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Evaluation of F_1 hybrids for horticultural and quality traits and pumpkin yellow vein mosaic disease resistance in pumpkin

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ABSTRACT

Pumpkins being cheap and having higher medicinal value, can act as a saviour to low-income families. However, being a minor crop, little attention has been paid to its improvement. The hybridization in pumpkins is economically feasible due to the monoecious nature and higher number of seeds per fruit. Moreover, developing superior hybrids can enhance production and consumption through ease in cultivation, meeting consumers' preferences and suitability to different seasons. Hitherto, 34 F1 hybrids were evaluated for standard heterosis during spring and rainy seasons. H9 (P-225 × GFR-6783) and H28 (VR-1365 × VR-13364) hybrids exhibited maximum standard heterosis for yield per plant and can be exploited for commercial cultivation. Resistance to PYVMD is a pre-requisite for the successful cultivation of pumpkin in the rainy season. 11 hybrids (H24, H25, H26, H27, H28, H29, H30, H31, H32, H33 and H34) tolerant to PYVMD offered the advantage of cultivating pumpkin in both seasons.

Keywords: *Cucurbita moschata*, PYVMD, Standard heterosis, Virus, Resistance.

INTRODUCTION

Pumpkin's popularity is expanding day by day due to its trademark taste and health benefits (carotene, minerals and fibres) at a reasonable price (Dhiman *et al.,* 5). But being a minor crop, it has received less attention as compared to other cucurbits. In this context, hybridization is the primary tool exploited by breeders to improve any crop (Kumar *et al.,* 11 and 12). The monoecious nature of the flower and the availability of a large number of seeds per fruit make its hybrid seed production economical. Moreover, significant heterosis has been reported for various traits by many workers (Bairagi *et al.,* 3; Pandey *et al*., 15).

Heterosis breeding can enhance production and consumption by developing superior hybrids that meet consumers' acceptability and make them suitable for cultivation in different seasons. The compact vines or bushy plants offer early maturity, accommodate more plants per unit area and ease intercultural operations leading to high yield. The varying fruit size causes difficulty in packaging and handling during the market chain (Maynard *et al.,* 13). Moreover, now consumers prefer whole medium-sized fruits over cut pieces due to unsanitary problems. Furthermore, severe incidence of pumpkin yellow vein mosaic disease (PYVMD) during rainy season restricts cultivation of pumpkin to the summer season only. It is being transmitted by whitefly (Jayashree *et al.,* 10) and causes up to 90% loss of the crop (Singh *et al.,* 17). Therefore, there is a need to develop hybrids with bushy growth habits, medium-sized fruits and virus resistance for year-round cultivation of pumpkin.

MATERIALS AND METHODS

Eighteen genotypes namely P1 (AC-1301), P2 (GFR-3154), P3 (GFRB-6712), P4 (GFR-6783), P5 (GFR-6791), P6 (MVSR-6711), P7 (MRBDG-6721), P8 (Punjab Samrat), P9 (P-108), P10 (P-225), P11 (PHG-2312), P12 (PHG-6722), P13 (VR-750), P14 (VR-1365), P15 (VR-1371), P16 (VR-1614), P17 (VR-1814) and P18 (VR-13364) were hybridized randomly to generate 34 hybrids (Table 1) in Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University(PAU), Ludhiana during spring season, 2019.

These hybrids were evaluated with 3 and 2 commercial checks during rainy 2019 and spring 2020, respectively. Punjab Nawab (PN), the first PYMVD-resistant variety released by PAU (Dhatt *et al*., 4) comprised the resistant check, Punjab Samrat (PS) being highly susceptible to PYMVD constituted the susceptible check. PPH-1, F_1 hybrid with bush growth habit from PAU and BSS-750, F_1 hybrid from Kalash Seeds constituted commercial checks in this investigation.

