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Heterosis for Root Yield and Quality Characters in Ashwagandha

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A B S T R A C T

An investigation as undertaken study the nature and magnitude of heterosis in ashwagandha for root yield components involving 11 germplasm 3 lines and 6 testers viz. RAS-7, RAS-15, WS-90-111, WS-90-12, WS-90-146, MSW-306, MWS-310, IGAU-1 and Poshita are selected and crosses were attempted using L x T design (Kempthorne, 1957). JA-20 and JA-134 were used as check varieties. heterosis was significant and positive for most of the characters, which revealed that its utilization in the ashwagandha breeding programme could be useful. The cross RAS-15 X WS-90-111 recorded negative heterosis over the better parent for days to 50% flowering, indicating scope for its utilization in evolving early flowering plant types. The hybrids IGAU-1 X WS-90-111, RAS-15 X MWS-310, RAS-7 X MWS-306, RAS-15 X WS-90-111 etc. showed good performance in terms of relative heterosis. The hybrids RAS-7 X MWS-306, IGAU-1 X WS-90-146, IGAU-1 X WS-90-111 etc. showed good performance in terms of better parent heterosis. The hybrids IGAU-1 X WS-90-111, IGAU-1 X WS-90-146, RAS-7 X MWS-306, RAS-7 X Poshita, RAS-15 X WS-90-146, RAS-15 X MWS-310 etc. showed good performance over both checks JA-20 and JA-134. These crosses could be exploited for obtaining high fresh root yield / plant.

Introduction

Ashwagandha, the 3rd important prioritized medicinal plant listed by NMPB is also known as Indian Ginseng. Ashwagandha is highly popular herb and widely used in lot of ayurvedic formulations, nutracitical product and other herbal product. Chhattisgarh is extremely rich and unique in bio-cultural-diversity, for medicinal plants as well as for ashwagandha, therefore the Government has declared, Chhattisgarh as Herbal State. This herb has a central and prominent place in Ayurvedic medicine. Ashwagandha is referred to as a “Royal Herb” because of its multifarous rejuvenative effects on the human body, It is a multipurpose herb that acts on various systems of the human body; the neurological system, the immune system, the energy-production system, the endocrinal system and the reproductive system. It is one of the important medicinal plants commercially cultivated in north western region of Madhya Pradesh for long period as a dry land crop in late kharif season. It belongs to the family Solanaceae that grows or reaches about 30-150 cm in height. It is erect, evergreen, tomentose shrub, found throughout the drier parts of India in waste places and on bunds. Roots are stout fleshy, whitish brown; leaves simple ovate, glabrous, those in the floral region smaller and opposite; flowers inconspicuous, greenish or lurid-yellow, in axillary umbellate cymes; berries small, globose, orange-red when mature, enclosed in the persistent calyx; seeds yellow, reniform. The roots are the main portions of the plant used therapeutically. The withaniods, somniferin and several other alkaloids present in the roots and to some extent leaves and seeds are used in Ayurvedic and Unani medicines particularly for hiccups, bronchitis, rheumatism, dropsy, several female disorders, stomach and lung inflammation and skin diseases. It has a characteristic odour and is bitter in taste. Ashwagandha (*Withania somnifera*) is a plant used in medicine from the time of Ayurveda, the ancient system of Indian medicine.

The dried roots of ashwagandha (*Withania somnifera*) Plants are categorized as rasayanas and have been used as antioxidant, adaptogen, aphrodisiac, liver tonic, anti-inflammatory agent, astringent and more recently to treat ulcers, bacterial infections, venom toxins and senile dementia. The root quality of ashwagandha encompasses chemical quality and physical (textural) quality (Kumar *et al.*, 2011). The medicinal properties of ashwagandha roots are attributed to the chemical quality i.e. presence of total alkaloids in them. The climatic condition of Chhattisgarh is quite different from the other traditional ashwagandha growing regions hence, there is urgent need of systematic breeding approach to develop suitable and high yielding varieties with desirable characteristics for Chhattisgarh plain.

