www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 484-491

www.thepharmajournal.com
Received: 19-02-2023
Accepted: 23-03-2023

Lingaraj B
Ph.D., Scholar, Department of Plant Pathology, College of Agriculture, UAS, Raichur, Karnataka, India

MK Naik
Director of Extension, UAS, Raichur, Karnataka, India

Yenjerappa ST
Professor and Head, Department of Plant Pathology, College of Agriculture, UAS, Raichur, Karnataka, India

Ajithkumar K
Scientist and Head, AICRP on Linseed, MARS, College of Agriculture, UAS, Raichur, Karnataka, India

Pampanna Y
Assistant Professor and Head, Horticulture Unit, MARS, College of Agriculture, UAS, Raichur, Karnataka, India

Kisan B
Assistant Professor, Department of Molecular Biology and Agricultural Biotechnology, College of Agriculture, UAS, Raichur, Karnataka, India

Corresponding Author:
Lingaraj B
Ph.D., Scholar, Department of Plant Pathology, College of Agriculture, UAS, Raichur, Karnataka, India

Screening of commercial cabbage cultivars for black rot resistance in Karnataka

Lingaraj B, MK Naik, Yenjerappa ST, Ajithkumar K, Pampanna Y and Kisan B

Abstract
Black rot of cabbage caused by *Xanthomonas campestris* pv. *campestris* (*Xcc*) is one of the most damaging disease that significantly reduces cabbage yields globally. The introduction of disease-resistant cabbage cultivars could be a simple and cost-efficient way to stop this deadly disease. We screened 28 cabbage cultivars under greenhouse conditions and 26 cultivars under field conditions for two seasons (*Kharif* 2021 and *rabi* 2021-22). None of the cultivars were immune or resistant to black rot in both greenhouse and field conditions. Under greenhouse conditions, only the Hari Rani cultivar recorded a moderately resistant reaction with a disease severity of 29.60 and a minimum AUDPC of 140.60 compared to the other cultivars. Whereas, six cultivars showed a moderately susceptible reaction, 11 were susceptible, and 10 were highly susceptible to black rot. During field screening of cultivars (*Kharif* 2021) identifies Hari Rani was a moderately resistant hybrid with 30.37 per cent of disease severity whereas during *rabi* 2021-22 none of them were recorded to be moderately resistant. The cultivar NEON was recorded highly susceptible to black rot during *rabi* 2021-22 season with a disease severity of 77.77 per cent whereas none of them showed a highly susceptible reaction during *Kharif* 2021.

Keywords: Black rot, *Xcc*, cabbage, cultivar, screening

Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.) is considered as one of the most important vegetable, widely grown for its nutritional and health benefits (Lee *et al*. 2015) [9]. Black rot caused by the seed-borne bacterium *Xcc*, is one of the most devastating diseases of brassicas (Vicente and Holub, 2013) [22], responsible for severe economic losses worldwide (Rimmer *et al*., 2007) [14]. *Xcc* is mainly a seed born pathogen, but can alive in crop residues and cruciferous weeds and ornamentals (Roberts *et al*. 1999; Vicente *et al*. 2001; Lema *et al*. 2011) [15, 21, 10]. The crop may be affected at any stage during the growth period *i.e*., from the stage of young seedling till maturity. The bacterial cells infect cabbage through hydathodes at the leaf margins. In cabbage, typical V-shaped chlorotic lesions or through stomata, causing round lesions. Warm and humid condition favors the disease development and splashing water from rain or sprinkler spreads the pathogen from plant to plant. *Xcc* is also introduced primarily from infected seeds in the greenhouse or field. The bacterium can survive in the soil if infected plant residues are not decomposed. Since temperature generally remains low during the vegetative growth stage of crucifer plants, one would not always expect the diseased plant to be easily detected (Schaad, 1982) [18]. In favorable condition, black rot disease can reduce crop yield by more than 50 per cent (Williams, 1980) [23]. However, farmers in Tanzania have reported up to 100 per cent yield loss in cabbage (Massomo *et al*. 2004) [11].

Use of pathogen-free seeds, seed treatment, sound sanitation practices, including the elimination of potential inoculum sources, such as infected crop debris (Williams, 1980; Kocks *et al*., 1998) [23, 7] and weeds (Williams, 1980; Schaad and Dianese, 1981) [23, 17] and use of resistant cultivars and crop diversification and rotation are crucial methods for managing black rot (Williams, 1980) [23]. Kocks and Ruissen (1996) [8] showed that increased field resistance reduced the development of black rot in time and space in cabbage. Moreover, the use of resistant cultivars is one of the most sustainable options, in comparison with chemical products used to control various diseases (Rodrigues *et al*., 2004; Seabra *et al*., 2008) [16, 19]. Thus, the evaluation of the resistance of cabbage cultivars to black rot is very important for material recommendation and resistance source selection (Morais *et al*., 2012) [12]. Numerous studies have been carried out to identify new sources of resistance in crucifers against black rot. In cabbage, Bain (1952) [2] initially found resistance in the cv. 'Huguenot' and in the

