RESEARCH ARTICLE Legume Research- An International Journal, Volume 45 Issue 5: 639-645 (May 2022)

Occurrence and Distribution of Dry Root Rot of Chickpea Caused by *Macrophomina phaseolina* (Tassi) Goid. in Arid Region of Rajasthan

Mahendra Partap, S.L. Godara

10.18805/LR-4429

ABSTRACT

Background: Dry root rot of chickpea caused by *Macrophomina phaseolina* (Tassi) Goid. is emerging as a serious threat to the chickpea production worldwide. The disease is gaining importance under the changing scenario of climate particularly in the rainfed ecologies of India and in arid and semi-arid region of Rajasthan. The current study was aimed to discusses current status of the disease and role of different factors in disease development to help in searching of possible management options for researchers to alleviate the problem.

Methods: A roving survey was conducted to record the occurrence and distribution of dry root rot in ten major chickpea growing districts of Rajasthan during *rabi* season 2014-15 and 2015-16. In each district, minimum three locations/villages were selected, in each location/village minimum three fields were selected and the incidence of disease was recorded after counting the diseased and healthy plants.

Result: Overall range of disease incidence in all the districts vary from 5.75 to 12.51 per cent with an average of 9.15 per cent in Rajasthan. The maximum disease incidence 12.51 per cent was observed in Jaisalmer district while minimum in Ajmer district. The disease was found very common in sandy and sandy loam soil than any other types of soil. The deshi/local varieties were found to be more susceptible to infection of *M. phaseolina* as compared to improved varieties. Disease incidence was also observed higher in sprinkler system of irrigation as compared to flood method and rainfed conditions. The maximum disease incidence was observed in plants at flowering and podding stages in the months of February and March.

Key words: Chickpea, Dry root rot, Incidence, *Macrophomina phaseolina*, Survey.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) also known as Bengal gram is one of the most important winter season food legume crops grown in India. Worldwide, the major chickpea producing countries are India, Australia, Myanmar, Ethiopia, Turkey, Russian Federation and Pakistan. India is the world leader in chickpea, share 67% production followed by Australia. In India, it is grown in about an area of 10.56 m ha with production of 11.23 m tonnes and productivity of 1063 kg/ha and highest production received from Madhya Pradesh (41%) followed by Maharashtra (16%) and Rajasthan (15%) (Anonymous, 2017-18a).

Chickpea is cultivated throughout the Rajasthan state, the major chickpea growing districts are Bikaner, Jaisalmer, Churu, Jhunjhunu, Hanumangarh, Sri Ganganagar, Jaipur, Sikar and Ajmer. The total area and production of chickpea in Rajasthan are 1.57 million ha and 1.67 million tonnes, respectively having productivity of 1062 kg/ha (Anonymous, 2017-18b). The chickpea productivity of Rajasthan is higher than the world and almost equal to India.

Chickpea suffers from several soil borne fungal diseases among these, dry root rot of chickpea an important disease in arid and semi-arid region of Rajasthan. The DRR in chickpea was first reported from India by Mitra (1931); later, the disease has been reported from most chickpea-growing areas in India and other countries like Iran (Kaiser *et al.,* 1968), the USA (Westerlund *et al.* 1974) and several countries in Asia and Africa (Nene *et al.* 1996). The first report of root rot occurrence in chickpea along with wilt was made by Padwick (1948). Dry root rot (DRR) of chickpea caused by nectrotropic fungus *Rhizoctonia bataticola* (Taub.) Butler [Pycnidial stage: *Macrophomina phaseolina* (Tassi) Goid.] is emerging as a serious threat to the chickpea production worldwide (Pande and Sharma, 2010). Dry root rot is a potentially emerging disease of chickpea in rainfed ecologies worldwide. The disease is gaining importance under the changing scenario of climate particularly in the semi-arid tropics of Ethiopia and in central and southern

Department of Plant Pathology, College of Agriculture, S.K. Rajasthan Agricultural University, Bikaner-334 006, Rajasthan, India.

Corresponding Author: Mahendra Partap, Department of Plant Pathology, College of Agriculture, S.K. Rajasthan Agricultural University, Bikaner-334 006, Rajasthan, India.
Email: mpbishnoi89@gmail.com

How to cite this article: Partap, M. and Godara, S.L. (2022). Occurrence and Distribution of Dry Root Rot of Chickpea Caused by *Macrophomina phaseolina* (Tassi) Goid. in Arid Region of Rajasthan. Legume Research. 45(5): 639-645. DOI: 10.18805/LR-4429.