Materials and Methods

The experimental material used in the present study consists of three lines, five testers and two checks as presented in table 1. The selected three line and six testers were arranged to generate a set of hybrid in a line x tester manner as proposed by Kempthrone (1957). The crosses was attempted by emasculation of the buds at pre-anthesis stage was done without damaging the pistils. The open flowers close to the emasculate buds were removed. The pollinated flower were immediately bagged again and labeled properly with date and cross combination. In this way 18 crosses were made in the present study. The bagged flowers were harvested separately from mother plants. The hybrid seeds of each cross were collected separately and sun dried. Heterosis as estimated as the percent change in F1 over the mid parent (relative heterosis) a better parent (heterobeltosis) following standard methods.

Results and Discussion

In the present study crosses from 3 lines and 6 testers evaluated for standard heterosis, heterobeltiosis and relative heterosis for fresh root yield, dry root yield, root length,root girth, fiber content, carbohydrate content,50% flowering and secondary roots (Fig. 1). The heterosis is presented in Table 1. The character wise results of heterosis are discussed below:

Days to 50% flowering

The relative heterosis ranged from -0.58 % (RAS-15 X MWS- 306) to 2.33% (IGAU-1 X WS-90-111). Among 18 hybrids, 4 hybrids showed significant positive relative heterosis relative heterosis for this trait.

The heterobeltiosis ranged from -1.14 % (RAS-7 X WS-90-111) to 2.33% (IGAU-1 X WS-90-111). Among 18 hybrids, 5 hybrids showed significant positive better heterosis for this trait. One hybrid showed negative significant. The hybrid showed significant negative heterobeltiosis for this trait was RAS-15 X WS-90-111.

The standard heterosis (over JA-134) ranged from 0.01 % (RAS-7 X WS-90-111) to -2.27% (RAS-15 X WS-90-146). Among 18 hybrids, none hybrid showed significant heterosis for this trait.

The standard heterosis (over JA-20) ranged from 0.01% (RAS-7 X WS-90-146) to 1.15% (RAS-7 X MWS-310). Among 18 hybrids, none of hybrid showed significant heterosis for this trait. Similar result was reported by Singh (2013).

No. of secondary roots

The mid parent heterosis ranged from 0.02% (RAS-15 X WS-90-111) to 53.38% (IGAU-1 X MWS-310). Among 18 hybrids, 6 hybrids showed significant positive relative heterosis for this trait. The hybrid showed significant positive relative heterosis for this trait for the cross IGAU-1 X MWS-310 followed by IGAU-1 X WS-90-12, IGAU-1 X Poshita.

The heterobeltiosis ranged from 0.03% (RAS-7 X MWS-306) to 83.25% (RAS-15 X MWS-306). Among 18 hybrids, 10 hybrids showed significant positive better heterosis for this trait for this trait.

The hybrid, RAS-15 X MWS-306showed significant positive heterobeltiosis for this trait followed by IGAU-1 X WS-90-12, IGAU-1 X Poshita, RAS -15 X Poshita.

The standard heterosis (over JA-134) ranged from 6.94 % (RAS-15 X WS-90-12) to 82.82% (IGAU-1 X Poshita). Among 18 hybrids, 14 hybrids showed positive significant heterosis for this trait.

The hybrid, IGAU-1 X Poshita showed significant positive standard heterosis for this trait followed by RAS-7 X Poshita, IGAU-1 X WS-90-111, IGAU-1 X Poshita, RAS-15 X Poshita. The standard heterosis (over JA-20) ranged from 0.02% (RAS-15 X WS-90-12) to 5.68% (IGAU-1 X Poshita). Among 18 hybrids, 12 showed significant positive heterosis for this trait. The hybrid, IGAU-1 X Poshita showed significant positive standard heterosis for this trait followed by RAS-7 X Poshita, IGAU-1 X WS-90-111, IGAU-1 X MWS-310, RAS-15 X Poshita. Similar result was reported by Singh (2013).