Nursery of experimental material for both seasons was raised in pro-trays. For screening against PYVMVD, the pro-trays were kept in the screen house for artificial mass inoculation by viruliferous whiteflies during the rainy season (Verma *et al*., 20). The experiment was carried out in Randomized Complete

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Table 1. Hybrid combinations along with their codes.

Hybrid Combinations	Codes	Hybrid Combinations	Codes	Hybrid Combinations	Codes	Hybrid Combinations	Codes
P2 × P3	H1	P12 × P4	H10	P2 × P7	H19	P14 × P18	H28
P4 × P3	H2	P1 × P6	H11	P4 × P7	H20	P15 × P18	H29
P8 × P3	H3	P2 × P6	H12	P8 × P7	H21	P13 × P18	H30
P11x P3	H4	P4 × P6	H13	P11 xP7	H22	P14 × P18	H31
P12x P3	H5	P5 × P6	H14	P12 xP7	H23	P15 × P18	H32
P2 × P4	H6	P8 × P6	H15	P14 xP13	H24	P16 × P18	H33
P8 × P4	H7	P9 × P6	H16	P15 × P13	H25	P17 × P18	H34
P9 × P4	H8	P10 × P6	H17	P14 × P16	H26		
P10x P4	H9	P12 × P6	H18	P15 × P16	H27		

Block Design with three replications. Hybrids, vine parents, and checks were transplanted on 3 m wide bed, while bushy parents and check on 1.5m wide bed with 45cm plant-plant spacing on both sides of bed (Anonymous, 1).

Data were recorded on 5 random plants within each treatment for 20 traits viz., vine length(cm), internodal length(cm), number of primary branches, leaf blade length(cm), leaf blade width(cm), petiole length(cm), node at 1st female flower, days to 50% female flowers, days to harvest, polar diameter(cm), equatorial diameter(cm), fruit shape index, fruit flesh thickness(cm), average fruit weight(kg), number of fruits per plant, fruit yield per plant(kg/plant), TSS(°Brix), Vitamin-C(mg/100g FW), carotenoid content(mg/100g FW), and dry matter(%). TSS was estimated with the help of refractometer while Vitamin-C was estimated as per the procedure given by Harris and Ray (8). Dry matter was estimated by oven drying pulp of each genotype at 60-65 ˚C whereas spectrophotometric estimation was used to analyse the carotenoid content. The heterosis over checks were estimated as per method of Fonseca and Patterson (7). The genotypes were characterized for response to PYVMD by using 0-4 rating scale (Verma *et al.*, 20)

RESULTS AND DISCUSSION

In the spring season, 34 hybrids were evaluated for 20 traits. But in rainy season, only 11 hybrids survived the severe incidence of PYVMD and were evaluated.

Vine and internodal length are indicators of growth and vigour of the plant. Hybrids with negative heterosis over PPH-1 can be utilized for intensive cultivation, while those with positive heterosis over BSS-750 and PN will give fruits for longer duration. Three and four hybrids showed significant negative heterosis over PPH-1, while three and five hybrids had significant positive heterosis over BSS-750 for vine and internodal length, respectively (Table 2). The heterotic hybrids in both magnitudes have been reported among 21 hybrids by Pradeepika (16).

Number of primary branches is associated with higher number of fruits. Only two hybrids in both seasons had positive and significant heterotic effects. The positive heterotic effect for leaf blade length and width improved photosynthetic efficiency of this crop (Singh, 18). In spring season, H2 and H20 while in rainy season, H32 and H26 showed highest heterotic value. The compact growth habit could be obtained in hybrids showcasing negative heterotic effects for petiole length. Only two hybrids, H14 and H16 during spring season, (Table 2) whereas no hybrids outperformed the checks for small petiole length in rainy season. These observations were in agreement with Singh (18).