Japanese cv. 'Early Fuji' and made selections and derived lines from them, similarly, Hunter *et al*. (1987) [6] also reported resistance in the introduction from China PI 436606 (Heh Yeh da Ping Tou). Griesbach *et al*. (2003) [5], evaluated cultivars against *Xcc* races 1 and 4, reported some degree of resistance in cv. Green Challenger , Utopia , Shinzan No. 2 , Natsutae , Rotan and Tenacity. Five cabbage cultivars Hari Rani, Kranti, Geetanjali, Bahar and Pragati were found to be resistant to black rot, these can be exploited as disease management practices in organic farming where chemical disease management has no value (De and De, 2019) [4]. By keeping all these references efforts were made on to identify the resistant sources in cultivars of cabbage against black rot.

2. Material and Methods

2.1 Plant material

A total of 28 commercial cultivars of cabbage were collected, among them, 23 cultivars were collected from local markets of different districts and five cultivars were obtained from East-West company Bengaluru (Table 1) and were raised for three weeks in the nursery trays and after used for pot experiment and field study.

2.2 Inoculum preparation

The cabbage leaves showing typical black rot symptoms were collected from cabbge fields at UASR, and the pathogen was isolated according to Schaad (1989) [25]. The bacterium (*Xcc*) was multiplied in a conical flask having nutrient broth and incubated for 48 hours at 30 °C on the shaker. After two days, the broth was subjected to a UV-visible spectrophotometer to adjust OD at A610 nm to 0.45, which confirms that the broth contained cell suspension of 1x 10^8 cfu/ml, then the pathogen culture was used for inoculating to the cabbage seedlings or plants.

2.3 *In vivo* evaluation of different cultivars against *Xcc*

The experimental set-up was done at department of plant pathology, UAS Raichur green-house in which two seedlings from each cultivar were transferred to two earthen pots each pot represented as a replication. In each plant, three leaves were selected for inoculation. The bacterial culture was inoculated using a scissor by clip inoculation method. The observations were recorded every two days interval up to 14 days by using 0-9 scale (Table 2) as described by Vicente *et al*. (2001) [21].

2.4 Field screening of cabbage cultivars against *Xcc*

Field experiments were conducted during *Kharif* 2021 and *rabi* 2021-22 at the University of Agricultural Sciences Raichur. In field, the cultivars were planted with a spacing of 45 cm × 45 cm and maintained in two replications. All the cultural practices were followed as per the package of practices. The bacterial pathogen was inoculated 30 days after transplanting. Three young leaves of each plant were inoculated by clipping leaf edges with sterile scissor followed by dipping in bacterial suspension (10^8 -10^9 CFU/ml) of *Xcc* (Vicente *et al*., 2001) [21]. Observations for the disease severity were drawn using 0-9 scale (Table 2) as described by Vicente *et al*. (2001) [21]. The two days interval disease severity values were used to calculate area under the disease progress curve (AUDPC) according to the equation of Campbell and Madden (1990).

$$\text{AUDPC} = \sum_{i}^{n-1} (y_i + y_{i+1})/2X(t_{i+1} - t_i)$$

3. Result and Discussion

3.1 *In vivo* evaluation of commercial cabbage cultivars against *Xcc*

A total of 28 locally available commercial cabbage cultivars were screened against black rot under greenhouse conditions by artificial inoculation using the clipping method. The first symptoms of black rot appeared in inoculated plant four days after inoculation as characteristic faint V-shaped lesions beginning at the margin of the leaf. Out of 28 cabbage cultivars, none of them showed immune and resistant reaction against black rot disease whereas only one hybrid *i.e* Hari Rani showed moderately resistant reaction with disease score and severity of 3 and 29.60 per cent respectively. Six hybrids *viz*., Dolares, F1 Balaji, Globe Master, Indam 296, NS-22 and Shila have recorded moderately susceptible reaction to black rot by showing a maximum disease score of 5 with disease severity ranged from 44.40 to 55.50 per cent (Table 3).

Eleven cabbage cultivars *viz*., EWS CAB 001, EWS CAB 004, Gold Express, Indam Radha, Indam Saina, Manisha F1, NEON, NO. 118, PUMA, T-625 and Vishwadeep showed susceptible reaction to the disease (Table 3) by recording disease score of 7 with a disease severity range of 59.20 to 77.77 per cent. The cultivars *viz*., Ankur Manas, Butter Train, Border, EWS CAB 002, EWS CAB 003, Ganesh (LHC-1601), Green Valley, NS-22, Saint and Super Ball 50 recorded highly susceptible reaction to black rot with a disease score of 9 and disease severity range of 81.40-96.20 per cent. Out of 28 cabbage cultivars only four cultivars *viz*., F1 Balaji, Hari Rani, Indam 296 and Shila did not show any infection on head whereas remaining 24 cultivars showed infection on head. Eight cultivars *viz*., EWS CAB 004, F1 Balaji, Globe Master, Hari Rani, Indam 296, NS-22, Shila and T-625 did not show any black ring when the cross section of stem was observed whereas remaining 20 hybrids showed the black ring symptom beneath the head and inside the stem.