Root girth

The relative heterosis ranged from 1.98% (IGAU-1 X MWS-306) to 69.70% (RAS-7 X Poshita). Among 18 hybrids, 10 hybrids showed significant positive relative heterosis for this trait. The hybrid, RAS-7 X Posita showed significant positive relative heterosis for this trait followed by RAS-15 X MWS-306, RAS-15 X MWS-310, IGAU-1 X WS-90-111, RAS-15 X WS-90-146 etc.

The heterobeltiosis ranged from 0.01% (RAS-15 X WS-90-111) to 30.23% (RAS-7 X Poshita). Among 18 hybrids, 6 hybrids showed significant positive heterobeltiosis for this trait. The hybrid, RAS-7 X Poshita showed significant positive heterobeltiosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X Poshita.

The standard heterosis (over JA-134) ranged from -0.98% (RAS-15 X WS-90-111) to 36.59% (RAS-7 X WS-90-146). Among 18, hybrids, 8 hybrids showed positive significant heterosis for this trait. The hybrid, RAS-7 X WS-90-146showed significant positive standard heterosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X Poshita, RAS-7 X Poshita.

The standard heterosis (over JA-20) ranged from -0.78% (RAS-7 X WS-90-12) to 45.08% (RAS-7 X WS-90-146). Among 18 hybrids, 10 hybrids showed significant positive heterosis for this trait.

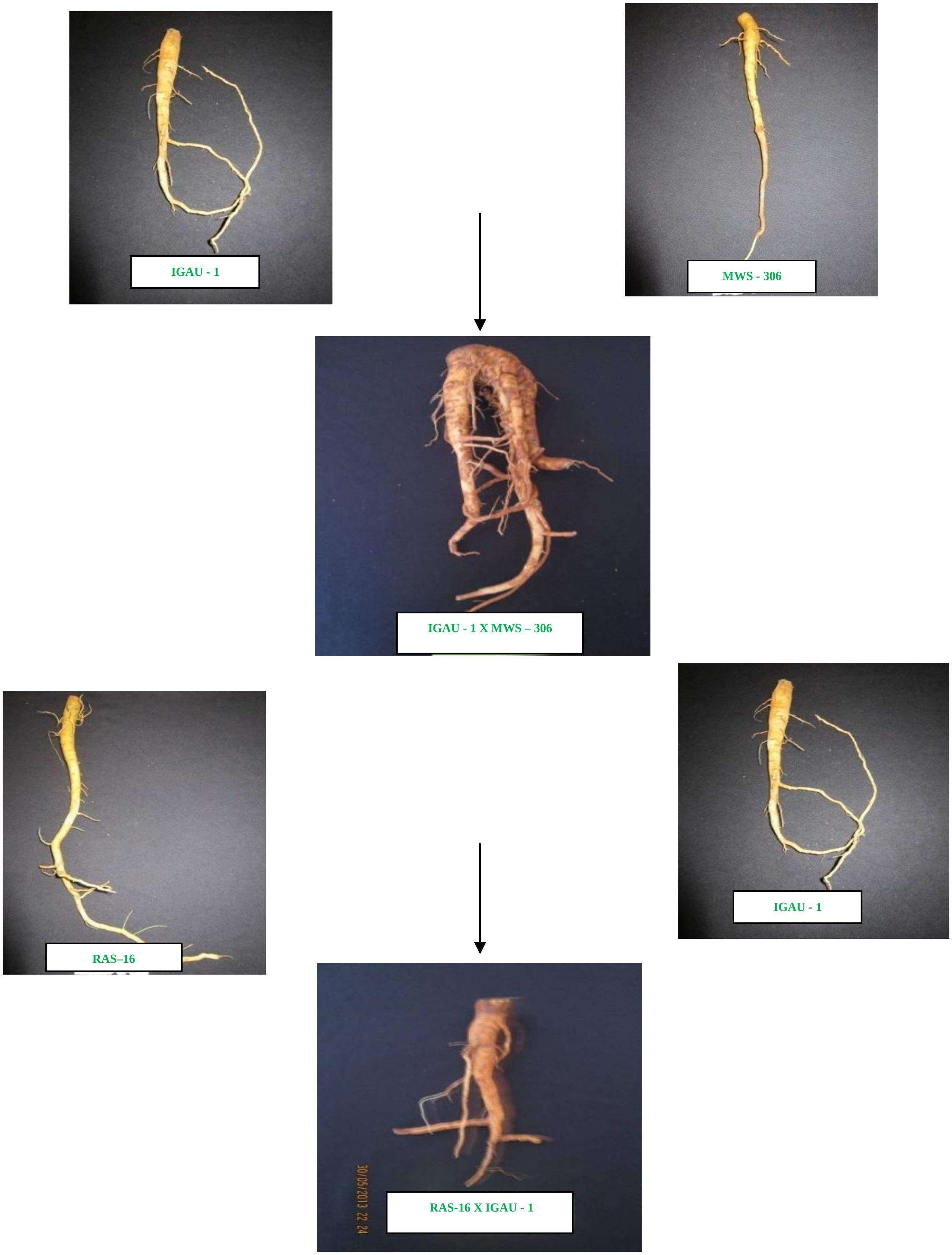
Table.1 Mid-parent heterosis, Heterobeltiosis and Standard heterosis in Ashwagandha

