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Characterization and evaluation of Arya melon (*Cucumis melo*) for agro-morphological traits and screening against ToLCNDV

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Melons (*Cucumis melo* L.) constitute a group of cucurbitaceous vegetables relished as salad, dessert and vegetable. India is the center of origin and diversity of wild and many cultivated melons (Gonzalo *et al.* 2019). Melons are reported as the reservoir of useful genes for several biotic and abiotic traits useful for crop improvement (Lakshamana Reddy *et al.* 2016). In India, these are the most common salad and dessert vegetables grown during spring-summer season while during rainy (*kharif)* season, cucumber (*Cucumis sativus* L.) is the most common cucurbitaceous crop used as salad vegetable. However, cucumber raising during rainy (*kharif*) season in northern India is turning out to be a challenge due to yield loss caused by spread of Tomato Leaf Curl New Delhi Virus (ToLCNDV). To save the crop, farmers are compelled to use high doses of pesticides that lead to health and environment threats. Moreover, occurrence of new viruses especially the ToLCNDV emerging in melon growing regions, leading to high economic loss, is a major concern for farmers and seed producers around the globe (Annu *et al.* 2019). Therefore, identification and utilization of source of resistance to ToLCNDV is the most efficient and safer approach for improvement of melons.

Arya (also locally called Arra, Arda) is actually a less-known vegetable melon cultivated mainly in Rajasthan and adjoining parts of Haryana. Ahlawat *et al.* (2018) collected different accessions of Arya from Rajasthan and Haryana. Recently Arya melon is reported as a novel botanical variety named as *Cucumis melo* var. Alwarensis A. Pandey *et* S. Rajkumar (Pandey and Rajkumar 2021) described from India. This cultivar is used for unripe fruits consumed as salads and vegetable and pre-mature fruits as dessert (Ahlawat *et al.* 2018). Organoleptic assessment made during study resulted in use of this crop as salad just like common cucumber in young stage. The study is an outcome of the authors search for identification of Arya as a probable newer source of resistance against ToLCNDV and extended use of the crop for salad purpose to supplement the demand of common cucumber especially during *kharif* when virus incidence leads to very high economic loss and compelled to use high doses of pesticides. Arya melon can also serve as a substitute to long melon during *kharif* season which is otherwise cultivated only during spring-summer. Keeping the potential of Arya melon the present study was carried out with the objective to: 1) characterize and evaluate Arya melon for agro-morphological traits; and 2) Screening of the germplasm against ToLCNDV.

The present study was carried out at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi and ICAR-National Bureau of Plant Genetic Resources (28°35'N and 77°12' E with an altitude of 228.6 m amsl), New Delhi in a Randomized Complete Block Design (RCBD) with 3 replications for characterization and evaluation of Arya melon during spring-summer season in the year 2020, 2021 and 2022. A total of 14 accessions were taken for study (Supplementary Table 1). The crop was raised on channels with a spacing of 60 cm between hills and 3.0 m between channels. There were 7 hills per replication out of which 5 plants were selected for taking observation. All other recommended practices were followed, except that no insecticides were applied to proliferate whitefly population and thus virus transmission and disease incidence. Symptoms on the upper leaves of each genotype were recorded by visual evaluation using the following scale (Islam *et al.* 2010) where 0, no symptoms; 1, mild symptoms on young leaves covering >10% of leaf area; 2, mosaic on young leaves covering >25% of leaf area symptoms; 3, mosaic on young leaves covering >50% of leaf area symptoms and 4, mosaic on young leaves covering >75% of leaf area symptoms. For the better comparison of resistance among the genotypes,

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vulnerability index (V) values were calculated as:

$$\text{Vulnerability index (V)} = \frac{(0n_o+1n_1+2n_2+3n_3+4n_4+5n_5)/nt}{(nc-1)\times 100}$$

where, n_0, n_1, $n_2 \ldots n_5$, Number of plants in score 0, 1, 2…5 respectively; nt, total number of plants; nc, total number of categories. On the basis of the vulnerability indices, the genotypes were categorized into 5 categories, viz. immune, VI, 0; resistant, VI, 1–25; moderately resistant, VI, 26–50; moderately susceptible, VI, 51–75; susceptible, VI= 76–100 (Islam *et al.* 2010).

The data were analysed using SPSS® software version 16 (SPSS Inc., Chicago, IL, USA, Norusis 1998) for mean, critical difference and standard error of mean among the studied accessions.

Arya melons in general have small leaves as compared to cucumber. Shape of the fruits (Arya melon, cucumber, *kachri* and long melon) differed from oval to elongate. The fruit shape in Arya melon was elongated resembling long melon, thus different from cucumber, musk melon and snap melon. Among the horticultural traits, comparatively wide range was observed for node number bearing first female flower (5.93–17.77) which determines the earliness of a variety (Table 1).

Wide range of variations was observed for fruit length (9.2–43.43 cm) and breadth (3.75–6.58 cm) at marketable stage. Arya melon has oval to elongated fruit up to 43.43 cm length (Table 1). The longest fruit was observed in IC629818B (43.43 cm) followed by IC629823 (34.17 cm). Variation for seed cavity length and breadth ranged from 11.07-49.7 and 4.03-6.43 cm, respectively. Arya has fruit weight up to 750–2000 g and differs from all forms of *C. melo* group in producing thick-cylindric to ob-cylindric fruits with partly smooth-ribbed pericarp, orange crispy pulp with strong musky external and internal aroma (Pandey *et al.* 2020). Arya AAPD-18/4A (IC629818A) was morphologically very similar to *Cucumis melo* var. *flexuosus* cv. Chandralekha and also number of fruits per plant range from 8 to 10, thus can serve as a substitute to long melon during *kharif* season. Moreover AAPD-18/9 (IC629823) and AAPD-18/4B (IC629818B) had cream coloured fruit which make them unique and suitable for cultivation during *kharif* season. Moreover, none of the Arya lines were affected with ToLCNDV during spring summer season.

