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Assessment of incidence and severity of wilt complex of pomegranate caused by *Ceratocystis fimbriata* and *Meloidogyne incognita* in major districts of north Karnataka

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Abstract
Pomegranate (*Punica granatum* L.) being one of the commercial horticulture crops is highly threatened by the wilt complex caused by *Ceratocystis fimbriata* and *Meloidogyne incognita*. To know the incidence, the survey was conducted during 2016-17 and 2017-18 in Bagalkot and Vijayapur districts of northern Karnataka. Among two districts, maximum average per cent disease index of wilt was noticed in Bagalkot (8.53%) than Vijayapura (7.15%). Among 6 taluks of Bagalkot, maximum average wilt disease incidence was noticed in Badami (19.91%) followed by Bagalkot (9.25%). Among 5 taluks of Vijayapura districts surveyed average wilt disease incidence was noticed maximum in Sindgi (13.49%) followed by Basavana bagevadi (8.51%). Among the pomegranate orchards maximum disease incidence was noticed in Neerbudihal village of Bagalkot district (71.12%) followed by Tanda village of Vijayapur district (26.8%). Lowest incidence was observed in Basarkod village of Vijayapur district (0.17%) followed by Kamatagi village of Bagalkot district (0.88%). The wilt incidence, root-knot infestation and shot hole bore incidence was higher in orchards of 4-5 years old compared to orchards below 2-3 years.

Keywords: Pomegranate wilt, *Ceratocystis fimbriata*, *Meloidogyne incognita,* per cent disease index

Introduction
Pomegranate (*Punica granatum* L.) is a popular fruit considered as symbol of fertility and prosperity, also called as "Fruit of Paradise" is a deciduous shrub or a small tree belongs to the family Lythreceae, having 2n=16 number of chromosome and it is native to Iran.

Pomegranate cultivation is a highly lucrative and remunerative agriculture business in India. It is regarded as a "vital cash crop", grown in an area of 224 thousand ha with a production of 2650 thousand MT and it occupies sixth place in fruit export market of India (Anon, 2018) [1]. Maharashtra is the largest producer occupying 2/3rd of total area in the country followed by Karnataka, Andhra Pradesh, Gujarat and Rajasthan. Karnataka state has the distribution of cultivating pomegranate under tropical condition in an area of 28.09 thousand hactare with a production of 328.92 thousand MT (Anon, 2017) where this crop has spread across different districts *viz.*, Vijayapur, Bellary, Bagalkot, Koppal, Chitradurga, Belagavi, Davangere, Tumkur, Bangaluru and Kalaburgi.

Successful cultivation of pomegranate in recent years has met with different traumas of pest and diseases. Bacterial blight, wilt, anthracnose, shot hole bore, thrips, fruit borer are some of the diseases and pests. Wilt caused by *Ceratocystis fimbriata* Ell. & Halst has become a major threat. In recent years at present the wilt incidence in traditional pomegranate growing areas of Bagalkot and Vijayapur districts of Karnataka has assumed an alarming situation. It was first noticed in two areas of the Vijayapur district in 1990. This was once deemed as a minor disease, but now has become a serious threat for pomegranate production resulting in severe yield losses.

The disease was prevalent in parts of Maharashtra, Karnataka, Andhra Pradesh, Gujarat and Tamil Nadu states (Jadhav and Sharma, 2009) [8]. Despite many factors conducive for the high severity of disease, selection of seedlings for planting, soil borne nature of pathogen and also association with plant parasitic nematodes are of prime importance. The estimation of yield losses due to root-knot nematode, *M. incognita* in pomegranate has been reported to the extent of 17.3 per cent (Jain *et al*., 2010) [9].

Their association with wilt complex is documented by Sonyal (2010) [19]. This might be the reason for the current rampant spread of the disease in south Indian states. This has drawn the attention of the present study to know the incidence of wilt complex in north Karnataka. Hence, a survey in the worst hit area of north Karnataka is the need of the hour to assess the disease incidence, severity, association of pathogens, and also to know prevalence with respect to locality, cultivar *etc.*

Material and methods

To assess the extent of disease severity of wilt complex, intensive roving survey was conducted during 2016-17 in two important pomegranate growing district of northern Karnataka. *i.e.,* in Bagalkot and Vijayapur districts to know the incidence of *Ceratocystis fimbriata* and association of nematodes.