Days to 50% Flowering					**No of secondary roots**				**Root girth**			
			SH1	**SH2**			**SH1**	**SH2**			**SH1**	**SH2**
PARENTS	**RH**	**HB**	**JA-20**	**JA-134**	**RH**	**HB**	**JA-20**	**JA-134**	**RH**	**HB**	**JA-20**	**JA-134**
RAS-7												
WS-90-111	1.15	2.33*	1.15	0.01	4.68	7.14**	3.62**	55.28**	13.88	10.70	23.32*	16.10
WS-90-12	0.01	0.01	1.15	0.02	13.60	24.33	3.87**	58.70**	-7.04	-10.93	-0.78	-6.59
WS-90-146	-0.57	0.02	0.01	-1.14	19.49	39.36	3.87**	58.70**	23.89**	18.39*	45.08**	36.59**
MWS-310	1.15	2.33*	1.15	0.01	6.68	29.04	2.32	37.99*	32.70**	18.39*	45.08**	36.59**
MWS-306	0.57	1.15	1.15	0.03	-1.14	0.03	3.10**	48.34**	20.33*	21.79*	30.31**	22.68*
POSITA	-1.14	-1.14	0.01	-1.14	4.16	13.64	4.90**	72.46**	69.70**	30.23**	45.08*	36.59**
RAS-15												
WS-90-111	1.16	-1.14**	0.02	-1.14	0.00	37.50	0.52	13.87	25.70*	0.01	5.18	-0.98
WS-90-12	0.04	1.16	0.03	-1.14	1.62	29.13	0.03	6.94	11.02	2.54	4.40	-1.71
WS-90-146	-0.58	0.01	-1.15	-2.27	19.26	41.63*	0.77	17.29	34.99**	3.59	26.94**	19.51
MWS-310	1.16	1.16	0.02	-1.14	41.84**	62.50**	2.07	34.58*	50.15**	5.71	29.53**	21.95*
MWS-306	0.58	1.16	0.04	-1.14	31.30**	83.25**	3.35**	51.76**	33.33**	6.54	13.99	7.32
POSITA	1.15**	2.33	1.15	0.04	13.15	79.13**	3.10**	48.34**	2.94	3.45	8.81	2.44
IGAU-1												
WS-90-111	2.33**	2.33*	1.15	0.03	21.13	48.34**	3.10**	48.34**	31.84**	29.27**	37.31**	29.27**
WS-90-12	0.01	1.16	0.03	-1.14	42.43**	62.11**	4.13**	62.11**	7.01	15.37	22.54*	15.37
WS-90-146	0.58	1.16	0.02	-1.14	19.36	27.64	1.55	27.64	12.05	12.05	37.31	29.27**
MWS-310	2.33**	2.33*	1.15	0.03	53.38**	58.70**	3.87**	58.70**	9.28	2.11	25.13*	17.80
MWS-306	1.73**	2.33*	1.15	0.02	25.05*	55.28**	3.62**	55.28**	1.98	1.69	8.81	2.44
Poshita	0.01	1.16	0.02	-1.14	30.86**	82.82**	5.68**	82.82**	25.00**	24.39*	32.12	24.39*

