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RESEARCH ARTICLE

Diversity in Melon (*Cucumis melo L.*) Landraces of Karnataka State of Southern India for Downy and Powdery Mildew Disease Resistance

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We present here the report on evaluation of melon landraces from the Karnataka state of India for resistance to downy mildew (*Pseudoperonospora cubensis*) and powdery mildew (*Podosphaera xanthii*), the major diseases of melon as well as other cucurbits. Thirty four melon landraces collected from different agro-climatic regions of the state were evaluated for resistance against downy mildew under natural epiphytotic conditions and powdery mildew under artificial conditions. Percent disease index (PDI) was calculated for each entry and based on that accessions were categorised as resistant, moderately resistant and susceptible. A very wide variation was observed among the accessions for resistance to both the diseases. Based on PDI, out of 34 accessions, COHB04, COHB37, COHB38, COHB41 and COHB43 were resistant to downy mildew. Ten genotypes were moderately resistant, fifteen were susceptible and four lines including susceptible check were highly susceptible to disease. Three landraces, COHB12, COHB38 and COHB40 were resistant to powdery mildew disease. Two genotypes were moderately resistant and rest of the lines were susceptible to disease. COHB38, an unexplored and uncultivated genotype was resistant to both the diseases. The highly resistant genotype COHB38 identified within the accessions tested offers an additional source for the development of downy and powdery mildew resistant melon cultivars.

Key Words: *Cucumis melo,* Downy mildew, Landraces, Powdery mildew resistance

Introduction

Melons (*Cucumis melo* L., 2n = 24) of Cucurbitaceae family are one of the global crops of high economic importance and provide health beneficiary nutrients. They are highly polymorphic and include a diverse botanical group. Melons have been divided into two subspecies and different horticultural groups (Jeffrey, 1980; Pitrat, 2008; Pitrat, 2016). East Africa was considered as the probable centre of origin of melon (Pitrat, 2008) but the recent data shows that melons might have originated in Asia (Sebastian *et al*., 2010). In India, depending upon the local market preferences in melon, several landraces have established themselves in different geographical pockets or riverbeds (Nandpuri, 1989; Fergany, 2011; Sudhakara, 2014; Reddy *et al*., 2016). Commercial melon varieties of superior yield and quality bred for bigger markets are being grown in larger areas and are narrowing down the genetic variability. Many of the locally adapted melons may not be very good with respect to yield and quality compared to the improved varieties and hybrids but they may be repositories of useful genes and also contribute to widen the crop genetic diversity. Melons of Karnataka are tailored to different agro-climatic regions and have considerable variability with respect to plant and fruit characters (Sudhakara, 2014). The landraces are being cultivated on river beds and some uncultivated melons are found as weed in rainy season.

Diseases are a limiting factor for profitable melon production. Downy mildew (*Pseudoperonospora cubensis*) and powdery mildew (*Podosphaera xanthii* and *Golovinomyces cichoracearum*) are the most widespread diseases of melon. The powdery mildew causal organism, *G. cichoracearum* is common in temperate and cooler areas (Lebeda *et al*., 2011) whereas *P. xanthii* occurs more frequently in sub-tropical and tropical areas (Kristkova *et al*., 2009). *P. xanthii* is most prevalent species in India (Gupta and Sharma, 2012). Though there are cultural practices employed and fungicides are being used to manage the disease, the most cost effective way of combating diseases is exploring the resistant genes and developing durably resistant varieties by pyramiding race specific genes (McCreight *et al*., 2005). Some melon fruits are usually

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consumed fresh and to avoid the risks of unacceptable levels of chemical residue due to fungicidal application, breeding for disease resistance is the preferred and environmentally safe means of managing disease and successful production of the crop. With emergence of new races, over the time, resistant varieties become susceptible and therefore the search for new resistant sources and introgression of resistant genes from donor parents to the cultivated lines is a continuous process. So, it is pertinent and needful to screen the different local lines of melon against diseases. Sources of resistance to downy and powdery mildew were reported in several Indian landraces (Seshadri and More, 1996; Dhillon *et al*., 2012; Liu *et al*., 2010; Fergany *et al*., 2011 and Reddy *et al*., 2016) and are being used worldwide to develop resistant varieties. The most commonly used sources of resistance were LJ 525, PI 79376, PI 124112, PI 313970, PI 124111, (Thomas *et al*., 1988; Balass *et al*., 1992; Pitrat and Besombes, 2008; Pitrate, 2008), PI 414723 (Epinat and Pitrat, 1989) and PI 134198 (Liu *et al*., 2010). The purpose of this study was to evaluate the unexplored and endemic landraces of Karnataka state for resistance to powdery and downy mildew diseases.