AUDPC of the different hybrids were calculated by recording the disease severity per cent at every two days interval, among them Hari Rani hybrid showed minimum AUDPC value of 140.60 (Table 4) followed by Globe Master with 214.60. The minimum AUDPC value indicates that the particular hybrid is resistant to *Xcc* compared to the other hybrids. The maximum AUDPC value of 510.50 was observed in Ankur Manas hybrid which was followed by Super Ball 50 with 477.30, higher AUDPC value indicates that the particular hybrid is susceptible to *Xcc*.

3.2 Field evaluation of commercial cabbage cultivars against black rot during *Kharif* 2021

During *Kharif* 2021, 26 commercial cabbage cultivars were screened against black rot of cabbage and observed large variation with respect to mean disease score ranging from 3 to 9. The first symptoms of black rot appeared in the field six days after inoculation as characteristic faint V-shaped lesions beginning at the margin of the leaf. Out of 26 hybrids, none of them were immune and resistant to black rot whereas, Hari Rani exhibited a moderately resistant reaction against black rot with 3 disease score (Table 5).

Eight cultivars *viz*., Border, EWS CAB 001, EWS CAB 002, EWS CAB 004, F1 Balaji, Indam 296, NS-22 and T-625 by recording disease score of 5 with 34.07 to 48.84 per cent of disease severity. Ten cultivars *viz*., Butter Train, EWS CAB 003, Globe Master, Gold Express, Indam Radha, Manisha F1, NEON, NO. 118, PUMA and Shila exhibited susceptible reaction by recording disease score of 7 with disease severity range of 42.92 to 56.24 per cent whereas, seven geotypes *viz*., Ankur Manas, Ganesh (LHC-1601), Green Valley, Indam Saina, Saint, Super Ball 50 and Vishwadeep showed highly susceptible reaction (51.06-68.08%). Majority of the cultivars also exhibited head infection (except EWS CAB 004, F1 Balaji, Hari Rani, Indam 296 and Shila) and black ring formation symptoms mainly based on susceptibility of the cabbage cultivars to black rot pathogen.

All cultivars exhibited AUDPC ranging from 115.53 to 333.22 (Table 6). The minimum AUDPC value was shown by Hari Rani hybrid which indicates that the hybrid is showing lower disease severity and inturn the hybrid might be resistant to black rot. On other hand, maximum AUDPC value (333.22) was possessed by Ankur MAnas hybrid which indicates that the hybrid is suffering from disease during the screening period and it might be susceptible to black rot.

3.3 Field evaluation of commercial cabbage cultivars to black rot during *rabi* 2021-22

During *rabi* 2021-22, 26 cabbage cultivars were screened against black rot of cabbage and large variation was observed with respect to mean disease score ranging from 3 to 9. Out of 26 hybrids, none of them were immune, resistant and moderately resistant against black rot. Seven cultivars showed moderately susceptible reaction *viz.*, EWS CAB 002, F1 Balaji, Gold Express, Hari Rani, Indam Radha, Indam 296, and T-625 (Disease severity ranged from 30.34 to 55.55). Thirteen cultivars exhibited susceptible reaction namely Butter Train, Border, EWS CAB 001, EWS CAB 003, EWS CAB 004, Globe Master, Indam Saina, Manisha F1, NO. 118, NS-22, PUMA, Shila, and Vishwadeep (51.06 to 59.94%). The six cultivars *viz*., Ankur Manas, Ganesh (LHC-1601), Green Valley, NEON, Saint and Super Ball 50 recorded highly susceptible reaction with severity ranged from 56.24 to 77.77 per cent. Majority of the cultivars also exhibited head infection and black ring formation symptoms mainly based on susceptibility of the cabbage cultivars to black rot pathogen (Table 7).

AUDPC was worked out for all the cultivars which ranged from 131.75 to 294.15 (Table 8). The minimum AUDPC value was shown by Hari Rani (131.75) and F1 Balaji (133.20) hybrids which indicates that the hybrid is showing lower disease severity and in turn the hybrid might be resistant to black rot. On other hand, maximum AUDPC value (294.15) possessed by Super Ball 50 hybrid indicated that the hybrid is suffering from disease during the screening period and it might be susceptible to black rot.

The cultivars except Hari Rani showed susceptible reaction under greenhouse as well as field level representing they might not having any disease resistant genes which are very much crucial in deployment of resistant genes. The findings are confirmatory with earlier studies on screening of cabbage or brassica cultivars to black rot pathogen. In support to this De and De (2019) [4] listed five hybrids of cabbage (Hari Rani, Kranti, Geetanjali, Bahar and Pragati) which were found resistant after screening with the disease. In our case also, Hari Rani recorded as resistant cultivar of cabbage in both greenhouse and field conditions represents that the cultivar having disease resistant genes. Basur (2012) [3] identified three hybrids, *viz*., Indu, Harhil, and Saint which are moderate resistant and two varieties Shila and Hybrid cabbage No-14 showed highly susceptible reaction to black rot among 10 varieties/hybrids tested. The present study also used Saint and Shila hybrid/variety wherein they showed susceptible to highly susceptible reaction because they were short duration, high yielding variety/hybrid which have been in cultivation for over a decade. This is particularly true with respect to Saint hybrid which has covered a cropping area of over 50 per cent in Karnataka (Yadahalli and Ravikumar, 2016) [24].