	Root Length				**Fiber content**				**Cabohydrate Content**			
			SH1	SH2			SH1	SH2			SH1	SH2
PARENTS	RH	HB	JA-20	JA-134	RH	HB	JA-20	JA-134	RH	HB	JA-20	JA-134
RAS-7												
WS-90-111	5.10	18.26	-1.89	47.87**	4.19	9.75*	2.26	-8.51*	-22.65**	-37.57**	-31.71**	-35.11
WS-90-12	21.6**	28.49*	20.00	80.85**	16.17**	55.82**	-4.51	-14.57**	17.89**	-3.36	1.59	-3.48
WS-90-146	-7.27	-3.32	-7.47	39.46*	8.27*	8.75*	12.13**	0.33	-46.76**	-52.30**	-59.51**	-61.53**
MWS-310	-2.36	9.62	-8.58	37.77*	3.41	15.67**	19.27**	6.71	-21.73**	-35.31**	-33.41**	-36.73**
MWS-306	26.93**	46.49**	16.31	75.29**	42.21**	49.64**	39.70**	24.99**	-41.36**	-49.48**	-53.05**	-55.39**
Poshita	17.38*	29.34**	34.33**	102.46**	29.62**	44.41**	48.90**	33.22**	10.94**	-7.75*	-6.51	-11.17**
RAS-15												
WS-90-111	10.96	11.25	-8.33	38.16*	18.65**	34.49**	25.30**	12.11**	-49.15**	-60.09**	-56.34**	-58.52**
WS-90-12	-14.55	-8.85	-24.89*	13.20	20.03**	75.62**	7.62	-3.71	-19.17**	-35.61**	-32.32**	-35.69**
WS-90-146	53.73**	66.15**	36.91**	106.34**	17.02**	24.91**	29.94**	16.26**	5.53	-8.48**	-22.32**	-26.19**
MWS-310	20.11	20.83	-0.43	50.06**	-20.80**	-17.61**	-2.74	-12.98**	-26.80**	-41.23**	-39.51**	-42.53**
MWS-306	1.33	3.24	-18.03	23.54	7.59*	21.82**	13.72**	1.75	-11.40**	-25.98**	-31.22**	-34.65**
Poshita	13.22	42.50**	17.42	76.97**	-12.58**	-9.40**	6.95	-4.31	-20.57**	-35.86**	-35.00**	-38.24**
IGAU-1												
WS-90-111	25.37**	42.12**	17.73	77.43**	38.79**	42.02**	32.32**	18.39**	-4.32	-24.41**	-17.32**	-21.44**
WS-90-12	19.56**	26.98*	18.58	78.72**	24.73**	61.59**	-0.98	-11.40**	17.95**	-5.45	-0.61**	-5.56
WS-90-146	1.37	6.28	1.72	53.30**	1.24	4.63	2.01	-8.73*	-14.64**	-25.43**	-36.71**	-39.86**
MWS-310	25.77**	42.05**	18.45	78.53**	-5.55	9.01*	6.28	-4.91	9.97**	-11.14**	-8.54**	-13.09**
MWS-306	19.65	38.92**	10.30	66.24**	19.55**	22.21**	14.09**	2.07	50.39**	26.51**	17.56**	11.70**
Poshita	12.56	23.30**	29.44**	95.08**	10.55**	27.08**	23.90**	10.86**	16.64**	-5.17	-3.90	-8.69**