Materials and Methods

Germplasm

This study included thirty four landraces of melon (only the low sweet type melons used for consuming ripen fresh fruits) collected directly from farmer's field in five agro-climatic zones of Karnataka state (Table 1) and check varieties. Kashi Madhu, a popular variety under cultivation (Pandey *et al*., 2008) was used as a susceptible check in both the experiments. Resistant checks were IIHR651 for downy mildew and IIVR231 for powdery mildew. The accessions were selfed for three generations under insect proof shade net and were evaluated for morphological traits and disease resistance in separate experiments.

Screening for downy mildew: The evaluation of landraces for downy mildew resistance was done under natural epiphytotic condition during June-September of 2014 and 2016. Ten plants per genotype were planted with a spacing of 2.5m × 0.45m with two replications. Nine leaves (three top, three middle and three bottom) in each plant were visually assessed for percent leaf area infected using linear 0 to 5 scale and the percent

Table 1. Description of *Cucumis melo* L. landraces from different agro-ecological regions of Karnataka state and reference genotypes included in the study

Source of germplasm	Accession and their local names	Botanical group	Use
Davanagere district–Southern Transition Zone (Three different places)	COHB01 (Mallapur Ganjam), COHB03 (Banaspathre), COHB05, COHB010& COHB11 (Ganjam)	*indicus*	Ripen fruits for slicing and juice making
	COHB02 & COHB07 (Sidoota), COHB04, COHB06 & COHB08 (Karabooja)	*chandalak*	
Shivamogga–Hilly Zone	COHB12 (Kekkarale)	*momordica*	Ripen fruits consumed with jaggery
Chamarajanagar–Southern Dry Zone (Two different places)	COHB13,COHB14, COHB15, COHB35 & COHB36	*chandalak* but monoecious	Ripen fruits for slicing and juice making
	COHB16,COHB17,COHB18,COHB19,COH B22,COHB23,COHB28,COHB30,COHB31& COHB32 (All are called as Minake irrespective of their phenotype)	Intermediate forms of *chandalak* and *momordica*	
Bijapur (Three different villages)–Northern Dry Zone	COHB38 (Puttikaayi)	Intermediate form of *acidulus* and *momordica*	Ripen fruits consumed with jaggery
	COHB37, COHB40, COHB41, COHB41a, COHB 42 & COHB42a (All are called as Puttikaayi but appear different)	*acidulus*	
Tumkur– Central Dry Zone	COHB43 (Budame kaayi)	*kachri*	Only ripen fruits are consumed.
Reference Genotypes			
ICAR-Indian Institute of Horticulture Research, Bengaluru	Kashi Madhu (Susceptible check for downy and powdery mildew)	*chandalak*	Ripen fruits for slicing and juice making
	IIHR651 resistant check for downy mildew	Not known	Ripen fruits for slicing and juice making
ICAR-Indian Institute of Vegetable Research, Varanasi	IIVR231 resistant check for powdery mildew	*momordica*	Semi dessert fruits

disease index (PDI) was calculated (Shashikumar *et al*., 2010). 0 = Healthy and no symptoms, 1=1.1-5 % leaf area covered with chlorotic/necrotic symptom, 2= 5.1-10% leaf area covered with chlorotic/necrotic symptom, 3=10.1-20 % leaf area covered with chlorotic / necrotic symptom, 4=20.1-30 % leaf area covered with chlorotic/necrotic symptom and 5=> 30 % leaf area covered with necrotic symptom. The observations were made four times with seven days interval once the disease was observed on susceptible host. Phenotypic data on plant responses to downy mildew was used to calculate PDI according to Wheeler (1969) where, PDI = (Sum of numerical disease ratings/Number of plants observed) × 100/ Maximum disease rating value. Based on the average PDI, the genotypes were categorized into four groups (Pitchaimuthu *et al*., 2012). 0.1-25 % as resistant, 26-40 % as moderately resistant, 41-60% as susceptible and >60 % as highly susceptible.