The survey was conducted in major taluks, selecting 3 villages in each taluk and two fields in each village. Samples of soil and roots were collected from the rhizosphere of pomegranate crop up to the root depth. The per cent disease incidence was calculated using the following formula.

$$\text{Per cent disease incidence} = \frac{\text{No. of plants showing wilting symptom}}{\text{Total number of plants}} \times 100$$

Each soil sample was filled in polythene bag and tied with a rubber band and labelled immediately. Information pertaining to the locality, crop history, *etc.* was also labelled along with the samples. Samples of soil and roots were analysed on the day of collection or after keeping for a few days under refrigerated conditions. The nematode population from soil was estimated.

Nematode infected galled root system was scored by using a disease rating (0 to 5 scale) given by Taylor and Sesser (1978) [20].

Number of galls per root

Grade	Number of galls per root
0	No galls per plant
1	1-2 galls per plant
2	3-10 galls per plant
3	11-30 galls per plant
4	31-100 galls per plant
5	More than 100 galls per plant

Results

To assess the extent of severity of wilt complex, intensive roving survey was conducted during 2016-17 in Bagalkot and Vijayapur districts of northern Karnataka. The survey was conducted to know the incidence of *Ceratocystis fimbriata* and association of root-knot nematode in pomegranate. The survey was conducted in all taluks of the two districts, selecting three villages in each taluka and two fields in each village, as explained in "Materials and Methods." The data are presented in Table 1, 2 and 3.

The results revealed that among six taluks of Bagalkot district surveyed (Table 3), maximum total per cent disease incidence was recorded in Badami (19.91%) followed by Bagalkot (9.25%), Hunagund (9.25%), Jamakhandi (7.22%), Bilagi (6.99%) and Mudhol (4.08%). The average per cent yellowing, partial wilting and complete wilt symptoms observed in Badami taluk were 15.45%, 1.94% and 2.71%; in Bagalkot taluk 0.95%, 2.86% and 5.44%; in Hunagund taluk 1.29%,1.55% and 6.19%; in Jamakhandi taluk 1.80%, 1.86% and 3.56%; in Bilagi taluk1.58%, 1.43% and 3.99% and in Mudhol taluk 0.99%, 1.13% and 1.96% respectively. Among the villages of Bagalkot districts (Table 1) maximum disease incidence was noticed in Neerbudihal village of Badami taluk (71.12%) followed by Kellor village of Hunagund taluk (15.43%). The least disease incidence was observed in Kamatagi village of Hunagund taluk followed by Yendigeri village (1.19%) of Badami taluk.

With respect to Vijayapur district, the results revealed that among five taluks surveyed (Table 3) maximum total per cent disease incidence was recorded in Sindagi (13.49%) followed by Basavana bagewadi (8.51%), Vijayapur (5.89%), Indi (4.15%), and Muddebihal (3.64%). The average per cent yellowing, partial wilting and complete wilt symptoms observed in Sindagi taluk were 3.46%, 3.70% and 6.33%; in Basavana bagewadi 0.66%, 1.27% and 6.58%; in Vijayapur taluk 0.87%, 1.59% and 3.52%; in Indi taluk 1.11%,1.26% and 1.76%; and in Muddebihal taluk 0.80%, 1.17% and 1.67% respectively. Among the villages of Vijayapur districts (Table 2), maximum disease incidence was noticed in Tanda village of Vijayapur district (26.8%) and lowest incidence was observed in Basarkod village of Vijayapur taluk (0.17%) followed by Kannolli of Sindagi taluk (1.07%).

Incidence of wilt complex of pomegranate was noticed in all the places surveyed**.** Among two districts, slightly higher average Per cent Disease Index (PDI) of wilt was noticed in Bagalkot district (8.53%) compared to Vijayapura district (7.15%). Among 6 taluks of Bagalkot maximum average wilt disease incidence was noticed in Badami taluk (19.91%) followed by Bagalkot taluk (9.25%). Among 5 taluks of Vijayapura districts surveyed, average wilt disease incidence was noticed maximum in Sindagi taluk (13.49%) followed by Basavana bagevadi taluk (8.51%). The least disease incidence was observed in Muddebihal taluk (3.64%) of Vijayapura district followed by Mudhol taluk (4.08%) of Bagalkot district. Among the pomegranate orchards maximum disease incidence was noticed in Neerbudihal village of Bagalkot district (71.12%) followed by Tanda village of Vijayapur district (26.8%). Lowest incidence was observed in Basarkod village of Vijayapur district (0.17%) followed by Kamatagi village of Bagalkot district (0.88%).