Submitted: 25-05-2020 **Accepted:** 16-12-2020 **Online:** 29-07-2021

India (Pande *et al.,* 2012). It causes enough yield losses that vary from 5 to 50% and may cause 100% losses in susceptible cultivars under favorable conditions. Gupta *et al.* (1983) reported incidence of root rot ranged from 3.58 to 20.63 per cent in northern Madhya Pradesh. A survey was conducted by Ghosh *et al.* (2013) during *rabi* season 2010-2011 indicated widespread and increased incidence of dry root rot in the central and southern states of India.

Certain agro-climatic characters of arid and semi-arid region like hot climate, very erratic rainfall, high evaporation and water scarcity are attributed for making sandy soils more conducive to soil-borne pathogen *M. phaseolina* causing dry root rots in many economically grown plants. Low organic matter and microbial population coupled with poor moisture retention capacity of soils favour survival and multiplication of the main source of inoculum of soil-borne pathogens. Sclerotia are the most important propagule for survival in soil. Soil populations of sclerotia increase if susceptible host crops are grown annually (Meyer *et al.,* 1973). Repeated freezing and thawing of soil, low C:N ratio and soil moisture content are critical factors affecting microsclerotia survival (Dhingra and Sinclair, 1975). Under low soil moisture condition production of microsclerotia gets enhanced whereas high soil moisture has negative effect on sclerotial production (Dhingra and Sinclair, 1977). In contrast to the many pathogens favored by change to moisture conditions (Garrett *et al.,* 2006), *M. phaseolina* may become more problematic in agricultural areas where climate change results in longer drought periods and higher temperatures (Mihail, 1989, 1992). It is necessary to know the severity of the disease and factors associated with disease development, which will help in devising suitable and effective management practices feasible to each location, looking into the prevailing conditions. Therefore, the present investigation was carried out to study the factors associated directly or indirectly with dry root rot disease incidence in arid and semi-arid region of Rajasthan.

MATERIALS AND METHODS

Areas surveyed

A roving survey was conducted to record the occurrence and distribution of dry root rot in major chickpea growing districts of Rajasthan *viz.,* Ajmer, Bikaner, Churu, Hanumangarh, Jaipur, Jaisalmer, Jhunjhunu, Jodhpur, Sikar and Sri Ganganagar during *Rabi* season 2014-15 and 2015-16. In each district, minimum three locations/villages were selected, in each location/village minimum three fields were selected and in each field, five plots of 10 m^2 were selected and the incidence of disease was recorded after counting the diseased and healthy plants.

Data collection

While surveying, data on variety grown, soil type, cropping pattern prevalence in the area, method of irrigation of chickpea crop, based on infected plants and total number of plants observed, disease incidence was calculated. Chickpea plants showing the typical dry root rot symptoms were collected from surveyed areas, packed in labelled paper bags and brought to the laboratory for isolation of the pathogen. Based on observations the disease incidence was calculated by following formula (Horsfall and Cowling, 1978).

$$\text{Dry root rot incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

RESULTS AND DISCUSSION

Dry root rot of chickpea is an important soil-borne disease in arid and semi-arid region of Rajasthan. A roving survey was conducted during *rabi* season 2014-15 and 2015-16 in major chickpea growing districts of Rajasthan revealed that dry root rot was a major disease problem in Jaisalmer, Jodhpur, Jhunjhunu, Churu and Bikaner districts. The survey was conducted when the crop stage was between 90 to 120 days.

The results presented in Table 1 and Fig 1 indicated that the disease incidence and distribution was noticed in all the chickpea fields wherever the survey was conducted. The maximum disease incidence was observed in plants at flowering and podding stage in the month of February and March. Overall range of disease incidence in all the districts varied from 5.75 to 12.51 per cent with an average of 9.15 per cent in Rajasthan. The maximum disease incidence was recorded in Jaisalmer (12.51%) followed by Jodhpur (11.31%), Jhunjhunu (10.99%), Churu (10.42%) and Bikaner (9.20%) which was above the state level average (9.15%) of Rajasthan. While, in case of Ajmer (5.75%), Jaipur (6.34%), Hanumangarh (7.52%), Sikar (8.68%) and Sri Ganganagar (8.73%) the disease incidence was found below the state level average. In the surveyed districts, no single district and location was completely free from the dry root rot disease incidence.

