). NMSU 96-300-2 produced fewer hybrids with low marketable bulb yields than other female parents. Some of the highest-yielding hybrids included NMSU 96-298-2 x 96-280-1, 96-298-2 x 96-395-1, 96-300-2 x 96-271-1, and 96-300-2 x 96-274-1. Each of these hybrids would produce high-yielding cultivars.

Average bulb size varied greatly among hybrids. Bulb size ranged from 13.1 oz (NMSU 96-300-2 x 96-335-1) to 20.9 oz (NMSU 96-24-2 x 96-395-1). Hybrids that produced the largest bulbs often did not produce the greatest marketable bulb yield per plot. The bulb size was generally larger when compared with commercial cultivars (Cramer et al., 2000). The percentage of bulbs with single centers ranged from 13.9% (NMSU 96-199-2 x 96-258-1) to 65.2% (NMSU 96-196-2 x 96-274-1) (table 4). The percentage of single-centered bulbs was generally higher in commercial cultivars (Cramer et al., 2000). The percentage needs to be increased for these parents before commercial hybrids can be released.

With regard to bulb quality, NMSU 96-300-2 x 96-335-1 produced round, globe-shaped bulbs with some deeper bulbs; desirable scale color; multiple scale layers; thin scale with some variability in thickness; hard bulbs; and uniform bulb maturity. NMSU 96-300-2 x 96-274-1 possessed desirable scale color, multiple scale layers, firm to hard bulbs, and uniform bulb maturity. However, bulb shape was highly variable, scale was thick, and some double bulbs were observed.

In conclusion, several parents could be used to produce high-yielding, excellent-quality hybrids. For fall-seeded hybrid onions, NMSU 97-28-2 as a female parent and NMSU 96-17-1 or NMSU 96-51-1 as male parents produced the best hybrids. For spring-seeded hybrid onions, NMSU 96-196-2 or 96-300-2 as female parents and NMSU 96-280-1, NMSU 96-274-1, or 96-395-1 as male parents produced the best hybrids. Several hybrid combinations were comparable in yield and quality to commercial cultivars (Cramer et al., 2000; 2001). These combinations included NMSU 97-28-2 x 96-17-1, 97-46-2 x 96-17-1, and 97-46-2 x 96-51-1 for fall-seeded onions, and NMSU 96-300-2 x 96-335-1 and NMSU 96-300-2 x 96-274-1 for spring-seeded onions.

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Table 1. Performance of fall-seeded hybrid onions with respect to their female and male parent lines.

Entry	Maturity date[z]	Seedstalks (%)[y]	Pink root[x]	Pink root (%)[w]	Marketable yield (%)[v]	Marketable yield (Number of 50 lb sacks/acre)[u]	Bulb weight (oz)[t]	Single centers (%)[s]
Female parents								
NMSU 97-19-2	May 21	14.0	2.0	60.0	89.8	1105	15.7	48.4
NMSU 97-28-2	May 21	11.5	1.7	42.2	88.9	1379	17.8	33.5
NMSU 97-46-2	May 23	6.9	2.0	58.3	87.8	1493	18.6	20.6
NMSU 97-88-2	May 18	5.3	1.6	39.6	83.1	1402	17.1	25.0
NMSU 97-109-2	May 19	3.5	1.7	40.2	90.7	1243	15.4	41.2
LSD (5%)	1***	3.3***	0.2**	9.0***	3.8***	107***	1.0**	4.7***
Male parents								
NMSU 96-5-1	May 20	12.9	1.5	35.3	85.2	1246	16.0	30.2
NMSU 96-16-1	May 19	15.1	1.8	47.8	88.0	1271	16.5	21.6
NMSU 96-17-1	May 21	1.0	2.0	56.7	90.6	1388	17.3	43.1
NMSU 96-51-1	May 23	3.2	2.0	61.9	90.1	1436	19.1	47.4
LSD (5%)	1**	3.0***	0.2**	9.0*	3.4*	96***	NS	5.2***
Mean	May 21	8.7	1.8	49.2	88.3	1323	17.0	34.0

[NS, *, **, ***]Nonsignificant, significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. Data are means of 142 (grand), 38 (NMSU 96-5-1, 96-16-1, 96-17-1), 32 (NMSU 97-19-2, 97-28-2, 97-46-2), 24 (NMSU 96-51-1, 97-109-2), and 22 (NMSU 97-88-2) observations.

[z]A plot was considered matured when at least 80% of the plant tops were down.

[y]The percentage of seedstalks was determined at harvest and calculated by dividing the number of plants with seedstalks by the total number of plants per plot.

