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Effect of Different Male Parents and Male Flower Numbers on Seed Yield and Quality of Triploid Watermelon Breeding

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ABSTRACT

In this study, the effects of different male parents and male flower number used for pollination of female flower were investigated for fruit and seed yield and quality in triploid watermelon. As plant material, tetraploid ST101 and ST82 were used as female parents; diploid WL92, WL124, WL134, WL216, WL259-B and WL235 were used as male parents. Plant length, main stem diameter, number of nodes on main stem parameters were investigated. Tetraploid female parents were pollinated with 1, 2 and 3 male flowers (mf) of diploid male parents and fruit setting values were determined. Seed yield, 1000 seeds weight, full and abortive seed numbers, embryo/seed ratio and seed germination rates were investigated. According to research results; plant length, number of nodes, stem diameter were highest in found WL92 (260.56 cm, 32.83 nodes and 8.52 mm, respectively); highest fruit setting ratio, fruit yield, weight, height, diameter and rind thickness were found in ST82 x WL259-B hybrid (63.10 %, 7.62 kg, 2856.67 g, 16.70 cm, 17.61 cm and 1.97 mm respectively). TSS was found to be the highest (8.99 %) in ST101 x WL92 hybrid, while highest seed yield and germination rate were determined in ST82 x WL216 cross (2.12 g/fruit, 45.56 % respectively); 1000 seed weight, abortive and full seed number, embryo/seed ratio, were superior in ST82 x WL134 cross (55.12 g, 40.33 seed/fruit, 143.50 seed/fruit, 43.70 % respectively). Increase of male flower had positive effects on fruit yield (2mf, 3mf), weight (2mf, 3mf), height (3mf) and diameter (2mf, 3mf).

Keywords: Tetraploid, diploid, watermelon, fruit and seed.

INTRODUCTION

Watermelon (*Citrullus lanatus* Thunb. Matsum and Nakai) which belongs to Cucurbitaceae family is cultivated on 3.4 million ha in the world and its production is 118.4 million tons (Whitaker and Bemis, 1976; FAO, 2018). Watermelon cultivars which used as commercially are classified as seeded and seedless (Şimşek and Sarı, 2010). Seedless watermelons have become very popular for consumers because they provide easy consumption of watermelon fruit flesh due to the lack of hard seeds (Solmaz et al., 2018). While the fresh weight of watermelon contains 48.7 mg lycopene on average, the fresh weight of seedless watermelons has a higher rate of lycopene (50 mg) (Perkins-Veazie et al., 2001). Seeded and diploid watermelon varieties uses a portion of its energy to produce seeds in the fruit, while seedless watermelon varieties uses the energy to increase the amount of sugar in fruit flesh instead of seed production (Mary and Gast, 1991).

Seedless watermelons are triploid and have 33 chromosome numbers (Kihara, 1951). Triploid watermelons are formed by pollination a line with tetraploid chromosome (4n) by a line with diploid (2n) chromosome. Lines with diploid chromosome (2n) are exposed to some chemicals to increase the number of chromosomes and as a result of this treatment, tetraploid lines (44 chromosome) are obtained. Colchicine and oryzaline increase the rate of obtaining tetraploid plants (Şimşek and Sarı, 2010). After chemical application, some of the plants remain in diploid structure, some of them form chimeric structure and in a small number of plants occurs chromosome folding and turns into tetraploid structure (Compton et al., 1996; Jaskani et al., 2004). Cell structures of tetraploid plants are larger than those of diploid plants. Therefore, the vegetative and flower structure of tetraploid plants are also larger than diploid plants (El-Morsy et al., 2009; Vainola, 2000). Whereas tetreaploid watermelons have advantages in terms of yield, disease resistance and storage, these fruits have disadvantages in terms of low seed yield, low seedling formation and low germination rate (Şimşek and Sarı, 2010). Germination of triploid watermelon seeds is quite difficult because the thickness of the tetraploid female seed coat passes to the triploid embryo and the embryo is weak (Phat et al., 2015). The cost of triploid watermelon seed is higher than the diploid seed cultivars in proportion to the small number of seeds obtained from the tetraploid female plant. Triploid seeds are expensive because the formation process of triploid seed is long and labor cost is high. In general, the germination percentage of tetraploid seeds is low because their embryos are smaller in size (Nerson et al., 1985). The germination rate of a triploid seed is generally between %60 and 80%. In contrast to the triploid seed, the germination rate of the diploid seed is 95% with increasing homogeneity and seedling strength. Thus, the triploid watermelon is generally supplied to the grower at an additional cost (Grange et al., 2003). The aim of this study is to determine the effects of different male parents and the number of flowers used in pollination on fruit and seed yield and quality in order to minimize the problem caused by the lack of embryo deficiency or weakness in triploid watermelon seeds.