During survey of dry root rot disease, a total forty-nine locations of ten districts was surveyed. The range of disease incidence in all locations was varied from 3.53 to 16.67 per cent with an average of 9.15 per cent. The maximum disease incidence was found in Suthar mandi (16.67%) followed by Nachna (14.47%) locations of Jaisalmer district, Phalodi (14.10%) location of Jodhpur district, Dabla (13.04%) location of Sri Ganganagar district, Dungergarh (12.99%) location of Bikaner district, Navalgarh (12.94%) location of Sikar district and Chidawa (12.50%) of Jhunjhunu district, Mohangarh (12.50%) of Jaisalmer and Sujangarh (12.50%) of Churu district. While minimum in disease incidence was found in Durgapura (3.53%) location of Jaipur district, Kishangarh (3.66%) and Beawar (4.55%) locations of Ajmer district. Rest of other areas or locations were recorded more than 5.00 per cent dry root rot incidence.

Observations of dry root rot incidence were also recorded on improved and local chickpea varieties. The variety GNG-1581, GNG-469 are high yielding and most commonly grown varieties of chickpea in the state. Improved varieties *viz.,* GNG-1581, GNG-469 and RGS-888 were sown by the farmers in forty-five locations while, local varieties found in four locations. Results given in Table 1

Table 1: Per cent disease incidence of dry root rot of chickpea incited by *Macrophomina phaseolina* in Rajasthan.

District / Village	Mean disease incidence (%)*	Crop variety	Soil type	Cropping pattern	Irrigation method	Stage of disease incidence
Ajmer						
Beawar	4.55	GNG-1581	Sandy loam	SG:MU	Flood	P
Bijainagar	5.33	GNG-1581	Sandy loam	CT:CB	Flood	P
Kekri	6.90	GNG-1581	Clay loam	CT:CB	Flood	P
Kishangarh	3.66	GNG-1581	Clay loam	SG:CT	Flood	P
Sarwar	8.33	Local	Sandy loam	CT:SG	Flood	F and P
Average	5.75					
Bikaner						
Akkasar	10.59	GNG-1581	Sandy loam	CB:GN	Sprinkler	P
Bajju	8.14	GNG-1581	Sandy loam	CB:GN	Sprinkler	P
Dungergarh	12.99	Local	Sandy	CB/Fallow	Sprinkler	F and P
Khajuwala	7.04	GNG-1581	Loamy sand	CB/Fallow	Flood	P
Lunkaransar	5.88	GNG-1581	Loamy sand	CB:GN	Flood	P
Napasar	10.23	GNG-469	Sandy loam	CB:GN	Sprinkler	P
Nokha	9.52	GNG-1581	Sandy loam	CB:MO	Sprinkler	P
Average	9.20					
Churu						
Bhadasar	9.41	GNG-1581	Sandy loam	CB:MO	Sprinkler	P
Bikamsra	10.47	GNG-1581	Sandy loam	CB:MO	Sprinkler	F and P
Ratangarh	8.75	GNG-1581	Sandy loam	CB:MO	Sprinkler	P
Sardarshahar	10.98	GNG-1581	Sandy loam	CB:MO	Sprinkler	P
Sujangarh	12.50	GNG-469	Sandy loam	MO:CB	Sprinkler	F and P
Average	10.42					
Hanumangarh						
Chohilanwali	5.88	GNG-1581	Clay loam	CT:CB	Flood	P
Mainawali	7.37	GNG-1581	Clay loam	CT:CB	Flood	P
Nohar	7.95	GNG-1581	Sandy loam	CB:MU	Flood	F and P
Rawatsar	8.89	GNG-1581	Clay loam	CB:CT	Flood	F and P
Average	7.52					
Jaipur						
Bassi	8.00	RSG-888	Loamy sand	PM:CB	Sprinkler	P
Chomu	7.50	RSG-888	Loamy sand	PM:CB	Sprinkler	P
Durgapura (ARS)	3.53	RSG-888	Loamy sand	PM:CB	Sprinkler	P
Average	6.34					
Jaisalmer						
Bikampur	10.98	GNG-1581	Sandy loam	CB:GN	Flood	P
Mohangarh	12.50	GNG-1581	Sandy loam	CB:CP	Flood	P
Nachna	14.47	GNG-1581	Sandy loam	CB:CP	Flood	P
Ramgarh	7.95	GNG-1581	Clay sandy	CB:CP	Flood	P
Suthar mandi	16.67	GNG-1581	Sandy	CB:CP	Flood	F and P
Average	12.51					
Jhunjhunu						
Bisau	9.76	GNG-1581	Sandy loam	PM:CO	Sprinkler	P
Chidawa	12.50	GNG-1581	Sandy loam	PM:CO	Sprinkler	P
Jaakhal	9.88	GNG-1581	Sandy loam	PM:CO	Sprinkler	P
Udaipur wati	11.84	GNG-1581	Sandy loam	PM:CO	Sprinkler	P
Average	10.99					