[x]Pink root rating. Root system of bulbs were rated based on a scale of 1 (no infected roots) to 9 (completely infected roots).

[w]Percentage of bulbs with pink root.

[v]Percentage of marketable bulb yield was calculated by dividing marketable bulb weight by total bulb weight.

[u]Number of 50 lb sacks/acre was calculated by weighing the marketable bulbs per plot and adjusting the plot size to one acre.

Number of 50 lb sacks/acre are multiplied by 0.056 to convert to t/ha.

[t]Bulb weight was calculated by dividing the marketable bulb weight by the number of marketable bulbs.

[s]The percentage of bulbs with single centers (single growing points) was determined by cutting each bulb transversely at the vertical center and measuring the number of growing points that extended 0.5 in. beyond the bulb's center.

Table 2. Performance of fall-seeded hybrid onion lines.

Hybrid[z]	Maturity date[y]	Seedstalks (%)[x]	Pink root[w]	Pink root (%)[v]	Marketable bulb yield (%)[u]	Marketable bulb yield (Number of 50 lb sacks/acre)[t]	Bulb weight (oz)[s]	Single centers (%)[r]
97-19-2 x 96-5 -1	May 21	32.0	1.6	39.1	86.8	884	15.6	32.2
x 96-16-1	May 20	17.3	2.1	67.0	87.7	1271	17.0	22.4
x 96-17-1	May 21	0.0	2.4	79.5	93.6	880	12.1	78.4
x 96-51-1	May 23	6.9	1.8	54.5	91.1	1386	18.1	60.7
97-28-2 x 96-5 -1	May 21	10.9	1.5	30.3	87.4	1409	17.6	30.3
x 96-16-1	May 21	31.2	1.6	39.5	87.2	1086	15.6	17.1
x 96-17-1	May 20	1.2	1.5	35.5	94.2	1757	19.2	35.3
x 96-51-1	May 23	2.5	2.0	62.2	86.6	1261	18.9	51.5
97-46-2 x 96-5 -1	May 24	13.5	1.8	46.0	82.3	1270	16.6	11.9
x 96-16-1	May 22	11.6	2.1	61.5	89.3	1414	17.3	17.8
x 96-17-1	May 23	2.0	2.0	56.5	87.3	1623	20.3	25.9
x 96-51-1	May 23	0.3	2.2	69.0	92.5	1663	20.3	27.5
97-88-2 x 96-5 -1	May 19	6.1	1.4	34.0	78.5	1293	16.0	30.2
x 96-16-1	May 17	7.7	1.5	35.0	85.2	1373	17.8	21.8
x 96-17-1	May 16	0.9	1.9	53.3	86.4	1584	17.7	22.4
97-109-2x 96-5 -1	May 16	1.9	1.3	26.5	91.1	1377	14.3	46.4
x 96-16-1	May 18	7.5	1.6	36.0	90.6	1214	14.6	28.7
x 96-17-1	May 21	0.9	2.1	58.0	90.5	1139	17.4	48.5
Mean	May 21	8.7	1.8	49.2	88.3	1323	17.0	34.0
LSD (5%)	NS	6.6***	0.5***	19.3***	NS	213***	3.2***	13.1***

NS, ***Nonsignificant, significant $P \leq 0.001$, respectively. Data are means of 8 observations.

zThe first number is the female parent, and the second number is the male parent.

yA plot was considered matured when at least 80% of the plant tops were down.

xThe percentage of seedstalks was determined at harvest and calculated by dividing the number of plants with seedstalks by the total number of plants per plot.

wPink root rating. Root system of bulbs were rated based on a scale of 1 (no infected roots) to 9 (completely infected roots).

vPercentage of bulbs with pink root.

uPercentage of marketable bulb yield was calculated by dividing marketable bulb weight by total bulb weight.

tNumber of 50 lb sacks/acre was calculated by weighing the marketable bulbs per plot and adjusting the plot size to one acre. Number of 50 lb sacks/acre are multiplied by 0.056 to convert to t/ha.

sBulb weight was calculated by dividing the marketable bulb weight by the number of marketable bulbs.

rThe percentage of bulbs with single centers (single growing points) was determined by cutting each bulb transversely at the vertical center and measuring the number of growing points that extended 0.5 in. beyond the bulb's center.

Table 3. Performance of spring-seeded hybrid onion lines with respect to their female and male parent lines.