MATERIAL AND METHOD

This study was conducted in glasshouse at the Department of Horticulture, Faculty of Agriculture, Cukurova University, Adana, Turkey in 2018 spring-summer season. As plant material, tetraploid ST101 and ST82 were used as female parents; diploid WL92, WL124, WL134, WL216, WL259-B and WL235 were used as male parents. Two pollination group were formed in this study. In the first group female parent was tetraploid ST 101, male parents were WL 124, WL 92 ve WL 235. In the second group the tetraploid ST82 was used as female parent, WL 134, WL 259-B ve WL 216 were used as male parents for pollination. Thus, the effect of three pollinator male parents for each female parents was investigated.

Diploid and tetraploid parents were grafted onto Nun 9075 and grafted seedlings were planted on 04/05/2018 with double row (100-50) x 50 cm spacing. For each tetraploid female parents, 135 seedling were planted in the greenhouse (3 pollinators male parents x 3 number of flowers x 3 repetitions x 5 plants). One, two and three male flowers were taken from each male parent and pollinated with tetraploid female parents. Single row cultivation, drip irrigation, fertilization and spraying were applied during the cultivation. Fertilizers were applied approximately 150 kg N/ha, 150 kg P/ha, 200 kg K/ha, 1.5 kg/ha S, 20 kg/ha Mg. Female flowers of tetraploid plants were isolated with cellophane bags and; diploid male flowers were isolated with clips, one day before anthesis. Next morning, female flowers were pollinated with male flowers. Plant length (cm), main stem diameter (mm), number of nodes (number/plant) were measured and counted in each plot to examine plant growth (4 plants for 1 genotype x 4 replicates = 16 measurements) . The first harvest was started on 13/07/2018 and harvests continued with daily controls until 13/08/2018. Fruit setting ratio, fruit yield per m^2, fruit height and diameter, the rind thickness, thetotal soluble solids, seed weight and seed number per fruit, 1000 seed weight, the weight of the full seeds, ratio of embryos and seed coat to seed, and seed germination parameters were investigated in this study.

Fruit setting ratio was calculated with dividing the number of flowers transformed into fruit to the total number of hybridized flowers than multiplied by 100, 3-4 days after hybridization. Fruit yield (kg/m^2) was calculated with collecting all the fruits in each plot, weighting and dividing into parcel size. Plant height was measured in the main stem. Afterwards, in order to determine fruit length and diameter, the fruits were cut horizontally in the middle and measured with a ruler. The rind thickness, was measured by a digital caliper. The total soluble solids (% TSS) was determined by using a digital hand refractometer. All seeds contained in all fruits of the plot were removed, fermented and then washed and dried. After full and abortive (empty, seed hardened, white seeds) seeds were counted, dry weights were weighed using a digital top loading weighing scale. Therefore the seed weights and seed yield per fruit were determined in terms g/fruit. After counting 100 seeds from each plot, it was weighed on the digital top loading weighing balance and multiplied by 10 to determine 1000 seed weights. The seeds were extracted from the fruits obtained from each plot were counted separately as full and empty, and the weights of the full seeds were recorded after drying. Seeds (5 seeds x 4 replications) were opened from each plot. Seed coat and embryos were separated from each other and weighed on scale to find out the ratio of embryo/seed**.** Seeds (4 replications and 5 seeds) of each plot were placed in filter paper (5 seeds

x 4 replications). Seeds were germinated at 25ºC according to ISTA rules. Seed germination was determined by dividing the germinated seeds to the total number of sown seeds.
This research was designed according to the split plots design. Data were subjected to ANOVA and the means were separated using the LSD multiple range test at P≤0.05. All the statistical analyses were performed using the JMP8 Software package.