Similarly Eight commercial cabbage cultivars were evaluated for resistance to black rot pathogen under field conditions during 2018 and spring season of 2019 (Silva *et al*., 2020) [20]. They observed that in both growing seasons, 'TCA-549' recorded the minimum severity of black rot and 'Melissa' recorded the maximum severity of black rot. AUDPC was 175 and 139 for 'TCA-549' in fall and spring, respectively and the AUDPC for 'Melissa' in fall and spring were 2376 and 905, respectively. Afrin *et al*. (2018) [1] also screened cabbage inbred lines for black rot disease resistance through bioassay and identified some novel lines that showed race-specific resistance to *Xcc* races. From the pathogenicity, they revealed that out of 27 cabbage lines, one (SCNU-C-4074), six (SCNU-C-3631, SCNU-C-3637, SCNU-C-3639, SCNU-C-4072, SCNU-C-4073 and SCNU-C-3273), two (SCNU-C-3273 and SCNU-C-4118), two (SCNU-C-3270 and SCNU-C-4118), two (SCNU-C-3470 and SCNU-C-41148) and four (SCNU-C-107, SCNU-C-3270, SCNU-C-3470 and SCNU-C-4059) showed resistance to *Xcc* races 1, 2, 3, 5, 6 and 7 respectively while none of them showed resistance against race 4.

Similar studies were conducted by Penazova *et al*. (2018) [13] where they evaluated 24 cabbage breeding lines against *Xcc*. Further, they observed that the five breeding lines (DP25, T1, IT10, Kalibos and Avak1) showed minimum disease incidence of less than 20 per cent and these can be used as potential sources of resistance for further breeding. The results agree with Massomo *et al*. (2004) [11] where they screened 31 introduced cabbage cultivars against black rot under field conditions in Tanzania. They scored partial resistant F1 hybrids *viz*., Amigo F1, Maja F1, Rotan F1, Ducati F1, Adelita F1, Bravo F1, Blue Thunder F1, Fortress F1, JK-1 F1, Gianty F1, T-689 F1, N-9690 F1, N 66 F1 and Riana F1.

Table 1: List of cultivars under screening against black rot pathogen

Sl. No	Cultivar	Company	Sl. No	Cultivar	Company
1	Ankur Manas	Ankur Seeds	15	Indam Radha	Indo American Hybrid Seeds
2	Butter Train	Ashoka Seeds	16	Indam Saina	Indo American Hybrid Seeds
3	Border	Advanta	17	Indam 296	Indo American Hybrid Seeds
4	Dollar	Welcome Crop Science	18	Manisha F1	East West Seeds
5	EWS CAB 001	East West Seeds	19	NEON	SAKATA Seeds
6	EWS CAB 002	East West Seeds	20	NO. 118	MAHYCO
7	EWS CAB 003	East West Seeds	21	NS-22	NAMDHARI Seeds
8	EWS CAB 004	East West Seeds	22	PUMA	SAKATA Seeds
9	F1 Balaji	Welcome Crop Science	23	Radha	Indo American Hybrid Seeds
10	Ganesh (LHC-1601)	Lotus Seeds	24	Saint	Seminis
11	Globe Master	TAKKI Seeds	25	Shila	Acent Hyveg
12	Gold Express	URJA Seeds	26	Super Ball 50	Advanta
13	Green Valley	Kalash Seeds	27	T-621	TAKII Seeds
14	Hari Rani	MAHYCO	28	Vishwadeep	Know You Seeds

Table 2: Disease rating (0-9) scale for screening of black rot

Scale	Description	Per cent leaf area infected	Disease Reaction
0	No symptoms on the leaves	No symptoms	Immune (I)
1	Small necrosis or chlorosis near the leaf margin	1-5 per cent	Resistance (R)
3	Typical small V-shaped lesion with black veins	6-15 per cent	Moderately resistance (MR)
5	Typical lesion half way to the middle vein	16-30 per cent	Moderately Susceptible (MS)
7	Typical lesion succeeding to the middle vein	31 to 50 per cent	Susceptible (S)
9	Lesion reaching the middle vein	> 50 per cent	Highly susceptible (HS)

Table 3: Screening of cabbage cultivars against black rot disease under greenhouse condition