Earliness is desirable to fetch high market price and vacate the field early for next crop, thereby enhancing cropping intensity. The traits contributing toward earliness are node at 1st female flower, days to 50% female flowers and days to harvest. Hybrids offering earliness over checks during spring season were H14, H18, and H11, whereas during rainy season these were H31, H33, and H34 showing worth of hybridization in developing early hybrids. Jayanth *et al.* (9) reported significant heterosis, while Singh (18) observed non-significant heterosis for these traits. Polar and equatorial diameter decide the fruit shape and size. Small fruits are desirable for elementary families while large fruits favours processing and long-distance transportation. The negative heterotic effects of polar and equatorial diameters were recorded in thirteen and four hybrids during spring season. Whereas during rainy season no hybrid surpassed the checks. Seven and twenty hybrids had maximum polar and equatorial diameters during spring season, while during rainy season eight hybrids outperformed the checks (Table 3).

Table 2. Standard heterosis (%) for growth and earliness related traits during spring and rainy seasons.

Traits	Season	Range (F_1 Hybrids)	SH over	Range of SH (%)	Direction of significance	No. of heterotic hybrids	Best three hybrids with SH (%)		
Vine length (m)	SS	0.47-4.65	PPH-1	-44.04-453.57	Positive	27	H29(453.57)	H25(432.14)	H27(397.61)
					Negative	3	H14(-44.04)	H18(-27.38)	H11(-16.66)
			BSS-750	-87.66-22.05	Positive	3	H29(22.05)	H25(17.32)	H27(9.71)
					Negative	30	H14(-87.66)	H18(-83.98)	H11(-81.62)
	RS	1.77-4.78	PN	-38.97-64.83	Positive	7	H29(64.83)	H25(62.41)	H27(49.66)
					Negative	3	H31(-38.97)	H33(-26.90)	H34(-7.93)
			BSS-750	-54.03-24.16	Positive	3	H29(24.16)	H25(22.34)	H27(12.73)
					Negative	8	H31(-54.03)	H33(-44.94)	H34(-30.65)
Internodal length (cm)	SS	1.37-8.86	PPH-1	-46.06-248.17	Positive	25	H29(248.17)	H27(228.34)	H5(216.92)
					Negative	4	H4(-46.06)	H16(-43.70)	H11(-40.94)
			BSS-750	-75.04-61.33	Positive	5	H29(61.33)	H27(51.91)	H5(46.63)
					Negative	29	H4(-75.04)	H16(-73.95)	H5(-72.67)
	RS	3.71-8.99	PN	-31.80-65.26	Positive	4	H29(65.26)	H27(56.80)	H25(50.74)