	Fresh root yield				**Dry root yield**			
			SH1	SH2			SH1	SH2
PARENTS	RH	HB	JA-20	JA-134	RH	HB	JA-20	JA-134
RAS-7								
WS-90-111	14.10	-2.17	93.03**	67.44**	44.95*	30.04	102.56**	79.55**
WS-90-12	1.13	-1.29	104.56**	77.44**	29.68**	13.62	135.26**	108.52**
WS-90-146	-2.08	-4.08	89.28**	64.19**	25.71	-9.47	41.03	25.00
MWS-310	31.81**	23.92	177.75**	140.93**	29.33	15.23	79.49*	59.09
MWS-306	66.05**	34.92*	166.22**	130.93**	45.90	9.88	71.15*	51.70
Poshita	28.11**	24.27	160.86**	126.28**	32.18**	25.93	96.15**	73.86**
RAS-15								
WS-90-111	72.74**	36.12	91.96**	66.51**	26.14	0.30	23.72	9.66
WS-90-12	4.65	-27.17**	50.94	30.93	-34.40	-55.73**	-8.33	-18.75
WS-90-146	43.90*	2.83	94.64**	68.84**	96.36	91.15	38.46	22.73
MWS-310	68.57**	14.83	157.37**	123.26**	170.63**	262.83**	162.82**	132.95**
MWS-306	41.55	17.39	44.77	25.58	21.19	16.26	-8.33	-18.75
Poshita	33.70	-7.28	94.64**	68.84**	17.72	-10.91	25.64	11.36
IGAU-1								
WS-90-111	70.45**	44.21**	193.83**	154.88**	64.19**	48.95*	126.28**	100.57**
WS-90-12	9.59	8.67	125.20**	95.35**	22.50**	6.19	119.87**	94.89**
WS-90-146	58.25**	52.63**	210.99**	169.77**	175.00**	99.58**	203.21**	168.75**
MWS-310	-12.28	-16.27	87.67**	62.79**	45.20**	30.80	98.72**	76.14**
MWS-306	26.72	1.71	107.24**	79.77**	55.56**	18.14	79.49**	59.09
Poshita	27.41*	25.54	163.54**	128.60**	10.72	6.75	62.18	43.75

Fig.1 Best heterotic cross for fresh root yield



The hybrid, RAS-7 X WS-90-146 showed significant positive standard heterosis for this trait followed by IGAU-1 X WS-90-111, RAS-7 X Poshita, RAS-7 X MWS-310. Similar result was reported by Singh (2013).

Root length

The relative heterosis ranged from 1.33% (RAS-15 X MWS-306) to 53.73 % (RAS-15 X WS-90-146). Among 18 hybrids, 7 hybrids showed significant positive relative heterosis for this trait. The hybrid, RAS-15 X WS-90-146 showed significant positive relative heterosis for this trait followed IGAU-1 X WS-90-111, RAS-15 X WS-90-146, RAS-7 X MWS-306.

The heterobeltiosis ranged from 3.24% (RAS-15 X MWS-306) to 66.15% (RAS-15 X WS-90-146). Among 18 hybrids, 10 hybrids showed significant positive heterosis for this trait. The hybrid, RAS-15 X WS-90-146showed significant positive heterobeltiosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X Poshita, IGAU-1 X WS-90-12 and RAS-7 X Poshita.

The standard heterosis (over JA-134) ranged from 13.20% (RAS-15 X WS-90-12) to 106.34% (RAS-15 X WS-90-146). Among 18 hybrids, 16 hybrids showed significant positive heterosis for this trait. The hybrid, RAS-15 X WS-90-146 showed significant positive standard heterosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X Poshita and RAS-7 X Poshita.

The standard heterosis (over JA-20) ranged from -0.43% (RAS-15 X MWS-310) to 36.91% (RAS-15 X WS-90-146). Among 18 hybrids, 1 hybrids showed significant negative heterosis and 3 hybrid showed significant positive heterosis for this trait. The hybrid, RAS-15 X WS-90-146 showed significant positive standard heterosis for this trait followed by IGAU-1 X Poshita, RAS-7 X Poshita etc. Similar result was reported by Singh (2013).