Higher wilt disease incidence was noticed in orchards more than 4-5 years old (11.15%) and while it was less in orchards below 1-2 years (3.48%). Root-knot nematode and shot hole bore association was noticed in orchards more than 4-5 years. The maximum incidence of wilt complex disease was observed in sandy loam (17.47%) followed by black soil (10.08%), sandy soil (9.81%) and red soil (5.85%). It was evident from the survey that among the commonly growing pomegranate cultivars (*viz.*, Bhagwa, Kesar, Ruby and Sindhur) Bhagwa was found to be highly susceptible to *C. fimbriata*, root-knot nematode and shot hole borer.

Symptoms of the disease caused by *C. fimbriata* and *M. incognita*

Wilt complex of pomegranate results in complete wilting of plant and is characterized by the initial symptoms as yellowing and wilting of leaves on one to several branches. At times only one or two stems of the tree showed wilting and it took a few weeks to some months for the entire tree to completely wilt. Although yellowing of leaves normally produced acropetally, occasionally some plants revealed wilt

symptoms all of a sudden by senescing the entire plant's foliage at once (Plate 1). Wilt infected plants often revealed dried foliage and fruits being attached to the branches for many months (Plate 2c). The xylem of the trunk turned brown to black with a star burst like pattern with blue strains on stem was noticed (Plate 2a & b). In many orchards diseased trees were observed dying in patches (Plate 1e), there by indicating the spread of the disease from an infected to an adjacent healthy tree. However, in some orchards wilt infection were spotted unevenly at different locations. Below ground symptoms like the dark black to greyish colour mycelial mat was observed on the root portion (Plate 3a) with characteristic fruity odour and root-knot nematode associated roots showed large galls or knots throughout the root system of infected plants (Plate 3b). The galls were white in colour turned to light brown and hardy when they became old. The intensity of root-knot nematode damage increased with increase in age of the plant. In general, more than four to five year old plants were severely affected by root-knot nematode. Egg masses were observed inside as well as outside of the galls. More number of females were found in a single compound gall. Severe infection resulted in dying of whole tree causing severe yield losses leading to death of affected plants in a few weeks.

a. Initial yellowing of tertiary branches

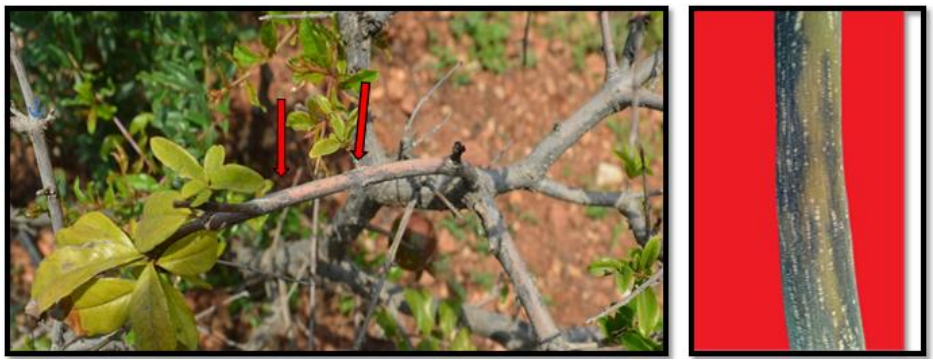
b. Yellowing of secondary branches

c. Partial wilting of plant

d. Complete wilting of plant

e. Over view of the field showing patchy appearance of wilt

Plate 1: Different stages of wilt symptoms in pomegranate



1. Blue stains on twigs

b. Brown and black discoloration inside the stem

c. Dried fruits in wilt infected plants remain attached to twigs

Plate 2: Different symptoms of wilt in pomegranate

Table 1: Status of wilt of pomegranate in Bagalkot district as recorded in survey during 2017-2018