Entry	Maturity date[z]	Pink root[y]	Pink root (%)[x]	FBR (%)[w]	Marketable bulb yield (%)[v]	Marketable bulb yield (Number of 50 lb sacks/acre)[u]	Bulb weight (oz)[t]	Single centers (%)[s]
Female parents								
NMSU 96-24-2	July 11	2.9	74.9	13.8	79.2	748	17.2	30.9
NMSU 96-196-2	July 12	3.6	82.8	14.2	81.5	623	18.5	47.6
NMSU 96-199-2	July 10	3.5	74.6	8.3	82.0	850	15.8	32.3
NMSU 96-237-2	July 12	3.1	75.9	18.8	86.7	732	16.4	28.9
NMSU 96-298-2	July 10	3.4	78.4	13.9	83.6	963	15.2	34.5
NMSU 96-300-2	July 10	3.9	83.7	9.8	86.9	1104	15.0	41.7
LSD (5%)	NS	0.4**	NS	3.8***	3.9*	NS	1.0*	6.6***
Male parents								
NMSU 96-160-1	July 6	3.1	74.7	3.0	75.6	654	18.1	29.8
NMSU 96-258-1	July 7	2.7	70.8	11.2	83.5	809	15.6	22.6
NMSU 96-271-1	July 7	2.3	61.5	9.6	82.6	814	14.7	38.0
NMSU 96-274-1	July 14	4.5	92.9	26.0	89.6	952	17.7	37.5
NMSU 96-280-1	July 7	2.5	69.4	7.2	81.6	905	15.3	48.0
NMSU 96-335-1	July 13	4.6	84.4	12.9	82.3	864	14.1	37.7
NMSU 96-395-1	July 21	4.0	94.3	18.3	86.8	916	18.4	36.0
LSD (5%)	1***	0.4***	7.7*	4.2***	NS	59***	1.1**	7.2***
Mean	July 11	3.4	78.5	12.8	83.3	850	16.3	36.1

NS, *, **, ***Nonsignificant, significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively. Data are means of 151 (grand), 28 (NMSU 96-298-2, 96-300-2), 27 (NMSU 96-199-2), 24 (NMSU 96-24-2, 96-280-1, 96-395-1), 23 (NMSU 96-196-2), 22 (NMSU 96-271-1), 21 (NMSU 96-237-2, 96-274-1), 20 (NMSU 96-258-1, 96-335-1), and 19 (NMSU 96-160-1) observations.

[z]A plot was considered matured when at least 80% of the plant tops were down.

[y]Pink root rating. Root system of bulbs were rated based on a scale of 1 (no infected roots) to 9 (completely infected roots).

[x]Percentage of bulbs with pink root.

[w]Percentage of bulbs with Fusarium basal plate rot (FBR). The basal plate of each bulb was transversely cut to reveal the presence or absence of FBR.

[v]Percentage of marketable bulb yield was calculated by dividing marketable bulb weight by total bulb weight.

[u]Number of 50 lb sacks/acre was calculated by weighing the marketable bulbs per plot and adjusting the plot size to one acre. Number of 50 lb sacks/acre are multiplied by 0.056 to convert to t/ha.

[t]Bulb weight was calculated by dividing the marketable bulb weight by the number of marketable bulbs.

[s]The percentage of bulbs with single centers (single growing points) was determined by cutting each bulb transversely at the vertical center and measuring the number of growing points that extended 0.5 in. beyond the bulb's center.

Table 4. Performance of spring-seeded hybrid onion lines.