Fiber content

The relative heterosis ranged from -20.80% (RAS-15 X MWS-310) to 42.21% (RAS-7 X MWS-306). Among 18 hybrids, 12 hybrids showed significant positive relative heterosis and 2 hybrids showed significant negative relative heterosis for this trait. The hybrid, RAS-15 X MWS-310 showed significant negative relative heterosis for this trait followed RAS-15 X Poshitaetc.

The heterobeltiosis ranged from -17.61% (RAS-15 X MWS-310) to 75.62% (RAS-15 X WS-90-12). Among 18 hybrids, 15 hybrids showed significant positive better heterosis and 2 hybrids showed significant negative better heterosis for this trait for this trait. The hybrid, RAS-15 X MWS-310showed significant negative heterobeltiosis for this trait followed by RAS-15 X Poshita etc. The standard heterosis (over JA-134) ranged from -14.57% (RAS-7 X WS-90-12) to 33.22% (RAS-7 X Poshita). Among 18 hybrids, 6 hybrids showed positive significant heterosis and 5 hybrid showed negative significant heterosis for this trait.The hybrid, RAS-7 X WS-90-12 showed significant negative standard heterosis for this trait followed by IGAU-1 X WS-90-12, IGAU-1 X WS-90-146 and RAS-15 X MWS-310 etc. The standard heterosis (over JA-20) ranged from 2.26% (RAS-7 X WS-90-111) to 48.90% (RAS-7 X Poshita). Among 18 hybrids, 10 showed significant positive heterosis for this trait.Similar result was reported by Singh (2013).

Carbohydrate content

The relative heterosis ranged from -49.15% (RAS-15 X WS-90-111) to 50.39% (IGAU-1

X MWS-306). Among 18 hybrids, 6 hybrids showed significant positive relative heterosis and 10 hybrids showed significant negative relative heterosis for this trait. The hybrid, IGAU-1 X MWS-306 showed significant positive relative heterosis for this trait followed IGAU-1 X WS-90-12, IGAU-1 X Poshitaetc.

The heterobeltiosis ranged from -60.09% (RAS-15 X WS-90-111) to 26.51% (IGAU-1 X MWS-306). Among 18 hybrids, 15 hybrids showed significant negative and 1 hybrid showed significant positive better heterosis better heterosis for this trait. The hybrid, IGAU-1 X MWS-306showed significant positive heterobeltiosis for this trait. The standard heterosis (over JA-134) ranged from -61.53 % (RAS-7 X WS-90-146) to 11.17% (IGAU-1 X MWS-306). Among 18 hybrids, 1 hybrid showed positive significant heterosis and 14 hybrids showed negative significant heterosis for this trait. The hybrid, IGAU-1 X MWS-306showed significant positive standard heterosis for this trait.

The standard heterosis (over JA-20) ranged from -59.51% (RAS-7 X WS-90-146) to 17.56% (IGAU-1 X MWS-306). Among 18 hybrids, 1 hybrid showed significant positive heterosis and 14 hybrids showed negative significant heterosis for this trait. The hybrid, IGAU-1 X MWS-306showed significant positive standard heterosis for this trait. Similar result was reported by Singh (2013).

Fresh root yield

The relative heterosis ranged from 1.13% (RAS-7 X WS-90-12) to 72.74% (RAS-15 X WS-90-111). Among 18 hybrids, 8 hybrids showed significant positive relative heterosis for this trait. The hybrid, RAS-15 X WS-90-111 showed significant positive relative heterosis for this trait followed IGAU-1 X WS-90-111, RAS-15 X MWS-310, RAS-7 X MWS-306 etc.