S. No	Taluk	Village		Age of the crop (years)	Soil type	Variety	Wilt incidence (%)					Root-knot (Grade)	Shot hole borer (Grade)
							Yellowing	Partial wilt	Complete wilt	Total wilt	Average wilt		
1.	Badami	Anwal	Field-1	2	Black	Sindhoor	2.14	1.71	2.85	6.71	5.46	2-3	2-3
			Field-2	2	Black	Sindhoor	1.00	1.20	2.00	4.20		2-3	0-2
		Neerboodihal	Field-1	5	Black	Sindhoor	62.50	4.37	6.25	73.12	71.12	0	3-4
			Field-2	5	Black	Sindhoor	56.20	6.25	6.62	69.12		0	2-3
		Shellikeri	Field-1	4	Red	Kesar	1.11	1.00	1.60	3.70	1.88	0-2	2-3
			Field-2	3	Red	Kesar	0.13	0.13	1.33	0.06		0	0
		Yandigeri	Field-1	2	Black	Sindhoor	0.14	0.28	0.14	0.57	1.19	0	0
			Field-2	2	Black	Sindhoor	0.36	0.54	0.90	1.81		0	1-2
2	Hunagund	Kamatagi	Field-1	2	Red	Kesar	0.18	0.25	0.12	0.55	0.88	0-3	0
			Field-2	2	Red	Kesar	0.44	0.22	0.55	1.21		0-3	0-3
		Kelloor	Field-1	5	Sandy	Kesar	2.45	4.09	3.27	9.81	15.43	0-4	0
			Field-2	4	Red	Sindhoor	2.22	2.22	16.6	21.04		0	2-4
		Shiroor	Field-1	5	Red	Sindhoor	2.22	2.22	16.6	21.04	10.77	0	0-3
			Field-2	5	Red	Sindhoor	0.20	0.30	0.00	0.5		0	0
3	Bilagi	Bilagi	Field-1	2	Sandy loam	Kesar	3.33	0.83	16.6	20.76	14.66	0	0
			Field-2	8	Red	Ruby	1.42	4.28	2.85	8.55		0	0
		Mannikeri	Field-1	2	Red	Kesar	0.13	0.13	0.00	0.26	1.67	0	0-2
			Field-2	3	Red	Kesar	1.66	1.25	0.16	3.07		3-4	0
		Sunaga	Field-1	3	Red	Kesar	1.66	1.25	0.16	3.07	4.66	0-4	0
			Field-2	2	Black	Kesar	1.25	0.83	4.16	6.24		1	0-2
4	Jamakhandi	Gani	Field-1	7	Sandy loam	Kesar	2.63	1.05	10.50	14.18	1.82	3-5	0
			Field-2	3	Red	Kesar	1.00	2.00	6.00	9.00		0-3	0
		Konnoor	Field-1	2	Black	Kesar	2.38	1.58	0.63	4.59	3.40	0-2	0-3
			Field-2	2	Black	Kesar	4.41	5.88	2.05	12.34		2-4	0-2
		Mareguddi	Field-1	3	Red	Kesar	0.18	0.37	1.88	2.43	1.59	0	0-3
			Field-2	3	Black	Kesar	0.18	0.28	0.28	0.74		0	0-3
5	Mudhol	Chikkur	Field-1	3	Red	Kesar	0.83	2.59	1.85	5.27	5.29	2-4	0
			Field-2	4	Red	Kesar	1.25	0.50	3.55	5.30		1-4	0-3
		Malapoor	Field-1	4	Red	Kesar	1.25	0.50	1.00	2.75	2.55	3-4	0-3
			Field-2	2	Red	Kesar	1.17	0.70	0.47	2.34		0	0
		Shirol	Field-1	2	Black	Kesar	0.33	0.83	1.11	2.27	4.41	0-3	0
			Field-2	2	Red	Kesar	1.11	1.66	3.77	6.54		0-3	0-3
6	Bagalkot	Govindakoppa	Field-1	6	Black	Bhagwa	2.22	7.77	11.11	21.10	11.39	3-5	0
			Field-2	4	Black	Bhagwa	0.21	0.42	1.05	1.68		0-3	0
		Kaladgi	Field-1	4	Black	Bhagwa	0.88	0.55	5.88	7.31	10.94	0-4	0
			Field-2	6	Black	Bhagwa	1.71	4.28	8.57	14.56		0	0
		Tulasigere	Field-1	3	Red	Ruby	0.25	3.75	3.75	7.75	5.42	0	0-3
			Field-2	5	Red	Bhagwa	0.45	0.36	2.27	3.08		0	0