Table 1: Continue...

Table 1: Continue...

Jodhpur						
Bapini	11.63	GNG-1581	Loamy	PM:MU	Sprinkler	P
Dechu	9.88	GNG-1581	Loamy sand	PM:MU	Sprinkler	P
Lohawat	12.20	GNG-1581	Clay loam	PM:SM	Sprinkler	P
Mandor (ARS)	8.89	GNG-1581	Sandy loam	PM:CB:MU	Sprinkler	F and P
Phalodi	14.10	GNG-1581	Sandy loam	PM:CB:SM	Sprinkler	F and P
Average	11.34					
Sikar						
Dataramgarh	6.02	GNG-1581	Sandy loam	PM:MU	Rainfed	P
Laxmangarh	10.26	Local	Sandy loam	PM:CO	Sprinkler	P
Losal	8.86	GNG-1581	Sandy loam	PM:CO	Rainfed	P
Navalgarh	12.94	Local	Sandy loam	PM:CO	Sprinkler	F and P
Neemkathana	5.32	GNG-1581	Sandy loam	PM:CO	Rainfed	P
Average	8.68					
Sri Ganganagar						
Bhagwangarh	7.37	GNG-1581	Loamy sand	CB:CP	Rainfed	P
Bhompura	7.14	GNG-1581	Sandy loam	CB:CP	Rainfed	P
Dabla	13.04	GNG-1581	Sandy loam	CB:CP	Rainfed	P
Muklawa	8.70	GNG-1581	Sandy loam	CB:CP	Rainfed	P
Ridmalsar	10.59	GNG-1581	Sandy loam	CB:CP	Rainfed	P
Rojari	5.56	GNG-1581	Sandy loam	CB:CP	Flood	F and P
Average	8.73					
General mean	9.15					

PM = Pearl millet [*Pennisetum americana* (L.) Leeke], SG = Sorghum [*Sorghum bicolor* (L.) Moench], MU = Mung [*Vigna radiata* (L.) Wilczek], CP = Chickpea [*Cicer arietinum* (L.)], BG = Black Gram [*Vigna mungo* (L.) Hepper], SM = Sesamum [*Sesamum indicum* (L.)], CO = Cow pea [*Vigna unguiculata* (L.) Walp.], CT = Cotton [*Gossypium hirsutum*], CB = Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.], GN = Groundnut [*Arachis hypogaea* (L.)], MO = Mothbean [*Vigna aconitifola* (Jacq.) Marchel]. F = Flowering, P = Podding stage. *Pooled data of two year.

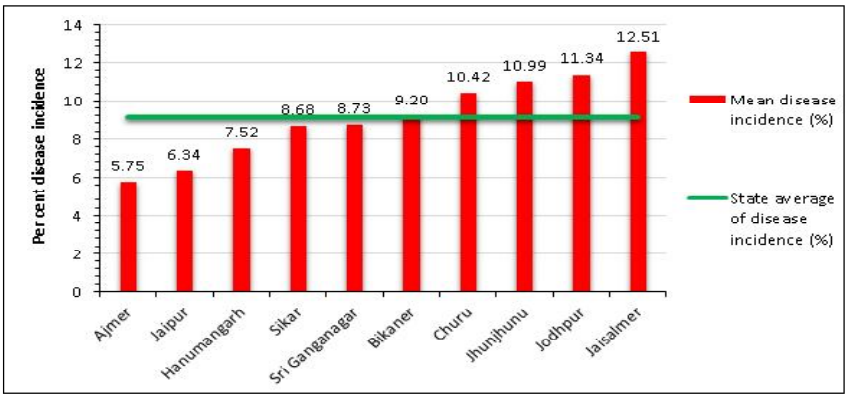

Fig 1: District wise incidence of dry root rot disease of chickpea in Rajasthan.

and Fig 2(A) referred that the disease incidence was more in local varieties (11.13%) in comparison to improved varieties (8.89%).