					Negative	6	H24(-31.80)	H26(-29.60)	H34(-15.63)
			BSS-750	-32.91-62.57	Positive	4	H29(62.57)	H27(54.25)	H25(48.28)
					Negative	7	H24(-32.91)	H26(-30.74)	H34(-17.00)
Number of primary branches	SS	1.63-4.80	PPH-1	-59.85-18.22	Positive	2	H19(18.22)	H18(11.08)	-
			BSS-750	-39.85-77.12	Positive	14	H19(77.12)	H18(66.42)	H11(50.18)
	RS	2.61- 4.73	PN	-31.13-24.80	Positive	2	H31(24.80)	H24(10.82)	-
			BSS-750	-4.74-72.63	Positive	7	H31(72.63)	H24(53.28)	H32(36.86)
Leaf blade length (cm)	SS	8.07-22.12	PPH-1	-39.02-67.19	Positive	23	H2(67.19)	H20(64.02)	H6(61.14)
			BSS-750	-29.58-93.01	Positive	27	H2(93.01)	H20(89.35)	H6(86.04)
	RS	11.04-17.78	PN	3.66-66.95	Positive	11	H32(66.95)	H25(52.21)	H26(51.36)
			BSS-750	-4.08-54.47	Positive	9	H32(54.47)	H25(40.83)	H26(40.05)
Leaf blade width (cm)	SS	10.67-30.44	PPH-1	-41.85-65.88	Positive	8	H2(65.88)	H20(56.02)	H4(54.71)
			BSS-750	-29.34-101.59	Positive	20	H2(101.59)	H20(89.60)	H4(88.01)
	RS	14.93-21.27	PN	-0.13-42.27	Positive	10	H26(42.27)	H32(41.20)	H25(31.64)
			BSS-750	-1.39-40.49	Positive	9	H26(40.49)	H32(39.43)	H25(29.99)
Petiole length (cm)	SS	7.47-39.08	PPH-1	-62.2-97.67	Negative	10	H14(-62.21)	H16(-35.91)	H18(-22.86)
			BSS-750	-44.00-192.95	Negative	2	H14(-44.00)	H16(-5.02)	-
	RS	16.86-32.44	PN	33.44-156.44	Negative	0	-	-	-
			BSS-750	26.16-142.45	Negative	0	-	-	-
Node at 1st female flower	SS	2.50-20.42	PPH-1	12.11-815.69	Negative	0	-	-	-
			BSS-750	-83.59-34.08	Negative	30	H14(-83.59)	H18(-80.30)	H11(-77.02)
	RS	12.30-27.00	PN	-48.17-13.78	Negative	7	H31(-48.17)	H33(-42.52)	H34(-36.58)
			BSS-750	-48.75-12.50	Negative	7	H31(-48.75)	H33(-43.17)	H34(-37.29)
Days to 50% female flowers	SS	35.67-57.15	PPH-1	-20.73-27.00	Negative	13	H14(-20.73)	H18(-19.04)	H11(-17.49)
			BSS-750	-41.35-(-)6.03	Negative	34	H14(-41.35)	H18(-40.10)	H11(-35.33)
	RS	52.29-64.13	PN	-3.75-18.04	Negative	5	H31(-3.75)	H33(-3.33)	H34(-2.78)
			BSS-750	-18.45-0.02	Negative	10	H31(-18.45)	H33(-18.09)	H34(-17.62)
Days to harvest	SS	72.28-100.20	PPH-1	-12.56-21.22	Negative	11	H14(-12.56)	H18(-11.41)	H11(-10.08)
			BSS-750	-29.30-(-)1.99	Negative	34	H14(-29.30)	H18(-28.37)	H11(-27.29)
	RS	90.49-115.52	PN	-4.88-25.29	Negative	1	H31(-3.17)	-	-
			BSS-750	-24.65-(-)0.75	Negative	10	H31(-21.71)	H33(-19.54)	H34(-19.49)