Table 2: Status of wilt of pomegranate in Vijayapur district as recorded in survey during 2017-2018

Sl. No	Taluk	Village		Age of the crop (years)	Soil type	Variety	Wilt incidence (%)					Root-knot (Grade)	Shot hole borer (Grade)
							Yellowing	Partial wilt	Complete wilt	Total wilt	Average wilt		
1	Indi	Atharga	Field-1	5	Black	Bhagwa	3.42	2.73	6.84	12.99	6.97	0	0
			Field-2	10	Black	Bhagwa Kesar	0.30	0.15	0.50	0.95		0-4	3
		Benakanalli	Field-1	3	Black	Bhagwa Kesar	0.20	0.57	0.20	1.14	1.79	0	0-3
			Field-2	4	Black	Bhagwa	0.00	1.11	1.33	2.44		0	0-5
		Tamba	Field-1	4	Black	Kesar	1.11	1.38	1.11	3.6	3.70	0	0
			Field-2	6	Red	Kesar	1.60	1.6	0.60	3.8		0-4	0-3
2	Vijayapur	Aliyabad	Field-1	5	Black	Kesar	1.33	1.66	2.00	4.99	4.69	3-4	0
			Field-2	4	Black	Kesar	0.80	1.60	2.00	4.40		2-3	0
		Halli	Field-1	5	Black	Bhagwa	0.20	0.75	1.50	2.45	2.30	3-4	0
			Field-2	5	Black	Kesar	0.30	0.69	1.15	2.14		2-4	0
		Jumanal	Field-1	3	Black	Kesar	0.88	0.55	5.88	7.31	10.94	2-5	0
			Field-2	4	Black	Kesar	1.71	4.28	8.57	14.56		0-4	0
3	Muddebihal	Basarkod	Field-1	3	Black	Kesar	0.00	0.00	0.10	0.10	0.17	0	0
			Field-2	3	Black	Kesar	0.07	0.05	0.12	0.24		0	0
		Hadalageri	Field-1	3	Red, Black	Kesar	0.99	2.13	7.10	10.22	6.35	0-4	0-3
			Field-2	3	Red	Kesar	0.80	1.6	0.08	2.48		0-4	0-2
		Rakkasgi	Field-1	6	Red	Kesar	1.60	1.6	0.60	3.80	4.40	0-4	0-3
			Field-2	3	Black	Bhagwa	1.33	1.66	2.00	4.99		0-4	0

Sl. No	Taluk	Village		Age of the crop (years)	Soil type	Variety	Wilt incidence (%)					Root-knot (Grade)	Shot hole borer (Grade)
							Yellowing	Partial wilt	Complete wilt	Total wilt	Average wilt		
4	Basavana bagewadi	Hunasyal	Field-1	4	Black	Kesar	0.99	2.13	7.10	10.22	10.02	0-4	0-3
			Field-2	2	Black	Kesar	0.55	0.36	8.90	9.81		0	0
		Managuli	Field-1	3	Black	Kesar	0.80	0.66	0.26	1.72	10.04	0	0-2
			Field-2	3	Black	Kesar	0.80	0.36	17.2	18.36		0-1	0
		Sankanal	Field-1	2	Black	Kesar	0.25	3.75	3.75	7.75	5.47	0-3	0
			Field-2	2	Black	Kesar	0.55	0.36	2.27	3.18		0	0
5	Sindagi	Bommanajol	Field-1	5	Black	Bhagwa	1.42	3.42	2.85	7.69	12.60	0	0-2
			Field-2	3	Red	Bhagwa	3.75	6.25	7.5	17.5		0-2	0-1
		Kannolli	Field-1	3	Black	Kesar	0.5	0.16	0.33	0.99	1.07	0	0-3
			Field-2	3	Black	Kesar	0.19	0.57	0.38	1.14		0	0-3
		Tanda	Field-1	4	Black	Kesar	0.90	1.81	10.9	13.61	26.81	0	0-4
			Field-2	5	Black	Kesar	14	10	16	40		0-5	0

Table 3: Status of wilt of pomegranate in Bagalkot and Vijayapur districts as recorded in survey during 2017-2018