Sl. No	Cultivars	Maximum Disease score	Disease severity (%)	Disease reaction	Head infection	Black ring symptom
1	Ankur Manas	9	96.20	HS	+	+
2	Butter Train	9	81.40	HS	+	+
3	Border	9	88.80	HS	+	+
4	Dolares	5	55.50	MS	+	+
5	EWS CAB 001	7	77.70	S	+	+
6	EWS CAB 002	9	88.80	HS	+	+
7	EWS CAB 003	9	81.40	HS	+	+
8	EWS CAB 004	7	59.20	S	+	-
9	F1 Balaji	5	51.80	MS	-	-
10	Ganesh (LHC-1601)	9	88.80	HS	+	+
11	Globe Master	5	55.50	MS	+	-
12	Gold Express	7	74.00	S	+	+
13	Green Valley	9	88.80	HS	+	+
14	Hari Rani	3	29.60	MR	-	-
15	Indam Radha	7	66.60	S	+	+
16	Indam Saina	7	77.70	S	+	+
17	Indam 296	5	44.40	MS	-	-
18	Manisha F1	7	70.30	S	+	+
19	NEON	7	62.90	S	+	+
20	NO. 118	7	59.20	S	+	+
21	NS121	9	88.80	HS	+	+
22	NS-22	5	55.50	MS	+	-
23	PUMA	7	66.60	S	+	+
24	Saint	9	88.80	HS	+	+
25	Shila	5	55.50	MS	-	-
26	Super Ball 50	9	92.50	HS	+	+
27	T-625	7	59.20	S	+	-
28	Vishwadeep	7	62.90	S	+	+

Table 4: AUDPC of black rot on different cabbage cultivars in greenhouse condition

Sl. No	Cultivars	Disease severity (%)							AUDPC
		2DAI	4DAI	6DAI	8DAI	10DAI	12DAI	14DAI	
1	Ankur Manas	0.00	11.10	18.48	36.99	59.19	81.39	96.20	510.50
2	Bullet Train	0.00	5.55	12.95	29.60	44.40	59.20	81.40	384.80
3	Border	0.00	5.55	18.50	29.60	51.80	74.00	88.80	447.70
4	Dolares	0.00	0.00	7.40	14.95	22.20	40.70	55.50	226.00
5	EWS CAB 001	0.00	1.85	11.10	22.20	33.30	51.80	77.70	318.20
6	EWS CAB 002	0.00	5.55	25.90	29.60	44.40	66.60	88.80	432.90
7	EWS CAB 003	0.00	3.70	14.80	29.60	48.10	66.60	81.40	407.00
8	EWS CAB 004	0.00	5.55	7.40	18.50	33.30	44.40	59.20	277.50
9	F1 Balaji	0.00	0.00	7.40	22.20	29.60	37.00	51.80	244.20
10	Ganesh (LHC-1601)	0.00	5.55	12.95	29.60	44.40	62.90	88.80	399.60
11	Globe Master	0.00	0.00	5.55	7.40	22.20	44.40	55.50	214.60
12	Gold Express	0.00	0.00	11.10	14.80	33.30	51.80	74.00	296.00
13	Green Valley	0.00	11.10	29.60	40.70	55.50	74.00	88.80	510.60
14	Hari Rani	0.00	0.00	7.40	11.10	14.80	22.20	29.60	140.60
15	Indam Radha	0.00	1.85	7.40	18.50	33.30	44.40	66.60	277.50
16	Indam Saina	0.00	3.70	9.25	25.90	44.40	59.20	77.70	362.60
17	Indam 296	0.00	9.25	9.25	18.50	29.60	33.30	44.40	244.20
18	Manisha F1	0.00	7.40	7.40	11.10	25.90	48.10	70.30	270.10
19	NEON	0.00	5.55	18.50	33.30	40.70	55.50	62.90	370.00
20	NO. 118	0.00	9.25	27.75	35.15	46.25	53.65	61.05	405.15
21	NS121	0.00	11.10	29.60	40.70	55.50	74.00	88.80	510.60
22	NS-22	0.00	1.85	11.10	25.90	37.00	51.80	55.50	310.80
23	PUMA	0.00	3.70	14.80	25.90	40.70	51.80	66.60	340.40
24	Saint	0.00	7.40	22.20	40.70	62.90	81.10	88.80	517.40
25	Shila	0.00	0.00	7.40	18.50	25.90	44.40	55.50	247.90
26	Super Ball 50	0.00	11.10	22.20	33.30	55.50	70.30	92.50	477.30
27	T-625	0.00	1.85	9.25	27.75	31.45	42.55	57.35	283.05
28	Vishwadeep	0.00	0.00	11.10	18.50	33.30	55.50	62.90	299.70

Table 5: Field screening of cabbage cultivars against black rot disease (*Kharif* 2021)