Screening for powdery mildew: The germplasm was evaluated for powdery mildew disease resistance during October-December 2015 under shade net conditions through artificial inoculation. The obligatory pathogen was isolated from diseased plants maintained in the greenhouse to inoculate seedlings at two true leaf stage (when all plants have produced two true leaves). Seedlings were evaluated for disease resistance reaction after observing infection on susceptible check Kashi Madhu using 0-5 scale of Zhang *et al*. (2013) where 0 = no evidence of infection, 1 = trace (up to 20 %) infection of cotyledons only, 2 = low infection (21–50 %) of cotyledons or trace infection of hypocotyls, 3 = moderate infection of cotyledons (51–70 %) and low infection of hypocotyls (21–50 %), 4 = severe infection (>71 %) of cotyledons and hypocotyls, slight infection of leaves (20 %), 5 = whole plant infected and/or dead because of disease. Three observations were recorded with four days interval. Calculation of PDI is same as that for downy mildew and genotypes were categorised into three groups based on their PDI. Genotypes having a PDI $\leq$ 40 were considered resistant, between 40 and 60 were partially or moderately resistant and $\geq$ 60 were classified as susceptible. The resistant lines were re-tested in 2016 and 2017 for powdery mildew disease resistance at seedling stage to confirm their resistance.

Results

A wide variation was observed among the landraces for resistance to both downy and powdery mildew diseases (Table 2, Fig.1 and Fig. 2). For downy mildew, landraces COHB04, COHB37, COHB38, COHB41 and COHB43 were resistant with PDI value less than 25 percent. Ten genotypes (including the resistant check IIHR651) were moderately resistant and their PDI ranged from 27.1 to 37.5 percent. Fifteen accessions were susceptible with the PDI ranging from 41.9 to 57.9 percent and five lines including susceptible check were highly susceptible to disease. For powdery mildew disease, COHB12, COHB38 and COHB40 were resistant with low PDI values ranging from 2.5 to 17.6 per cent. Genotypes COHB37, COHB43 and IIVR231 (resistant check) were moderately resistant but COHB43 showed segregation for resistance and susceptibility. All the other accessions were susceptible to disease and the PDI for susceptible genotypes ranged from 46.5 to 100 percent. COHB38, an unexplored, uncultivated and weedy genotype was resistant to both downy and powdery mildew diseases with PDI of 19.2 % and 2.5 %, respectively. COHB37 was resistant to downy mildew and moderately resistant to powdery mildew. COHB12 (snap melon) and COHB40 showed resistance to powdery mildew and moderate resistance to downy mildew.

Discussion

Karnataka state is one of the major melon growing states in southern part of India and has ten different agro-climatic regions which include coastal, hilly area, arid or dry zone and transitional belts between hilly and dry zones. The different botanical types of melons grown traditionally in the state include *acidulous*, *agrestis*, *kachri*, *momordica* (snapmelon or Phut), *chandalak* and *indicus*. *Acidulus* melons are one of the widely grown and used melons for vegetable purpose. *Chandalak* and *indicus* type melons are cultivated on the residual moisture on river beds and wide variability exists among them. *Momordica* and *agrestis* are grown in a small scale whereas *kachri* are not cultivated but grow as weed in finger millet fields. Apart from these melons some intermediate forms are also available. An *acidulous* type of melon also grows in northern part of the state as a weed in sorghum field and the ripen fruits are marketed in local markets. The high yielding commercial varieties are replacing the landraces and narrowing down the genetic diversity which intern makes the crop susceptible to diseases. Downy and powdery mildew are the major foliar diseases of melons that affect yield and fruit quality. We made an attempt to collect the cultivated landraces and uncultivated types directly from farmers (Table 1). A very wide variation was observed among the melons

Table 2. Percent disease index (PDI) and reaction of melon landraces for downy and powdery mildew diseases