None of the accessions of Arya melon were affected due to ToLCNDV at both ICAR-IARI fields as well as ICAR-NBPGR fields during rainy (*kharif*) season. All the Arya lines under study scored zero for disease scoring, thus

Table 1 Mean performance of Arya melons and other *Cucumis* genotypes for different horticultural traits (pooled data)

Genotype	Node number bearing first female flower	Leaf length (cm)	Leaf width (cm)	Fruit length at marketable stage (cm)	Fruit breadth at marketable stage (cm)	Fruit length at maturity (cm)	Fruit breadth at maturity (cm)	Length of seed cavity at maturity (cm)	Seed cavity breadth at maturity (cm)
IC629815	8.00	12.17	11.93	17.67	4.46	26.67	7.32	13.90	6.43
IC629818A	8.67	12.63	11.87	26.67	4.40	59.53	8.61	44.73	5.03
IC629818B	17.77	12.00	11.97	43.43	3.75	54.93	6.98	49.70	5.97
IC629820	8.27	12.00	12.17	9.53	4.10	13.93	8.63	11.97	6.10
IC629821	10.93	11.70	12.00	12.50	4.95	16.17	8.53	17.30	6.40
IC629821A	8.53	12.10	11.40	27.20	6.58	34.47	6.17	31.93	5.53
IC629822	10.43	11.93	11.77	9.20	5.56	19.50	6.05	17.90	5.83
IC629823	14.77	12.00	11.97	34.17	4.62	44.03	8.58	39.43	5.97
IC261145	14.47	8.17	10.77	10.93	4.62	13.13	6.98	11.07	5.93
IC410617	13.43	19.40	24.13	14.00	5.95	16.33	8.51	14.23	5.87
IC410617A	8.13	19.40	24.13	15.00	5.95	17.33	8.51	14.23	5.87
Pusa Long Green	5.93	21.83	19.90	18.93	5.72	24.00	8.05	20.83	4.80
Pusa Uday	8.10	19.10	16.03	15.60	4.35	21.27	9.23	18.33	4.03
Chandra Lekha	8.90	12.33	10.10	32.00	4.43	36.73	5.37	32.57	4.87
Mean	10.65	13.80	13.72	21.16	4.59	28.65	7.40	25.12	5.58
SEm±	1.06	0.56	0.61	2.15	0.33	2.42	0.41	2.16	0.19
CD (P=0.05)	3.09	1.63	1.78	6.24	0.96	7.02	1.61	6.27	0.56
CD (P=0.01)	4.18	2.21	2.40	8.44	1.30	9.49	1.19	8.47	0.76
CV (%)	17.31	7.05	7.71	17.57	11.74	14.60	9.53	14.86	5.97

Table 2 Disease reaction of Arya melons and other *Cucumis* genotypes under study against ToLCNDV under natural epiphytotic conditions at NBPGR farm and IARI farm (pooled data of 2020 and 2021)

Genotype	VI at IARI farm	Disease reaction Category at IARI farm	VI at NBPGR farm	Disease reaction Category at NBPGR farm
IC629815	0	Immune	0	Immune
IC629818A	0	Immune	0	Immune
IC629818B	0	Immune	0	Immune
IC629820	0	Immune	0	Immune
IC629821	0	Immune	0	Immune
IC629821A	0	Immune	0	Immune
IC629822	0	Immune	0	Immune
IC629823	0	Immune	0	Immune
IC261145	81.66	Susceptible	83.33	Susceptible
IC410617	36.00	Moderately resistant	40.66	Moderately resistant
IC410617A	45.00	Moderately resistant	42.66	Moderately resistant
Pusa Long Green	60.00	Moderately susceptible	61.66	Moderately susceptible
Pusa Uday	78.33	Susceptible	81.66	Susceptible
Chandra Lekha	86.66	Susceptible	83.33	Susceptible

classified as immune to ToLCNDV while IC410617 and IC410617-A of cucumber were found moderately resistant (Table 2). In our previous study also IC410617 was found resistant to ToLCNDV (Ranjan *et al.* 2015) and IC401617-A is a selection from IC410617. During the period under study, the virus load was very high as all other accessions including cucumber, long melon and kachri were highly infested. This is probably the first report to suggest that Arya melon is immune to ToLCNDV under Delhi conditions. This can serve as a potential source of resistance to other melon types which are otherwise crossable with each other. Melon accessions belonging to the Indian *momordica, kachri, acidulous* and *agrestis* groups are reported to be resistant to begomoviruses (Yousif *et al.* 2007, Pitrat 2016, Romay *et al.* 2019, Martin-Hernandez and Pico 2021), and several QTLs associated with resistance have been identified in this germplasm (Saez *et al.* 2017, Romay *et al.* 2019). Crossability of Arya with other melons has been studied (Choudhary *et al.* 2019) and found that they are inter-crossable. Hence, efforts could be made to transfer the resistant gene to commercial melon varieties.

SUMMARY

Arya, a novel variety of melon from India is found immune to ToLCNDV under field conditions. It can serve as a potential source of resistance for ToLCNDV that can be imparted to other melons. Unlike other melons, Arya melons can be successfully grown both during spring summer and rainy *(kharif)* season. Arya IC629818-A bear long and good number of fruits per plant (8-10), thus can serve as a substitute to long melon during *kharif* season. Moreover, IC629823 and IC629818B had long cream coloured fruit which make them unique and attractive to the consumers.

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