Sl. No	Cultivars	Disease score	Disease severity (%)	Disease reaction	Head infection	Black ring symptom
1	Ankur Manas	9	68.08	HS	+	+
2	Butter Train	7	56.24	S	+	+
3	Border	5	45.14	MS	+	-
4	EWS CAB 001	5	46.99	MS	+	+
5	EWS CAB 002	5	48.84	MS	+	+
6	EWS CAB 003	7	52.54	S	+	+
7	EWS CAB 004	5	43.66	MS	-	-
8	F1 Balaji	5	34.07	MS	-	-
9	Ganesh (LHC-1601)	9	57.72	HS	+	+
10	Globe Master	7	49.62	S	+	-
11	Gold Express	7	52.59	S	+	+
12	Green Valley	9	58.46	HS	+	+
13	Hari Rani	3	30.37	MR	-	-
14	Indam Radha	7	42.92	S	+	-
15	Indam Saina	9	54.02	HS	+	+
16	Indam 296	5	38.48	MS	-	-
17	Manisha F1	7	55.55	S	+	+
18	NEON	7	55.87	S	+	+
19	NO. 118	7	49.58	S	+	+
20	NS-22	5	45.14	MS	+	-
21	PUMA	7	45.51	S	+	-
22	Saint	9	56.23	HS	+	+
23	Shila	7	44.40	S	-	-
24	Super Ball 50	9	60.68	HS	+	+
25	T-625	5	47.36	MS	+	-
26	Vishwadeep	9	51.06	HS	+	+

Table 6: AUDPC of black rot on different cabbage cultivars (*Kharif* 2021)

Sl. No	Cultivars	Disease severity (%)							AUDPC
		2DAI	4DAI	6DAI	8DAI	10DAI	12DAI	14DAI	
1	Ankur Manas	0.00	0.00	11.11	28.14	37.77	55.55	68.08	333.22
2	Bullet Train	0.00	0.00	8.14	15.55	28.14	40.00	56.24	239.90
3	Border	0.00	0.00	3.33	11.11	21.48	36.29	45.14	189.56
4	EWS CAB 001	0.00	0.00	6.29	17.77	27.40	39.35	46.99	228.61
5	EWS CAB 002	0.00	0.00	6.66	18.51	30.37	41.48	48.84	242.88
6	EWS CAB 003	0.00	0.00	7.04	19.29	28.88	40.74	52.54	244.44
7	EWS CAB 004	0.00	0.00	7.03	13.33	22.22	33.70	43.66	196.22
8	F1 Balaji	0.00	0.00	1.85	7.03	19.25	26.66	34.07	143.65
9	Ganesh (LHC-1601)	0.00	0.00	7.77	16.29	30.37	41.85	57.72	250.28
10	Globe Master	0.00	0.00	3.70	11.11	19.25	32.59	49.62	182.92
11	Gold Express	0.00	0.00	4.07	12.22	23.70	35.92	52.59	204.41
12	Green Valley	0.00	0.00	10.37	18.51	34.81	43.33	58.46	272.50
13	Hari Rani	0.00	0.00	1.85	3.70	12.96	24.07	30.37	115.53
14	Indam Radha	0.00	0.00	3.33	10.37	18.51	36.29	42.92	179.92
15	Indam Saina	0.00	0.00	7.03	12.22	20.37	38.51	54.02	210.28
16	Indam 296	0.00	0.00	2.59	7.40	15.55	29.62	38.48	148.80
17	Manisha F1	0.00	0.00	5.92	11.85	25.92	37.77	55.50	218.42
18	NEON	0.00	0.00	3.70	8.88	25.93	35.55	55.87	203.99
19	NO. 118	0.00	0.00	5.92	13.33	22.22	34.07	49.58	200.66
20	NS-22	0.00	0.00	2.96	9.62	17.40	30.37	45.14	165.84
21	PUMA	0.00	0.00	4.44	12.59	26.66	38.88	45.51	210.65
22	Saint	0.00	0.00	7.03	19.25	34.07	42.59	56.23	262.11
23	Shila	0.00	0.00	5.92	10.74	18.51	25.18	44.40	165.10
24	Super Ball 50	0.00	0.00	10.00	22.59	31.85	43.70	60.68	276.96
25	T-625	0.00	0.00	4.07	11.11	19.25	36.29	47.36	188.80
26	Vishwadeep	0.00	0.00	4.44	11.85	20.00	35.55	51.06	194.74

Table 7: Field screening of cabbage cultivars against black rot disease (*rabi* 2021-22)

Sl. No	Cultivars	Disease score	Disease severity (%)	Disease reaction	Head infection	Black ring symptom
1	Ankur Manas	9	59.20	HS	+	+
2	Butter Train	7	59.94	S	+	+
3	Border	7	55.87	S	+	+
4	EWS CAB 001	7	51.06	S	+	+
5	EWS CAB 002	5	49.21	MS	-	-
6	EWS CAB 003	7	51.80	S	+	-
7	EWS CAB 004	7	61.05	S	+	+
8	F1 Balaji	5	30.34	MS	-	-
9	Ganesh (LHC-1601)	9	56.24	HS	+	+
10	Globe Master	7	56.98	S	+	+
11	Gold Express	5	55.55	MS	+	+
12	Green Valley	9	56.24	HS	+	+
13	Hari Rani	5	33.33	MS	-	-
14	Indam Radha	5	39.96	MS	-	-
15	Indam Saina	7	59.94	S	+	+
16	Indam 296	5	42.92	MS	-	-
17	Manisha F1	7	59.20	S	+	+
18	NEON	9	77.77	HS	+	+
19	NO. 118	7	55.87	S	+	-
20	NS-22	7	48.84	S	-	-
21	PUMA	7	64.01	S	+	+
22	Saint	9	67.34	HS	+	+
23	Shila	7	57.35	S	+	-
24	Super Ball 50	9	76.59	HS	+	+
25	T-625	5	54.76	MS	+	-
26	Vishwadeep	7	58.46	S	+	+