RESULTS AND DISCUSSİON

Plant Measurements

Two tetraploid female parents and 6 diploid male parents were used in the experiment. Results of plant length (cm), main stem diameter (mm) and number of nodes are presented in Table 1. The highest plant length was measured in WL 92 (260.56), while the lowest value was found in ST 101 (131.75 cm). The thickest main stem diameter was obtained from WL 92 (8.62 mm) genotype, while the thinnest value was recorded WL 216 (7.43 mm). The highest number of nodes were obtained from WL 92 (32.83) and WL 259-B (31.67), which are in the same statistical group. The lower number of nodes were obtained from WL 134 (31.39) and ST 82 (25.25) and in the same statical group.

In considering plant length (260.56 cm), main stem diameter (8.62 mm) and number of nodes (32.83 number/plant); our results found to be lower than reported by Solmaz et al (2018) (341.3 cm, 11.1 mm, 38.1 number/plant repectively). While St 101 were used in both studies it is thought that the differences may caused by cultivation conditions.

Table 1. Plant Length, Main Stem Diameter and Number of Nodes in Tetraploid Female and Diploid Male Parents

Genotype Name	Plant Length (cm)	Main Stem Diameter (mm)	Number of Nodes
ST 82	176.14 D	8.38 B	25.25 D
ST 101	131.75 E	8.36 B	25.56 CD
Tetraploid Average	153.94	8.37	25.40
WL 134	215.81 C	8.01 C	31.39 A
WL 216	179.19 D	7.43 E	29.36 B
WL 259-B	218.17 C	7.73 D	31.67 A
WL 92	260.56 A	8.62 A	32.83 A
WL 124	236.03 B	8.44 AB	27.03 C
WL 235	245.11 B	8.35 B	29.19 B
Diploid Average	225.81	8.10	30.25

LSD $_{\text{(Plant Leinght)}}$: 12.57***; LSD $_{\text{(Main Shoot Diameter)}}$: 0.24***; LSD $_{\text{(Number of Nodes)}}$: 1.71***

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Fruit Setting Ratio, Fruit Yield and Fruit Measurements

Fruit setting rates (%), fruit yield (kg / m^2), fruit weight (g), fruit height (cm), fruit diameter (mm), rind thickness (mm) and TSS (%),values are presented in the Table 2-8.

Fruit setting ratio was found to be the highest (59.37%, 63.10% respectively) in ST 82 x WL134 and ST82 x WL 259-B cross, which are in the same statistical group. And the lowest value (35.18%) was obtained from the ST101 x WL 92 cross. Male flower number and genotype x male flower number interaction had not effects on fruit setting ratio.

Table 2. Fruit Setting Rates Obtained By Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (%)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	46.66 (50.68)	76.92 (50.80)	54.54 (49.53)	59.37 A
ST 82 x WL 216	33.33 (42.64)	54.54 (41.19)	50.00 (44.45)	45.96 B
ST 82 x WL 259-B	50.00 (52.87)	77.77 (53.31)	61.53 (53.69)	63.10 A
ST 101 x WL 92	38.88 (36.39)	33.33 (34.62)	33.33 (36.51)	35.18 C
ST 101 x WL 124	48.00 (39.32)	37.50 (39.27)	35.00 (39.12)	40.17 BC
ST 101 x WL 135	50.00 (42.77)	47.36 (42.97)	40.90 (41.66)	46.09 B
Number of Male Flowers Average	44.48	54.57	45.88	

LSD $_{(Genotype)}$: 5.29***; LSD $_{(Number\ of\ Male\ Flowers)}$: NS; LSD $_{(Genotype\ x\ Number\ Of\ Male\ Flowers)}$: NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Increase of male flower number had possitive effects on fruit yield and fruit weight (Table 3 and 4). The highest yield and weight were harvested from pollination with 2 and 3 male flowers (6.10 kg/m^2, 6.37 kg/m^2; 2315.59 g, 2373.70 g, respectively) while lowest yield and weight were obtained from 1 male flower pollination (5.29 kg/m^2; 1986.30 g). The highest yield was found in ST 82 x WL 259-B cross (7.62 kg/m^2), while the lowest yield (5.03 kg/m^2) was faunded in ST 101 x WL 135 cross. The highest fruit weight was obtained from ST 101 x WL 92 cross (2856.67g), while the heaviest were found in ST101 x WL 235 and ST 101 x WL 92 (1906.67 g, 1740.00 g respectively) crosses in the same statistical group. Genotype x male flower number interaction was not significant.