SS= Spring season, RS= Rainy season, SH= Standard heterosis, and PN= Punjab Nawab

Table 3. Standard heterosis (%) for yield and its related traits during spring and rainy seasons.

Traits	Season	Range (F_1 Hybrids)	SH over	Range of SH (%)	Direction of significance	No. of heterotic hybrids	Best three hybrids with SH (%)		
Polar diameter (cm)	SS	5.50-16.74	PPH-1	-59.41-23.54	Positive	7	H8(23.54)	H7(17.34)	H22(8.93)
					Negative	27	H14(-59.41)	H18(-36.53)	H9(-32.62)
			BSS-750	-53.19-42.47	Positive	18	H8(42.47)	H7(35.32)	H22(25.62)
					Negative	13	H14(-53.19)	H18(-26.81)	H9(-22.30)
	RS	11.34-14.66	PN	16.07-50.05	Positive	11	H34(50.05)	H31(42.07)	H26(40.53)
					Negative	0	-	-	-
			BSS-750	-3.24-25.09	Positive	8	H34(25.09)	H31(18.43)	H26(17.15)
					Negative	1	H29(-3.24)	-	-
Equatorial diameter (cm)	SS	8.28-24.73	PPH-1	-43.75-68.00	Positive	26	H8(68.00)	H7(44.97)	H28(40.76)
					Negative	4	H11(-43.75)	H31(-14.20)	H33(-5.77)
			BSS-750	-47.63-56.42	Positive	20	H8(56.42)	H7(34.98)	H28(31.06)
					Negative	9	H11(-47.63)	H31(-20.11)	H33(-12.27)
	RS	12.79-20.96	PN	-17.59-35.05	Positive	8	H28(35.05)	H27(32.41)	H25(21.46)
					Negative	3	H31(-17.59)	H33(-9.79)	H32(-4.06)
			BSS-750	-19.00-32.74	Positive	8	H28(32.74)	H27(30.15)	H25(19.38)
					Negative	3	H31(-19.00)	H33(-11.34)	H32(-5.70)
Fruit shape index	SS	0.57-1.09	PPH-1	-38.04-18.48	Positive	1	H31(18.48)	-	-
					Negative	33	H9(-38.04)	H2(-36.96)	H18(-36.96)
			BSS-750	-22.97-47.03	Positive	6	H31(47.03)	H33(18.92)	H34(12.16)
					Negative	20	H9(-22.97)	H2(-21.62)	H18(-21.62)
	RS	0.60-1.08	PN	-4.76-71.43	Positive	6	H31(71.43)	H33(38.10)	H34(31.75)
					Negative	0	-	-	-
			BSS-750	-18.92-45.95	Positive	4	H31(45.95)	H33(17.57)	H34(12.16)
					Negative	5	H27(-18.92)	H25(-16.22)	H30(-14.86)
Fruit flesh thickness (cm)	SS	1.24-4.13	PPH-1	-59.27-36.75	Positive	5	H4(36.75)	H2(26.82)	H19(18.87)
			BSS-750	-54.41-51.84	Positive	9	H4(51.84)	H2(40.81)	H19(31.99)
	RS	2.17-3.37	PN	-3.56-49.78	Positive	10	H29(49.78)	H25(36.44)	H24(24.44)
			BSS-750	-19.63-24.81	Positive	3	H29(24.81)	H25(13.70)	H24(3.70)
Average fruit weight (kg)	SS	0.58-5.06	PPH-1	-49.12-343.86	Positive	27	H10(343.86)	H7(240.35)	H28(181.58)
					Negative	4	H14(-49.12)	H33(-33.33)	H3(-27.19)
			BSS-750	-62.58-226.45	Positive	16	H10(226.45)	H7(150.32)	H28(107.10)
					Negative	9	H14(-62.58)	H33(-51.23)	H3(-46.45)
	RS	0.79-3.25	PN	-46.26-121.09	Positive	6	H28(121.09)	H27(69.39)	H25(38.78)
					Negative	4	H33(-46.26)	H31(-44.90)	H30(-19.05)
			BSS-750	-48.37-112.42	Positive	5	H28112.42)	H27(62.75)	H25(33.33)
					Negative	4	H33(-48.37)	H31(-47.06)	H30(-22.22)
Number of fruits per plant	SS	1.00-2.65	PPH-1	-36.31-68.79	Positive	5	H15(68.79)	H3(61.15)	H1(50.96)
			BSS-750	-31.97-80.27	Positive	7	H15(80.27)	H3(72.11)	H1(61.22)
	RS	1.12-1.76	PN	-38.46-3.30	Positive	0	-	-	-
			BSS-750	-21.13-23.94	Positive	2	H31(23.94)	H29(20.42)	-
Fruit yield per plant (kg/plant)	SS	0.75-5.15	PPH-1	-53.13-221.88	Positive	27	H9(221.88)	H10(218.75)	H28(186.25)
			BSS-750	-67.11-125.88	Positive	15	H9(125.88)	H10(123.68)	H28(100.88)
	RS	1.14-4.35	PN	-57.62-61.71	Positive	3	H28(61.71)	H27(24.91)	H29(20.45)
			BSS-750	-48.65-95.95	Positive	4	H28(95.95)	H27(51.35)	H29(45.95)

SS= Spring season, RS= Rainy season, SH= Standard heterosis, and PN= Punjab Nawab

Elsharkawy *et al.* (6) also reported heterotic effects in both directions for these traits.