Table 8: The area under disease progress curve of black rot on different cabbage cultivars (*rabi* 2021-22)

Sl. No	Cultivars	Disease severity (%)							AUDPC
		2DAI	4DAI	6DAI	8DAI	10DAI	12DAI	14DAI	
1	Ankur Manas	0.00	0.00	5.92	18.51	30.34	43.29	59.20	255.32
2	Bullet Train	0.00	0.00	7.40	15.54	24.42	37.37	59.94	229.40
3	Border	0.00	0.00	5.92	15.54	23.31	39.96	55.87	225.33
4	EWS CAB 001	0.00	0.00	2.59	11.10	19.98	37.74	51.06	193.88
5	EWS CAB 002	0.00	0.00	5.92	18.50	28.12	38.48	49.21	231.25
6	EWS CAB 003	0.00	0.00	6.29	19.24	25.53	33.33	51.80	220.58
7	EWS CAB 004	0.00	0.00	7.40	14.80	24.05	33.33	61.05	220.21
8	F1 Balaji	0.00	0.00	1.11	5.92	19.24	25.16	30.34	133.20
9	Ganesh (LHC-1601)	0.00	0.00	7.03	12.58	28.86	36.26	56.24	225.70
10	Globe Master	0.00	0.00	1.85	9.25	19.24	33.30	56.98	184.26
11	Gold Express	0.00	0.00	3.33	8.51	17.39	37.00	55.55	188.01
12	Green Valley	0.00	0.00	8.14	28.12	34.78	44.40	56.24	287.12
13	Hari Rani	0.00	0.00	3.70	7.03	12.58	25.90	33.33	131.75
14	Indam Radha	0.00	0.00	4.44	10.36	19.61	34.04	39.96	176.86
15	Indam Saina	0.00	0.00	7.77	12.21	18.50	38.48	59.94	213.86
16	Indam 296	0.00	0.00	6.29	18.50	28.12	33.30	42.92	215.34
17	Manisha F1	0.00	0.00	7.03	11.85	25.90	41.44	59.20	231.64
18	NEON	0.00	0.00	5.55	11.47	33.30	47.36	77.77	273.13
19	NO. 118	0.00	0.00	11.10	24.42	31.45	39.59	55.87	268.99
20	NS-22	0.00	0.00	4.81	11.10	28.49	37.74	48.84	213.12
21	PUMA	0.00	0.00	3.70	16.28	27.77	42.92	64.01	245.35
22	Saint	0.00	0.00	7.77	19.24	35.15	42.55	67.34	276.76
23	Shila	0.00	0.00	5.55	11.47	20.37	39.59	57.35	211.31
24	Super Ball 50	0.00	0.00	9.99	22.57	31.82	44.40	76.59	294.15
25	T-625	0.00	0.00	5.92	12.21	31.08	40.70	54.76	234.58
26	Vishwadeep	0.00	0.00	4.07	11.10	19.24	39.22	58.46	205.72

4. Conclusion

Plant breeders aim at development of cultivars (hybrids/varieties) with higher yield or higher biomass or quality parameters but these cultivars even if they are not specifically bred for disease resistance might have resistance which was unnoticed by them. This study was successful in identifying disease resistant cultivar among commercial available cultivars which are nor specifically bred for black rot of cabbage. Hence, screening of commercially available cultivars is important to identify disease resistant cultivars. Our results demonstrate that, there is a great potential of managing black rot in cabbage by host resistance. We suggest that partially resistant cultivar Hari Rani likely to be adopted by farmers and may thus, replace black rot susceptible cabbage varieties currently grown in Karnataka.