Table 3. Average Fruit Yield Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (kg / m^2)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	4.94	7.11	7.87	6.64 B
ST 82 x WL 216	4.96	6.51	7.13	6.20 BC
ST 82 x WL 259-B	7.13	8.17	7.54	7.62 A
ST 101 x WL 92	4.45	5.10	4.36	4.64 D
ST 101 x WL 124	5.05	4.90	6.28	5.41 CD
ST 101 x WL 135	5.24	4.83	5.02	5.03 D
Number of Male Flowers Average	5.29 B	6.10 A	6.37 A	

LSD $_{(Genotype)}$: 833.73***; LSD $_{(Number\ of\ Male\ Flowers)}$: 589.54***; LSD $_{(Genotype\ x\ Number\ Of\ Male\ Flowers)}$: NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Increase of male flower's amount in pollination had positive effects on fruit length and diameter (Table 5 and 6). The longest fruit was harvested from 3 male flowers (15.90 cm), while the shortest flower were obtained from 1 and 2 male flowers (14.78 cm, 15.11 cm respectively). Pollination with 2 and 3 male flowers had the widest fruit diameters (16.42 cm, 16,54 cm respectively). The longest fruit was obtained in ST 82 x WL 259-B cross (16.70 cm), while shortest fruit was determined ST 101 x WL 92 cross (13.90 cm). The widest fruit was obtained from ST 82 x WL 259-B (17.61 cm) cross, while the lowest diameter were found in ST 101 x WL 92, ST 101 x WL 124 and ST 101 x WL 235 crosses (15.28cm, 15.91 cm, 15.33 cm respectively). There was a significant difference between genotype and number of male flowers combinations in length of fruits. The most effective combination were ST 82 x WL 134 (17.48 cm) and ST 82 x WL 259-B (17.34 cm) in 3 male flower pollination. The least effective combination was found in ST 101 x WL 92 (13.38 cm) from 2 male flower.

Table 4. Average Fruit Weight (g) Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (g)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	1853.33	2664.67	2953.33	2490.44 B
ST 82 x WL 216	1860.00	2443.33	2676.67	2326.67 BC
ST 82 x WL 259-B	2673.33	3065.56	2831.11	2856.67 A
ST 101 x WL 92	1670.00	1913.33	1636.67	1740.00 D
ST 101 x WL 124	1894.44	1840.00	2357.78	2030.74 CD
ST 101 x WL 235	1966.67	1966.67	1786.67	1906.67 D
Number of Male Flowers Average	1986.30 B	2315.59 A	2373.70 A	

LSD $_{(Genotype)}$: 351.27***; LSD $_{(Number\ of\ Male\ Flowers)}$: 248.39***; LSD $_{(Genotype\ x\ Number\ Of\ Male\ Flowers)}$: NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Table 5. Length of Fruits Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (cm)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	14.27 def	16.39 ab	17.48 a	16.05 B
ST 82 x WL 259-B	15.59 bcd	17.16 a	17.34 a	16.70 A
ST 82 x WL 216	14.60 c-f	15.50 bcd	16.42 ab	15.51 BC
ST 101 x WL 92	14.65 c-f	13.38 f	13.67 ef	13.90 D
ST 101 x WL 124	14.44 def	13.93 ef	15.98 abc	14.78 C
ST 101 x WL 235	15.12 b-e	14.31 def	14.53 c-f	14.65 CD
Number of Male Flowers Average	14.78 B	15.11 B	15.90 A	

LSD $_{(Genotype)}$: 0.87***; LSD $_{(Number\ of\ Male\ Flowers)}$: 0.62***; LSD $_{(Genotype\ x\ Number\ Of\ Male\ Flowers)}$: 1.51***