S. No.	District	Taluk	Yellowing (%)	Partial wilt (%)	Complete wilt (%)	Total wilt (%)	Root-knot (Grade)	Shot hole borer (Grade)
1	Bagalkot	Badami	15.45	1.94	2.71	19.91	0-3	0-4
2		Bagalkot	0.95	2.86	5.44	9.25	0-5	0-3
3		Bilagi	1.58	1.43	3.99	6.99	0-4	0-2
4		Hunagund	1.29	1.55	6.19	9.03	0-4	0-4
5		Jamakhandi	1.80	1.86	3.56	1.89	0-5	0-3
6		Mudhol	0.99	1.13	1.96	4.08	0-4	0-3
Mean			3.68	1.80	3.98	8.53		
1.	Vijayapur	Basavana bagewadi	0.66	1.27	6.58	8.51	0-4	0-3
2.		Indi	1.11	1.26	1.76	4.15	0-4	0-5
3.		Muddebihal	0.80	1.17	1.67	3.64	0-4	0-3
4.		Vijayapur	0.87	1.59	3.52	5.98	4-5	0
5.		Sindagi	3.46	3.70	6.33	13.49	0-5	0-4
Mean			1.38	1.80	3.97	7.15		

Discussion

The survey revealed that wilt incidence is in alarming stage in all pomegranate growing areas surveyed. The per cent of wilt incidence varied from locality to locality. Farmers are using local planting material which is neither certified nor completely ensured that they are free from disease. Thus, initial inoculum through infected planting materials from one place to another probably attributes for the spread of the disease. The higher disease incidence in Bagalkot and Vijayapura in the present study may be due to the mono cropping of same susceptible varieties since many years. Most of the farmers are unaware of wilt complex disease. The lack of proper diagnosis for the disease and unawareness of proper management practices by farmers might have led to severity of wilt complex. The faster multiplication of nematode population in the soil probably due to congenial soil temperature and association of these nematodes along with the fungus might have aggravated wilt complex incidence which in turn results in severe loss to the farmers.

However, earlier surveys in Karnataka revealed the presence of *C. fimbriata* and *M. incognita* with an average disease incidence of 0.1 -33.3 per cent (Benagi *et al*., 2009) [2], 8.69% (Jadhav and Sharma, 2009) [8] and 5.69% (Somasekhara *et al*, 2009) [16]. Sonyal *et al*., 2010 [19] reported that wilt incidence ranged from 22.3 to 45.2 per cent in different surveyed locations of six northern Karnataka districts. Somu (2017) [17] carried out survey in major pomegranate growing districts of Karnataka to know the incidence of wilt during 2015-16, which revealed that the highest incidence of disease in Bagalkot district (15.27%) and least in Chitradurgra district (3.75%). Bagalkot and Vijayapura districts are traditional pomegranate growing belts where pomegranate is grown in large area as a sole crop. The higher incidence of pomegranate wilt disease in these districts may be due to the continuous cultivation of the crops since many years resulting in more build-up of inoculum.

It was evident from the survey that among the commonly growing pomegranate cultivars, *viz.,* Bhagwa, Kesar, Ruby and Sindhur; the cultivar Bhagwa was found to be highly susceptible to *C. fimbriata*, root-knot nematode and shot hole borer. Chaudhari *et al.*, 2016 [3] screened four pomegranate cultivars/varieties against wilt disease of pomegranate under glass house condition. The maximum wilt disease incidence was recorded in the cultivar Bhagwa which was followed by Mridula, Arakta and G-137. Over all it was found that none of the variety showed resistance to wilt disease. Farmers are using local planting material which is neither certified nor completely ensured that they are from disease free orchards. Thus, initial inoculum through planting material, accompanied with susceptible variety and prevailing congenial soil and climatic conditions help to aggravate the disease. Somu *et al.*, 2017 [17] reported that the overall mean incidence of wilt in major pomegranate growing district of Karnataka was recorded 6.97 per cent on different cultivars such as Bhagwa, Ruby and Super Bhagwa. He also noticed that higher incidence (10.97%) in older orchards which attributed to build up of inoculum in the soil due to continuous cultivation of the crop year after year at same locations.