5. References

1. Afrin KS, Rahim MA, Park JI, Natarajan S, Rubel MH, Kim HT, *et al*. Screening of cabbage (*Brassica oleracea* L.) germplasm for resistance to black rot. Plant breeding and biotechnology. 2018;6(1):30-43.
2. Bain DC. Reaction of brassica seedlings to black rot. Phytopathology 1952;42:316-319.
3. Basur VN. Investigations on cabbage black rot caused by *Xanthomonas campestris* pv. *campestris* (Pammel). M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka (India) 2012, 148.
4. De T, De LC. Disease management in organic agriculture. International Journal of Recent Scientific Research. 2019;10:33458-33461.
5. Griesbach E, Loptien H, Miersch U. Resistenz gegen *Xanthomonas campestris* pv. *campestris* (Pammel) Dowson im Kohl *Brassica oleracea* L. Journal of Plant Diseases and Protection. 2003;110:461-475.
6. Hunter JE, Dickson MH, Ludwig JW. Source of resistance to black rot of cabbage expressed in seedlings and adult plants. Plant Disease. 1987;71(3):263-266.
7. Kocks CG, Ruissen MA, Zadoks JC, Duijkers MG. Survival and extinction of *Xanthomonas campestris* pv. *campestris* in soil. European Journal of Plant Pathology. 1998;104:911-923.
8. Kocks CG, Ruissen MA. Measuring field resistance of cabbage cultivars to black rot. Euphytica. 1996;91:45-53.
9. Lee J, Izzah NK, Jayakodi M, Perumal S, Joh HJ, Lee HJ, *et al*. Genome-wide SNP identification and QTL mapping for black rot resistance in cabbage. BMC plant biology. 2015;15(1):1-1.
10. Lema M, Soengas P, Velasco P, Francisco M, Cartea ME. Identification of sources of resistance to *Xanthomonas campestris* pv. *campestris* in *Brassica napus* crops. Plant disease. 2011;95(3):292-297.
11. Massomo SM, Mortensen CN, Mabagala RB, Newman MA, Hockenhull J. Biological control of black rot (*Xanthomonas campestris* pv. *campestris*) of cabbage in Tanzania with *Bacillus* strains. Journal of Phytopathology. 2004;152(2):98-105.
12. Morais JOP, Cardoso AF, Leao EF, Peixoto N. Desempenho de cultivares de couve-flor de verao em Ipameri. Ciencia Rural. 2012;42:1923-1928.
13. Penazova E, Kopta T, Jurica M, Pecenka J, Eichmeier A, Pokluda R. Testing of inoculation methods and susceptibility testing of perspective cabbage breeding lines (*Brassica oleracea* var. *capitata*) to the black rot disease caused by *Xanthomonas campestris* pv. *campestris*. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 2018;66(4):139-148.
14. Rimmer SR, Shattuck VI, Buchwaldt L. Compendium of

brassica diseases. American Phytopathological Society. 2007;15(3):60-62.
15. Roberts SJ, Hiltunen LH, Hunter PJ, Brough J. Transmission from seed to seedling and secondary spread of *Xanthomonas campestris* pv. *campestris* in Brassica transplants: effects of dose and watering regime. European Journal of Plant Pathology. 1999;105:879-89.
16. Rodrigues VJ, Michereff SJ, Menezes D, Aguiar Filho MR, Silva LG, Biondi CM. Epidemiologia comparativa da alternariose em cultivares de brássicas sob cultivo convencional e orgânico. Summa Phytopathologica. 2004;30(2):226-233.
17. Schaad NW, Dianese JC. Cruciferous weeds as sources of inoculum of *Xanthomonas campestris* in black rot of crucifers. Phytopathology. 1981;71(11):1215-1220.
18. Schaad NW. Detection of seed-borne bacterial plant pathogens. Plant Disease. 1982;66(10):885-890.
19. Seabra JS, Paixao GDS, Maringoni AC, Goto R, Camara RDC. Reacao de hibridos de brocolis tipo cabeça unica a podridao negra. Summa Phytopathologica. 2008;34:76-77.
20. Silva AL, Candian JS, Rego ER, Coolong T, Dutta B. Screening cabbage cultivars for resistance to black rot under field conditions. Horticulture Technology. 2020;30(3):448-455.
21. Vicente JG, Conway J, Roberts SJ, Taylor JD. Identification and origin of Xanthomonas campestris pv. campestris races and related pathovars. Phytopathology. 2001;91(5):492-499.
22. Vicente JG, Holub EB. *Xanthomonas campestris* pv. *campestris* (cause of black rot of crucifers) in the genomic era is still a worldwide threat to brassica crops. Molecular Plant Pathology. 2013;14(1):2-18.
23. Williams PH. Black rot: a continuing threat to world crucifers. Plant disease. 1980;64(8):736-742.
24. Yadahalli KB, Ravikumar MR. Survey of bacterial black rot of cabbage in Haveri, Belagavi and Dharwad district of northern Karnataka. Indian Phytopathology. 2016;69(4s):401-404.
25. Schaad NW, Postnikova E, Lacy GH, Sechler A, Agarkova I, Stromberg PE, *et al*. Reclassification of Xanthomonas campestris pv. citri (ex Hasse 1915) Dye 1978 forms A, B/C/D, and E as X. smithii subsp. citri (ex Hasse) sp. nov. nom. rev. comb. nov., X. fuscans subsp. aurantifolii (ex Gabriel 1989) sp. nov. nom. rev. comb. nov., and X. alfalfae subsp. citrumelo (ex Riker and Jones) Gabriel *et al*., 1989 sp. nov. nom. rev. comb. nov.; X. campestris pv malvacearum (ex Smith 1901) Dye 1978 as X. smithii subsp. smithii nov. comb. nov. nom. nov.; X. campestris pv. alfalfae (ex Riker and .... Systematic and applied microbiology. 2005 Aug 1;28(6):494-518.