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Table 6. Fruit Diameter Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (cm)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	16.02	16.96	17.73	16.90 AB
ST 82 x WL 259-B	17.46	18.04	17.32	17.61 A
ST 82 x WL 216	15.82	17.02	17.03	16.62 B
ST 101 x WL 92	14.87	15.37	15.60	15.28 C
ST 101 x WL 124	15.44	15.55	16.73	15.91 C
ST 101 x WL 235	15.60	15.55	14.83	15.33 C
Number of Male Flowers Average	15.87 B	16.42 A	16.54 A	

LSD $_{(Genotype)}$: 0.71***; LSD $_{(Number\ of\ Male\ Flowers)}$: 0.50***; LSD $_{(Genotype\ x\ Number\ Of\ Male\ Flowers)}$:NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Rind thickness of fruits was not significant in terms of statistical values (Table 7). Although not important, values ranged from 11.78 mm (ST 82 x WL 134 of 1 male flower) and 15.10 mm (ST 101 x WL 235 of 2 male flower).

Table 7. Rind Thickness of Fruits Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (mm)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	11.78	13.77	14.05	13.20
ST 82 x WL 259-B	12.64	12.85	12.30	12.60
ST 82 x WL 216	12.02	11.94	14.38	12.78
ST 101 x WL 92	13.57	14.15	13.13	13.62
ST 101 x WL 124	12.67	14.81	14.45	13.98
ST 101 x WL 235	14.57	15.10	12.39	14.02
Number of Male Flowers Average	12.88	13.77	13.45	

LSD $_{(Genotype)}$: NS; LSD $_{(Number\ of\ Male\ Flowers)}$: NS; LSD $_{(Genotype\ x\ Number\ of\ Male\ Flowers)}$:NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

TSS was found to be the highest **(**8.99%) in ST 101 x WL 92 and ST 101 x WL 235 (8.89%) cross, which are in the same statistical group (Table 8). The lowest value (6.57%) was obtained from the ST 82 x WL 134 cross. Male flower number and genotype x male flover number interaction had not effects on TSS.

Table 8. TSS Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (%)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	4.78	6.97	7.95	6.57 D
ST 82 x WL 216	7.20	8.17	7.97	7.78 BC
ST 82 x WL 259-B	6.83	7.01	7.21	7.01 CD
ST 101 x WL 92	8.67	8.55	9.75	8.99 A
ST 101 x WL 124	8.95	8.67	7.78	8.46 AB
ST 101 x WL 235	9.43	8.53	8.72	8.89 A
Number of Male Flowers Average	7.64	7.98	8.23	

LSD $_{(Genotype)}$: 1.08***; LSD $_{(Number\ of\ Male\ Flowers)}$: NS; LSD $_{(Genotype\ x\ Number\ Of\ Male\ Flowers)}$:NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

The values in terms of fruit setting ratio, fruit yield, rind thickness, fruit diameter and TSS varied in other reported studies. According to the results, this study in terms of fruit setting ratio (63.10 %) agree with the results (61.57 %) presented by Hussein (2017). Fruit weight was also found different when compared with other studies (Solmaz et al., 2018) . In considering rind thickness (15.10 mm) and fruit diameter (16.70 cm), the results found to be lower than reported by Solmaz et al. (2018) (17.07 mm, 22.3 cm respectively). These differences may be the result of using different rootstock and scion in graft combinations.

3.3. Seed Yield and Seed Measurements

The highest values in seed yield (g/fruit), 1000 seed weight (g), empty seed number (number/fruit) and full seed number (number/fruit) were determined in ST 82 x WL 134 (1.94 g/fruit, 55.12 g, 131.66 number/fruit, 36.49 number/fruit respectively), ST 82 x WL 216 (2.12 g/fruit, 53.08 seed weight, 128.06 number/fruit, 40.33 number/fruit respectively) and ST 82 x WL 259-B (1.78 g/fruit, 55.04 g weight, 143.50 number/fruit, 32.56 number/fruit respectively) crosses which are in the same statistical group. Otherwise the lowest values in seed yield (g/fruit), 1000 seed weight (g), empty seed number (number/fruit) and full seed number (number/fruit) were found in ST 101 x WL 92 (0.25 g/fruit, 38.61

seed weight, 59.89 number/fruit, 7.39 number/fruit respectively), ST 101 x WL 124 (0.44 g/fruit, 40.41 seed weight, 91.44 number/fruit, 13.09 number/fruit respectively) and ST 101 x WL 235 0.34 g/fruit, 39.42 seed weight, 75.59 number/fruit, 9.44 number/fruit, crosses in the same group. Male flower number and genotype x male flower number interaction had not effects on this seed parameters (Table 9, 10, 11 and 12).