As per the survey carried out in pomegranate growing areas there was variation in per cent wilt incidence with respect to the soil type. The maximum incidence of wilt complex was observed in sandy loam soil (17.47%) followed by black soil (10.08%), sandy soil (9.81%) and red soil (5.85%). The wilt incidence, shot hole borer and root-knot infection was high in black soil compared to red soil (Somu *et al.*, 2017) [18]. On the

contrary Imran Khan (2017) reported that the maximum incidence of wilt complex disease was observed in red sandy soil (36.41%), followed by sandy loam soil (35.25%), red soil (33.15%) and black soil (28.50%).

The weather data of Bagalkot and Vijayapur district shows that the temperature ranges between 25-30 ^{0}C with 55-60% humidity which is congenial for the fungus *C. fimbriata* for easy and rampant sporulation and spread of the disease. Somu *et al*., 2017 [18] revealed that the maximum growth of *C. fimbriata* (81.00 mm) was obtained at 25 ^{0}C, whereas optimum range was 20 ^{0}C to 30 ^{0}C. Vijaya (2005) observed that maximum growth of *C. Paradoxa* obtained at 30 ^{0}C and optimum range is between 20 to 35 ^{0}C. A basic characteristic of soil fungi is their mycelial growth form and mycelial exploration through soil as influenced by soil physical characteristics since hyphae must ramify through the complex heterogeneous network of pores. The effects of physical conditions on hyphal spread are difficult to ascertain because of the geometric complexity of the pore networks (Vogel 1997) [21]. Many factors may modulate fungal growth in soils, such as nutrient availability, pH, aeration, and microbivory (Frey 1999) [5].

During the survey root-knot incidence was noticed up to grade 5 was higher. Most of the infected fields recorded root-knot incidence more than 3 grade. In survey, in very few fields root-knot infection was not noticed. The nematode population build up in the soil was probably due to steady increase in soil temperature. Association of these nematodes along with fungus aggravated wilt complex incidence which results in severe loss to the farmers. The maximum population of root-knot nematode (1260 J_2/200 cm^3 of soil), root galls (117/5 g roots) and egg masses (120/5 g roots) were recorded in the 52nd meteorological week, when the maximum and minimum temperatures of air were 28.1 ^{0}C and 10.0 ^{0}C respectively (Walunj *et al.,* 2013) [22].

The warm climate favours the development of root-knot nematodes. Soil temperatures, in Bagalkot and Vijayapur districts, for most of the year, are suitable for nematode activity. The nematodes occur throughout the year where intensive agriculture is practiced. Nematodes generally take 5 to 15 years to develop; but once developed, it is almost impossible to eradicate them (Khan *et al*, 1993) [10].

Symptoms of the disease caused by *C. fimbriata* and *M. incognita*

The typical symptoms of wilt complex of pomegranate results in complete wilting of plant and is characterized by the initial symptoms as yellowing and wilting of leaves on one to several branches. At times only one or two stems of the tree showed wilting and it took few weeks to some months for the entire tree to completely wilt. Wilt infected plants often revealed dried foliage and fruits being attached to the branches for many months. The xylem of the trunk turned brown to black with a star burst like pattern with blue strains on stem was noticed. Below ground symptoms like the dark black to greyish colour mycelial mat was observed on the root portion with characteristic fruity odour. In severely infected fields similar symptoms of wilt were earlier recorded by many scientists *viz.*, Somasekhara and Wali, 1999 [15]; Huang *et al.*, 2003 [6]; Sharma 2009 [14]; Khosla *et al*, 2013 [11]; Xu *et al.*, 2011 [23]; Jadhav and Sharma, 2009 [8]; Raja 2017 [13], and Somu, 2017 [18].

Root-knot nematode associated roots showed large galls or knots throughout the root system of infected plants. In general plants aged more than four to five years were severely affected by root-knot nematode. Plants infested severely by root-knot nematode exhibited yellowing of foliage resulting in stunted plant growth. These plants produced less number of fruits or no fruits. In severe cases the galls were predominantly found on entire root system. The galls were white in colour turned light brown in colour and hardy when they become old. The symptoms observed in the present studies were more or less similar to those described by Kore and Mitkar, 1993 [12] and Chaudhari *et al.*, 2016 [3]. Perineal pattern is the most important morphological characters used for reliable species identification. The root-knot nematode species on pomegranate were characterized by the presence of high, squarish dorsal arch that often continued a distinct whorl in the tail terminal area. The striae were smooth to wavy. Sometimes, zig zagged and distinct lateral lines. The observed characters were same with the descriptions given by Eisenback *et al*, (1981) [4].

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