Hybrid[z]		Maturity date[y]	Pink root[x]	Pink root (%)[x]	FBR (%)[w]	Marketable bulb yield (%)[v]	Marketable bulb yield (Number of 50 lb sacks/acre)[v]	Bulb weight (oz)[u]	Single centers (%)[t]
96-24-2	x 96-160-1	July 7	2.8	62.1	9.4	71.6	611	17.6	24.7
	x 96-258-1	July 8	2.9	80.0	15.3	81.4	923	13.3	32.0
	x 96-271-1	July 7	2.2	61.0	11.4	66.2	507	16.8	25.4
	x 96-274-1	July 14	3.3	88.0	22.0	90.6	957	18.3	23.7
	x 96-280-1	July 8	2.2	62.5	2.5	81.7	814	16.1	47.7
	x 96-395-1	July 22	3.8	96.0	22.3	83.5	673	20.9	32.1
96-196-2	x 96-160-1	July 5	3.1	80.3	0.0	73.7	463	20.8	38.0
	x 96-258-1	July 8	2.0	70.0	0.0	75.4	352	19.2	22.2
	x 96-271-1	July 7	2.5	62.7	16.8	76.8	627	15.5	48.1
	x 96-274-1	July 14	4.4	95.0	24.1	89.5	861	20.1	65.2
	x 96-280-1	July 7	2.7	74.8	8.5	80.5	629	17.5	51.1
	x 96-335-1	July 15	4.8	92.0	13.8	77.7	477	16.8	44.3
	x 96-395-1	July 22	4.1	89.6	22.4	89.0	707	20.1	43.2
96-199-2	x 96-160-1	July 5	2.9	72.9	0.0	84.8	552	18.4	29.1
	x 96-258-1	July 8	2.7	64.9	4.9	81.8	516	17.3	13.9
	x 96-271-1	July 7	2.7	62.0	8.1	82.3	934	14.4	41.8
	x 96-274-1	July 14	4.4	90.0	22.2	93.1	1105	16.5	28.4
	x 96-280-1	July 7	3.0	76.0	4.2	72.3	848	15.9	46.4
	x 96-335-1	July 7	4.4	57.0	3.0	68.3	845	10.4	31.0
	x 96-395-1	July 23	4.1	99.0	13.4	92.4	1080	18.4	34.7
96-237-2	x 96-160-1	July 4	2.5	62.5	6.7	84.3	539	20.3	23.1
	x 96-258-1	July 7	2.7	68.7	10.6	83.2	609	17.6	23.0
	x 96-271-1	July 7	2.2	58.3	15.8	91.2	661	13.6	31.8
	x 96-274-1	July 15	4.4	92.4	40.1	84.9	489	19.9	17.5
	x 96-280-1	July 7	2.1	63.0	15.0	88.6	838	13.7	42.5
	x 96-335-1	July 14	4.4	85.0	20.6	87.7	971	15.7	33.2
	x 96-395-1	July 22	3.5	93.5	20.7	84.5	702	18.4	20.5
96-298-2	x 96-160-1	July 7	2.9	73.2	1.1	64.1	607	16.6	26.5
	x 96-258-1	July 7	2.7	70.0	13.2	87.3	1016	15.0	18.7
	x 96-271-1	July 7	2.2	56.7	7.9	86.1	468	13.2	41.6
	x 96-274-1	July 14	4.9	93.0	39.9	84.2	770	16.6	29.2
	x 96-280-1	July 6	2.3	68.0	8.7	85.5	1229	14.5	46.4
	x 96-335-1	July 13	4.7	96.0	12.9	89.2	1004	14.3	39.5
	x 96-395-1	July 21	3.8	92.0	13.9	88.5	1239	16.0	39.9
96-300-2	x 96-160-1	July 5	4.0	89.0	1.9	83.5	993	17.3	34.5
	x 96-258-1	July 6	2.6	70.0	14.7	85.8	1045	14.2	25.7
	x 96-271-1	July 7	2.1	68.0	2.4	93.9	1202	14.6	40.5
	x 96-274-1	July 14	5.8	99.0	14.8	92.9	1293	15.6	50.8
	x 96-280-1	July 6	2.9	72.0	4.0	81.0	1075	14.2	54.1
	x 96-335-1	July 14	5.0	92.0	14.1	88.7	1021	13.1	40.7
	x 96-395-1	July 21	4.8	96.0	17.1	82.7	1093	16.2	45.5
LSD (5%)		2***	1.2***	24.0***	9.8***	11.2***	138***	2.7***	16.0***
Mean		July 11	3.4	78.5	12.8	83.3	850	16.3	36.1

***Significant at $P \leq 0.001$. Data are means of 4 observations.

[z]The first number is the female parent, and the second number is the male parent.

[y]A plot was considered matured when at least 80% of the plant tops were down.

[x]Pink root rating. Root system of bulbs were rated based on a scale of 1 (no infected roots) to 9 (completely infected roots).

[w]Percentage of bulbs with pink root.

[w]Percentage of bulbs with Fusarium basal plate rot (FBR). The basal plate of each bulb was cut transversely to reveal the presence or absence of FBR.

[v]Percentage of marketable bulb yield was calculated by dividing marketable bulb weight by total bulb weight.

[u]Number of 50 lb sacks/acre was calculated by weighing the marketable bulbs per plot and adjusting the plot size to one acre. Number of 50 lb sacks/acre are multiplied by 0.056 to convert to t/ha.

[t]Bulb weight was calculated by dividing the marketable bulb weight by the number of marketable bulbs.

[s]The percentage of bulbs with single centers (single growing points) was determined by cutting each bulb transversely at the vertical center and measuring the number of growing points that extended 0.5 in. beyond the bulb's center.

June 2001 **Las Cruces, NM**
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