Table 9. Average Seed Yield Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (g/fruit)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	1.15	1.52	3.17	1.94 A
ST 82 x WL 216	2.27	1.97	2.11	2.12 A
ST 82 x WL 259-B	2.08	1.74	1.54	1.78 A
ST 101 x WL 92	0.26	0.32	0.17	0.25 B
ST 101 x WL 124	0.32	0.37	0.63	0.44 B
ST 101 x WL 235	0.22	0.29	0.52	0.34 B
Number of Male Flowers Average	1.05	1.03	1.35	

$LSD_{(Genotype)}$: 0.58***; $LSD_{(Number\ of\ Male\ Flowers)}$: NS; $LSD_{(Genotype\ x\ Number\ of\ Male\ Flowers)}$:NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Table 10. Average 1000 Seed Weight Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (g)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	53.14	53.87	58.33	55.12 A
ST 82 x WL 216	53.90	49.40	55.93	53.08 A
ST 82 x WL 259-B	55.42	52.68	57.01	55.04 A
ST 101 x WL 92	39.77	35.72	40.33	38.61 B
ST 101 x WL 124	41.12	42.61	37.49	40.41 B
ST 101 x WL 235	33.21	44.30	40.74	39.42 B
Number of Male Flowers Average	46.09	46.43	48.31	

$LSD_{(Genotype)}$: 7.84***; $LSD_{(Number\ of\ Male\ Flowers)}$: $LSD_{(Genotype\ x\ Number\ of\ Male\ Flowers)}$:NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Table 11. Average Empty Seed Number Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (seed/fruit)

Genotype Name	Number of Male Flowers			Genotype Average
	1F	2F	3F	
ST 82 x WL 134	122.17	122.13	150.67	131.66 A
ST 82 x WL 216	122.83	144.83	116.50	128.06 A
ST 82 x WL 259-B	140.94	136.50	153.06	143.50 A
ST 101 x WL 92	71.33	55.50	52.83	59.89 B
ST 101 x WL 124	91.11	80.17	103.06	91.44 B
ST 101 x WL 235	63.00	90.44	73.33	75.59 B
Number of Male Flowers Average	101.90	104.93	108.24	

$LSD_{(Genotype)}$: 32.20***; $LSD_{(Number\ of\ Male\ Flowers)}$: NS; $LSD_{(Genotype\ x\ Number\ of\ Male\ Flowers)}$:NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Table 12. Average Full Seed Number Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (seed/fruit)

Genotype Name	Number of Male Flowers 1F	2F	3F	Genotype Average
ST 82 x WL 134	26.67	28.31	54.50	36.49 A
ST 82 x WL 216	42.67	40.33	38.00	40.33 A
ST 82 x WL 259-B	36.83	33.00	27.83	32.56 A
ST 101 x WL 92	7.30	8.83	6.00	7.39 B
ST 101 x WL 124	1.78	8.83	19.67	13.09 B
ST 101 x WL 235	9.00	7.83	11.50	9.44 B
Number of Male Flowers Average	22.21	21.19	26.25	

LSD $_{(Genotype)}$: 9.47***; LSD $_{(Number\ of\ Male\ Flowers)}$: NS; LSD $_{(Genotype\ x\ Number\ Of\ Male\ Flowers)}$:NS

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

The values of the embryo/seed ratio are presented in Table 13. The highest values were found in ST 82 x WL 134 (43.70%) and ST 101 x WL 92 (42.43%), while the lowest values were determined from ST 82 x WL 216 (33.75%) and ST 101 x WL 124 (32.76%) crosses which are in the same group. There was a significant difference between genotype and number of male flowers combinations in embryo/seed ratio. The most effective combination were obtained from 2 male flower of ST 101 x WL 92 (52.31%) while, the lowest value were found in 1 male flower ST 82 x WL 259-B (30.14%), 2 male flower of ST 82 x WL 216 (29.71%), 3 male flowers of ST 101 x WL 92 (30.00%), 2 male flowers in ST 101 x WL 124 (27.95%) and 2 male flowers in ST 101 x WL 235 (30.36%). Male flower number had not effects on this seed parameters.