Sl. No.	Accession No.	Downy mildew		Powdery mildew	
		PDI (%)	Disease reaction	PDI (%)	Disease reaction
1	COHB01	57.38 ± 3.00	S	67.00 ± 3.46	S
2	COHB02	35.00 ± 0.00	MR	73.25 ± 3.17	S
3	COHB03	29.84 ± 1.33	MR	63.00 ± 3.46	S
4	COHB04	18.05 ± 0.10	R	84.50 ± 5.19	S
5	COHB05	50.88 ± 4.59	S	64.50 ± 5.19	S
6	COHB06	56.88 ± 4.74	S	75.00 ± 3.46	S
7	COHB07	72.77 ± 3.20	HS	100.0 ± 0.00	S
8	COHB08	33.11 ± 1.73	MR	100.0 ± 0.00	S
9	COHB10	41.94 ± 1.92	S	100.0 ± 0.00	S
10	COHB11	37.50 ± 2.50	MR	100.0 ± 0.00	S
11	COHB12	28.33 ± 0.00	MR	17.57 ± 5.62	R
12	COHB13	46.11 ± 2.56	S	100.0 ± 0.00	S
13	COHB14	44.81 ± 3.63	S	84.80 ± 5.54	S
14	COHB15	47.77 ± 3.62	S	100.0 ± 0.00	S
15	COHB16	66.33 ± 6.43	HS	100.0 ± 0.00	S
16	COHB17	51.80 ± 1.76	S	77.55 ± 3.40	S
17	COHB18	47.50 ± 3.84	S	100.0 ± 0.00	S
18	COHB19	66.80 ± 5.99	HS	100.0 ± 0.00	S
19	COHB22	63.88 ± 6.39	HS	66.75 ± 5.48	S
20	COHB23	47.66 ± 4.05	S	100.0 ± 0.00	S
21	COHB28	57.88 ± 4.33	S	100.0 ± 0.00	S
22	COHB30	47.36 ± 1.44	S	77.50 ± 2.88	S
23	COHB31	51.77 ± 0.37	S	68.25 ± 4.90	S
24	COHB32	36.80 ± 0.80	MR	100.0 ± 0.00	S
25	COHB35	34.58 ± 3.33	MR	100.0 ± 0.00	S
26	COHB36	50.44 ± 1.76	S	100.0 ± 0.00	S
27	COHB37	17.47 ± 1.49	R	41.00 ± 1.15	MR
28	COHB38	19.22 ± 0.21	R	2.50 ± 2.88	R
29	COHB40	27.14 ± 1.33	MR	13.00 ± 3.46	R
30	COHB41	17.50 ± 0.10	R	46.50 ± 2.88	S
31	COHB41a	29.00 ± 0.90	MR	53.00 ± 5.77	S
32	COHB42	51.85 ± 1.28	S	64.00 ± 4.61	S
33	COHB42a	28.88 ± 0.64	MR	69.50 ± 2.88	S
34	COHB43	16.00 ± 1.44	R	40.50 ± 2.88	^MR
35	Kashi Madhu*	76.11 ± 4.61	HS	100.0 ± 0.00	S
36	IIHR-651**	31.00 ± 1.73	MR		
37	IIVR231**			42.00 ± 1.15	MR

** Resistant checks & * Susceptible check ^ segregated for resistance
R = Resistant MR =Moderately Resistant S = Susceptible & HS =Highly susceptible

for resistance to downy and powdery mildew diseases. For downy mildew, accessions were screened under natural disease epiphytotic conditions and the reaction of landraces ranged from resistant (five landraces) to high susceptibility (four landraces). Ten genotypes were moderately resistant and fifteen accessions were susceptible to disease. Powdery mildew resistance screening was done under artificial condition. Since the pathogen is an obligatory parasite, disease inoculum was maintained on susceptible host for inoculating accessions. Resistance was noticed for three landraces, moderate resistance was observed for two lines but majority of the accessions (30) were found susceptible to powdery mildew. Some lines showed moderate resistance to downy mildew but were susceptible to powdery mildew (Table 2). Genotypes resistant to both the diseases are more useful in breeding. COHB38 showed resistance to both downy mildew and powdery mildew diseases. COHB38 is a selection from the segregating lines of an uncultivated plant from northern dry Zone. The fruits of original plant look like *acidulous* melon with patches on skin but on selfing, it segregated for disease