Fruit shape index is estimated from ratio of polar to equatorial diameter. Only one hybrid in spring, whereas four in rainy season had maximum heterosis for fruit shape index indicating oval to oblong fruit shape with less seed cavity. While, twenty hybrids during spring with minimum fruit shape index exhibited round and flat shape with more seed cavity. The positive heterotic effect for flesh thickness is desirable to develop hybrids with more edible portion. The highest heterotic effect was seen in H4 and H29 during spring and rainy seasons (Table 3), respectively. Tamilselvi *et al.* (19) also obtained heterosis in his genetic material of 36 hybrids.

Fruit weight is a major trait considered in any hybrid development programme as it directly contributes to yield. The positive heterosis effects were noticed in sixteen and five hybrids during spring and rainy seasons, respectively. The significant heterosis for minimum fruit weight was exhibited by four hybrids in each season (Table 3). Singh (18) and Elsharkawy *et al.* (6) also estimated heterosis for this trait. The positive heterosis was considered for obtaining hybrids with higher number of fruits per plant. H15 and H31 outyielded all hybrids for this trait. For fruit yield per plant, fifteen and three hybrids during spring and rainy seasons, respectively (Table 3) expressed their potential. Kumar *et al.* (11) too reported heterosis for this trait.

The vitamin C, carotenoid content and TSS are associated with nutritional quality, while dry matter improves the shelf life of pumpkin. The highest positive heterotic effect was observed in H33 for TSS, whereas for vitamin C, carotenoid content and dry matter was seen in H9 and H27 (Table 4) deciphering their potential in processing industries. Kumar *et al.* (12) and Pandey *et al.* (15) too reported heterotic effects for these traits.

PYVMD is a devastating disease of pumpkin in India during rainy season (Muniyappa *et al*., 14). This disease occurs throughout cropping period. Therefore, screening was done at 4 stages namely nursery, vegetative, flowering and fruiting (Table 5). Artificial screening at nursery stage categorised 34 hybrids into four resistant (H24, H28, H32, H34), seven moderately resistant (H25, H26, H27, H29, H30, H31, H33) and remaining 23 as susceptible to PYMVD. Upon transplantation, reaction of resistant and moderately resistant hybrids remained same at vegetative stage, but shifted to moderately resistant at flowering and fruiting stage. Change in disease reaction could be due to increment in viral/whitefly load. Parents exhibited similar disease reaction as of hybrids (Table 5). Similar findings had been reported by Arvind (2) against yellow mosaic disease in bitter gourd.

The existence of high genetic variability among parents for majority of traits has successfully yielded heterotic hybrids in the current study. Majority of the

Table 4. Standard heterosis (%) for quality traits during spring and rainy seasons.