The heterobeltiosis ranged from -1.29% (RAS-7 X WS-90-12) to 52.63% (IGAU-1 X WS-90-146). Among 18 hybrids, 1 hybrids showed significant negative better heterosis and 3 hybrids showed significant positive better heterosis for this trait. The hybrid, IGAU-1 X WS-90-146showed significant positive heterobeltiosis for this trait followed by IGAU-1 X WS-90-111, RAS-7 X MWS-306 etc.

The standard heterosis (over JA-134) ranged from 25.58% (RAS-15 X MWS-306) to 169.77% (IGAU-1 X WS-90-146). The hybrid, IGAU-1 X WS-90-146 showed significant positive standard heterosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X Poshita, RAS-7 X Poshita, RAS-15 X MWS-310 etc.

The standard heterosis (over JA-20) ranged from 44.77% (RAS-15 X MWS-306) to 210.99% (IGAU-1 X WS-90-146). Among 18 hybrids, 16 hybrids showed significant positive heterosis for this trait. The hybrid, IGAU-1 X WS-90-146showed significant positive standard heterosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X Poshita, RAS-7 X Poshita, RAS-15 X MWS-310 etc. Similar result was reported by Singh (2013).

Dry root yield

The relative heterosis ranged from 10.72% (IGAU-1 X POSITA) to 175.00% (IGAU-1 X WS-90-146). Among 18 hybrids, 9, hybrids showed significant positive relative heterosis for this trait. The hybrid, IGAU-1 X WS-90-146showed significant positive relative heterosis for this trait followed IGAU-1 X WS-90-111, IGAU-1 X MWS-310, RAS-15 X MWS-310, RAS-7 X WS-90-111 etc.

The heterobeltiosis ranged from 0.30% (RAS-15 X WS-90-111) to 262.83% (RAS-15 X MWS-310). Among 18 hybrids, 1 hybrid showed significant negative better heterosis and 3 hybrids showed significant positive better heterosis for this trait. The hybrid, RAS-15 X MWS-310showed significant positive heterobeltiosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X WS-90-146 etc.

The standard heterosis (over JA-134) ranged from 9.66% (RAS-15 X WS-90-111) to 168.75% (IGAU-1 X WS-90-146). Among 18 hybrids, 11 hybrid showed positive significant standard heterosis over JA-134, for this trait. The hybrid, IGAU-1 X WS-90-146 showed significant positive standard heterosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X WS-90-12, RAS-7 X Poshita, RAS-15 X MWS-310 etc.

The standard heterosis (over JA-20) ranged from -8.33% (RAS-15 X WS-90-12) to 203.21% (IGAU-1 X WS-90-146). Among 18 hybrids, 11 hybrids showed significant positive heterosis for this trait. The hybrid, IGAU-1 X WS-90-146 showed significant positive standard heterosis for this trait followed by IGAU-1 X WS-90-111, IGAU-1 X WS-90-12, RAS-7 X Poshita, RAS-15 X MWS-310 etc. Similar result was reported by Singh (2013).

The estimation of relative heterosis, heterobeltosis and standard heterosis where also obtained for eight characters. High degree relative heterosis, heterobeltosis and standard heterosis

Heterosis was significant and positive for most of the characters, which revealed that its utilization in the ashwagandha breeding programme could be useful. The cross RAS-15 X WS-90-111 recorded negative heterosis over the better parent for days to 50% flowering, indicating scope for its utilization in evolving early flowering plant types. The hybrids IGAU-1 X WS-90-111, RAS-15 X MWS-310, RAS-7 X MWS-306, RAS-15 X WS-90-111 etc. showed good performance in terms of relative heterosis. The hybrids RAS-7 X MWS-306, IGAU-1 X WS-90-146, IGAU-1 X WS-90-111 etc. showed good performance in terms of better parent heterosis. The hybrids IGAU-1 X WS-90-111, IGAU-1 X WS-90-146, RAS-7 X MWS-306, RAS-7 X Poshita, RAS-15 X WS-90-146, RAS-15 X MWS-310 etc. showed good performance over both checks JA-20 and JA-134. These crosses could be exploited for obtaining high fresh root yield plant^{-1}

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