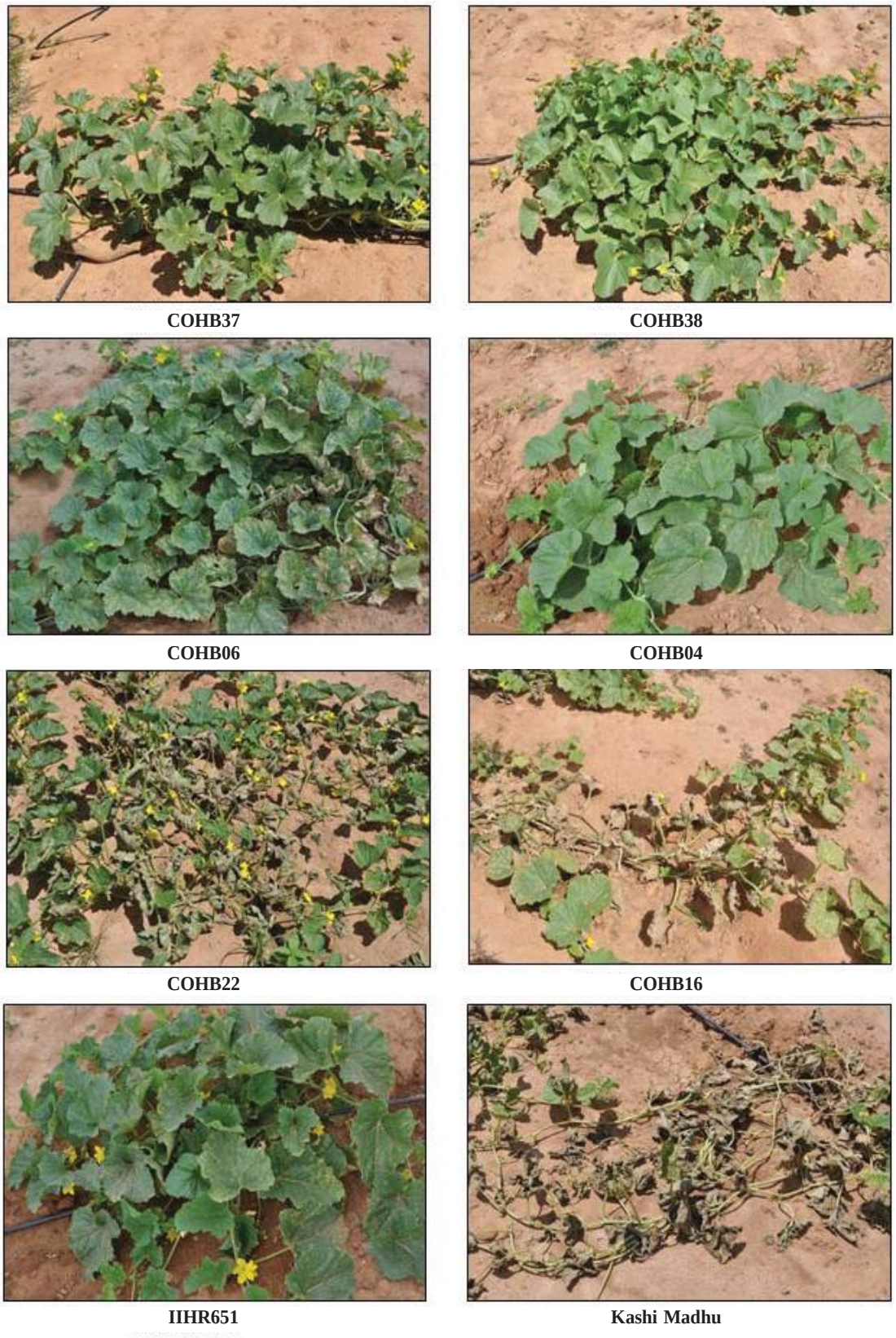

Fig. 1. Reaction of melon landraces for downy mildew disease

Fig. 2. Reaction of melon landraces for powdery mildew disease

resistance as well as fruit characters. It may be an intermediate type between *acidulous* and *momordica* melon but fruit cracking is not observed as in *momordica*. COHB37 (*acidulous*) was resistant to downy mildew but moderately resistant to powdery mildew. COHB12 (*momordica*) and COHB40 (*acidulous*) were resistant to powdery mildew but moderately resistant to downy mildew. The other resistant genotypes in the present study belong to *acidulous, indicus*, *kachri* and some intermediary types between *momordica* and *chandalak*. Variation for disease resistance was also observed among landraces collected from Kerala and Tamilnadu of South India (Fergany *et al*., 2011). Some powdery mildew resistant *acidulus* (AM22, AM67 and AM 90) and *momordica* (AM 86) melons were also identified. The Indian melon line 90625 (PI 313970) belongs to the *acidulus* botanical group was described as resistant to powdery mildew (Dogimont *et al*., 1996). Five unique genes conferring resistance to powdery mildew were identified in 90625 that acted as a potential source of resistance for strains in France (Pitrat and Besombes, 2008).

Germplasm evaluation for identification of new sources of disease resistance for the emerging new races of pathogen and genetic improvement through resistant gene introgression play great role in production and

productivity of crops. The unexplored resistant genotypes of the present study could be used in resistant gene introgression to cultivated varieties and also useful in studying the inheritance of disease resistant genes in a new background. The resistant line has also shown cross compatibility with other botanical groups of melon tested in our experiments. In melon improvement, the landraces especially snap melons of Indian origin have played an important role in providing disease resistance genes for major diseases throughout the world (Thomas *et al*., 1988; Balass *et al*., 1992; Pitrat and Besombes, 2008; Pitrate, 2008). Snapmelon accessions of *momordica* botanical class from North India have served as resistant sources for both powdery mildew and downy mildew diseases (Seshadri and More, 1996; Perchepied *et al*., 2005; Pitrat and Besombes, 2008, Pitrate, 2008; Liu *et al*., 2010; Dhillon *et al*., 2012; Reddy *et al*., 2016). Local types and wild relatives may look inferior but can contribute useful genes especially for biotic stresses (Simpson and Sedjo, 1998).