Traits	Season	Range (F_1 Hybrids)	SH over	Range of SH (%)	Direction of significance	No. of heterotic hybrids	Best three hybrids with SH (%)		
TSS (°Brix)	SS	3.22-10.20	PPH-1	-54.65-43.66	Positive	6	H33(43.66)	H7(20.56)	H29(20.56)
			BSS-750	-10.56-183.11	Positive	25	H33(183.33)	H7(137.78)	H29(137.78)
	RS	3.57-10.00	PN	-59.57- 13.25	Positive	1	H33(13.25)	-	-
			BSS-750	0.00-180.11	Positive	10	H33(180.11)	H29(140.62)	H27(84.31)
Vitamin C (mg/100g FW)	SS	24.22-99.56	PPH-1	-22.67-217.88	Positive	31	H9(217.88)	H5(212.93)	H10(204.12)
			BSS-750	-34.58-168.94	Positive	26	H9(168.94)	H5(164.78)	H10(157.29)
	RS	34.69-74.27	PN	99.37-326.84	Positive	11	H29(326.84)	H27(314.20)	H30(302.36)
			BSS-750	-6.14-100.95	Positive	7	H29(100.95)	H27(94.99)	H30(89.42)
Carotenoid content (mg/100g FW)	SS	3.03-40.23	PPH-1	-44.10-642.25	Positive	29	H9(642.25)	H7(611.62)	H10(549.82)
			BSS-750	-76.09-217.77	Positive	13	H9(217.77)	H7(204.66)	H10(178.20)
	RS	2.99-20.01	PN	-67.81-115.39	Positive	6	H27(115.39)	H29(97.52)	H28(80.19)
			BSS-750	-76.29-58.68	Positive	4	H27(58.68)	H29(45.52)	H28(32.75)
Dry matter (%)	SS	2.60-12.23	PPH-1	-68.71-47.17	Positive	7	H9(47.17)	H7(37.79)	H27(28.88)
			BSS-750	-50.48-132.95	Positive	16	H9(132.95)	H7(118.10)	H27(104.00)
	RS	3.93-10.62	PN	-40.00-62.14	Positive	5	H27(62.14)	H33(31.30)	H32(30.84)
			BSS-750	-24.42-104.23	Positive	8	H27(104.23)	H33(65.38)	H32(64.81)

SS= Spring season, RS= Rainy season, SH= Standard heterosis, PN= Punjab Nawab and FW= Fresh weight.

Table 5. Screening of hybrids against PYVMD under epiphytotic conditions during rainy season.

Hybrids	Disease reaction at different stages											
	Nursery			Vegetative			Flowering			Fruiting		
	Cross	P 1	P 2	Cross	P 1	P 2	Cross	P 1	P 2	Cross	P 1	P 2
H24	R	R	R	R	R	MR	MR	MR	MR	MR	MR	MR
H25	MR	MR	R	MR	MR	MR	MR	MR	MR	MR	MR	MR
H26	MR	R	R	MR	R	R	MR	MR	MR	MR	MR	MR
H27	MR	MR	R	MR	MR	R	MR	MR	MR	MR	MR	MR
H28	R	R	R	R	R	MR	MR	MR	MR	MR	MR	MR
H29	MR	MR	R	MR	MR	MR	MR	MR	MR	MR	MR	MR
H30	MR	R	MR	MR	R	MR	MR	MR	MR	MR	MR	MRw
H31	MR	R	MR	MR	R	MR	MR	MR	MR	MR	MR	MR
H32	R	MR	MR	R	MR	MR	MR	MR	MR	MR	MR	MR
H33	MR	R	MR	MR	R	MR	MR	MR	MR	MR	MR	MR
H34	R	R	MR	R	R	MR	MR	MR	MR	MR	MR	MR
PN (RC)		R			R			R			R	
BSS (RC)		MR			MR			MS			MS	
PS (SC)		S			S			HS			HS	

P1= Female parent, P2= Male Parent, HR = Highly resistant, R= Resistant, MR= Moderately resistant, MS= Moderately susceptible, S= Susceptible, HS= Highly susceptible, RC= Resistant check and SC= Susceptible check.

hybrids showed noteworthy improvement in all traits as compared to their parents in desirable direction. These significant hybrids over checks shall further be tested in multilocation trials to confirm their potential and to identify the best hybrids over seasons and locations for commercialization.

AUTHORS' CONTRIBUTION

Conceptualization of research (ASD and MS); Designing of the experiments (ASD, MS and AS); Contribution of experimental materials (ASD, MS, AS and MK); Execution of field/lab experiments and data collection (MK, MS, AS, JSK); Analysis of data and interpretation (MK, MS, AS, OPM, NC, MKS); Preparation of the manuscript (MK and MS).

DECLARATION

The authors declare that they have no conflict of interest.

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