Table 13. Average Embryo/Seed Ratio Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (%)

Genotype Name	Number of Male Flowers 1F	2F	3F	Genotype Average
ST 82 x WL 134	44.72 ab (41.99)	39.95 abc (39.22)	46.42 ab (42.97)	43.70 A
ST 82 x WL 216	34.77 bc (36.15)	29.71 c (33.04)	36.75 bc (37.33)	33.75 B
ST 82 x WL 259-B	30.14 c (33.06)	46.03 ab (42.73)	39.01 bc (38.63)	38.40 AB
ST 101 x WL 92	44.97 ab (42.08)	52.31 a (46.37)	30.00 c (32.88)	42.43 A
ST 101 x WL 124	35.25 bc (36.22)	27.95 c (31.89)	35.08 bc (36.22)	32.76 B
ST 101 x WL 235	45.24 ab (42.28)	30.46 c (33.46)	35.56 bc (36.61)	37.09 AB
Number of Male Flowers Average	39.18	37.74	37.14	

LSD $_{(Genotype)}$: 4.32***; LSD $_{(Number\ of\ Male\ Flowers)}$: NS; LSD $_{(Genotype\ x\ Number\ of\ Male\ Flowers)}$: 7.48***

NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

Seed germination rate was found to be highest (45.00%) in ST 82 x WL 216 cross, while low germination rates were determined in ST 101 x WL 92 (6.67%) and ST 101 x WL 124 (8.33%) crosses. There was a significant difference between genotype and number of male flowers combinations in seed germination rate. The most effective combinations were obtained from 2 male flower of ST 82 x WL 134 (65.00%) and 2 male flowers of ST 82 x WL 216 (40.00%) crosses. No germination was found in ST 101 x WL 92; 3 male flowers (00.00%) and ST 101 X WL 124; 3 male flower (00.00%) pollination. Here, the number of male flowers had no effect on germination rate, which ranged between 23.77%–31.67% for all seed lots.

Table 14. Average Seed Germination Rate Obtained by Pollination of Tetraploid Female with Different Number of Diploid Male Flowers (%)

Genotype Name	Number of Male Flowers			Genotype Average
	1F %	2F %	3F %	
ST 82 x WL 134	35.00 bcd (42.02)	65.00 a (40.28)	5.00 def (18.79)	35.00 AB
ST 82 x WL 216	35.00 a-d (35.19)	40.00 a (52.62)	35.00 bcd (34.68)	45.00 A
ST 82 X WL 259-B	20.00 cde (25.59)	40.00 abc (38.05)	45.00 abc (40.79)	35.00 AB
ST 101 x WL 92	10.00 ef (15.42)	10.00 ef (15.42)	0.00 f (1.81)	6.67 C
ST 101 X WL 124	15.00 def (18.79)	10.00 def (18.79)	0.00 f (1.81)	8.33 C
ST 101 x WL 235	40.00 abc (13.13)	0.00 f (13.13)	55.00 ab (13.13)	31.67 B
Number of Male Flowers Average	25.83	31.67	23.33	

$LSD_{(Genotype)}$: 10.33***; $LSD_{(Number\ of\ Male\ Flowers)}$: NS; $LSD_{(Genotype\ x\ Number\ of\ Male\ Flowers)}$: 17.90***
NS: Not Significant; *: ***: P ≤ 0.001; **: P ≤ 0.01; *: P ≤ 0.05: shows difference according to LSD comparison

The results of this study in terms of seed yield, 1000 seed weight, full seeds number and germination rate were found to be different from the results reported by other researhes. Solmaz et al, (2018) found the highest seed yield as 5.6 g/fruit, the highest 1000 seed weight as 43.5 g. The highest ratio of embryo/seed was 33.39% in the study of Houssein, (2017). Phat et al. (2015) reported that, the highest seed germination rates were found between 67% and 80%. These differences may be explained by thicker seed coat and the thinner embryos of tetraploids than diploids. Climatic conditions and environmental factors may also affected seed yield and seed number.

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