Breeding powdery mildew resistant melon cultivars started in the 1930 in California with the release of 'PMR 45' (Jagger and Scott 1937) using resistant gene of snap melon from Kathiawar region of Gujarat (Dhillon *et al*., 2012) and since then, many resistant cultivars have been created in different cultigroups of melons. Till now more than 28 putative races of *P. xanthii* have been identified (McCreight, 2006) and 30 different sources of resistance have been found in melon. The most commonly used sources of resistance are K 6205, K 6206, K 5692 and K 5519 (Malinina, 1974), PI 321005 (Zonia *et al*., 1983), PI 414723 (Epinat and Pitrat, 1994), LJ 525 (source for PMR 45), PI 79376 (source for PMR 5, PMR 6), PI 124112, PI 12411 (MR-1), all of them are from India (Perchepied *et al*., 2005; Pitrat and Besombes, 2008 and Pitrate, 2008).

Global genebanks contain Indian melon accessions originating from the north (Rajasthan) and central (Madhya Pradesh) parts of India (Staub and McCreight, 2004). The genetic diversity among the melon landraces of North and central India (McCreight *et al*., 1993 and Reddy *et al*., 2016), Tamilnadu and Kerala states of Southern India has been studied earlier (Fergany *et al*., 2011) but very minimum representation of germplasm of Karnataka state is observed (Reddy *et al*., 2016). The melon landraces of Karnataka state are unexplored for research purpose and literature about their documentation and usage is also very scanty. In this regard, the present study is very much relevant in collecting, evaluating and adding a new source of disease resistance line to melon crop improvement. The identification of highly resistant plants for downy and powdery mildew diseases within the accessions tested offers additional sources for the development of disease resistant melon cultivars and also to study the genetics of resistance in new background. Apart from this, the study also helps in documenting and conserving the endemic germplasm of the Karnataka state which is under-represented at national and world gene pool of melon.

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Ethical Statements

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Conflict of Interest: Nil

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