Disease variation was also found in soil types. Sandy, loam and clay soil types were found in thirty-six, eight and five locations of Rajasthan, respectively. Results given in Table 1 and Fig 2(B) indicated that the maximum average disease incidence was recorded in sandy soil (9.87%) followed by loamy soil (7.60%). Minimum disease incidence was recorded in clay soil (7.55%).

The effect of cropping pattern on dry root rot incidence were also recorded during the survey of chickpea fields. In mostly four types of cropping patterns were followed in ten districts of Rajasthan. The Cluster bean-based cropping pattern was found in twenty-five locations of Bikaner, Churu, Hanumangarh, Jaisalmer and Sri Ganganagar district.

The Pearl millet-based cropping pattern was found in seventeen locations of Jaipur, Jhunjhunu, Jodhpur and Sikar district. Cotton-based cropping pattern was found in five locations of Alwar and Hanumangarh district. Results presented in Table 1 and Fig 2(C) referred that the maximum average disease incidence was found in cluster bean (9.93%) followed by pearl millet (9.59%) and cotton (6.76%) based cropping pattern. Minimum disease incidence was observed in sorghum-based cropping pattern (4.10%), which was found in only two locations of Alwar district.

Results also indicated that the disease incidence was recorded more (9.25%) under irrigated conditions in comparison to rainfed conditions (8.38%) [Fig 2(D)]. Disease incidence was recorded maximum in sprinkler system (10.27%) as compare to rainfed conditions (8.38%) and flood method (8.32%). In chickpea, little information is available on the impacts of irrigation on dry root rot and almost nothing is known about how the disease is affected by different methods and levels of irrigation. Irrigation can play a detrimental rather than beneficial role in managing plant diseases. Irrigation water can spread pathogen propagules and increasing the level of disease inoculum in soil.

In the present study, it was evident from survey data, dry root rot incidence varied from locality to locality. The unpredictable moisture stress, wind current and higher temperature especially in arid region probably predisposed the chickpea crop to favourable conditions for dry root rot disease development. Occurrence and distribution of dry root rot of chickpea may also be due to soil type, varieties grown, environmental conditions *viz.,* high temperature, low soil moisture content, relative humidity and cropping pattern like cluster bean-chickpea, bajra-chickpea and chickpea-chickpea and build-up of inoculums. Monoculture of chickpea crop in this region is main source of primary inoculum. The present findings were supported by various earlier workers. Gupta *et al*. (1983) reported incidence of root rot in northern Madhya Pradesh ranged from 3.58 to 20.63 per cent and disease was more severe at pod formation to grain filling stage particularly under stress condition. Tripathi and Sharma (1983) reported that incidence was high from late-October to mid-November which was decreased in December-January and then again increased in the months of February-March. Similarly, significant reduction from 25 to 70 per cent in chickpea production is caused by this disease in India noticed by Ahmed and Mohammad (1986) and Pandey and Singh (1990). Higher temperature and soil moisture depletion during crop growth period particularly at pre-harvesting stage were predisposing chickpea to DRR (Sharma and Pande, 2013). A survey conducted in the central and southern states of India indicated widespread and increased incidence of DRR. The distribution and incidence of chickpea dry root rot disease was recorded with respect to soil types, cropping system and cultivars used and incidence ranged from 5 to 50 per cent or more in badly infected soils (Ghosh *et. al.,* 2013).

Soil texture also had a significant impact on root rot infections. In the present survey severe root rot disease incidence was observed in sandy loam as compared to loamy sandy and clay loam. Similar to the present results, Cruz Jimenez (2011) observed highest *M. phaseolina* root populations in sandy soils, followed by seedlings planted in loamy sand and loam soil textures. Likewise, increased populations of *M. phaseolina* and root rot severity of

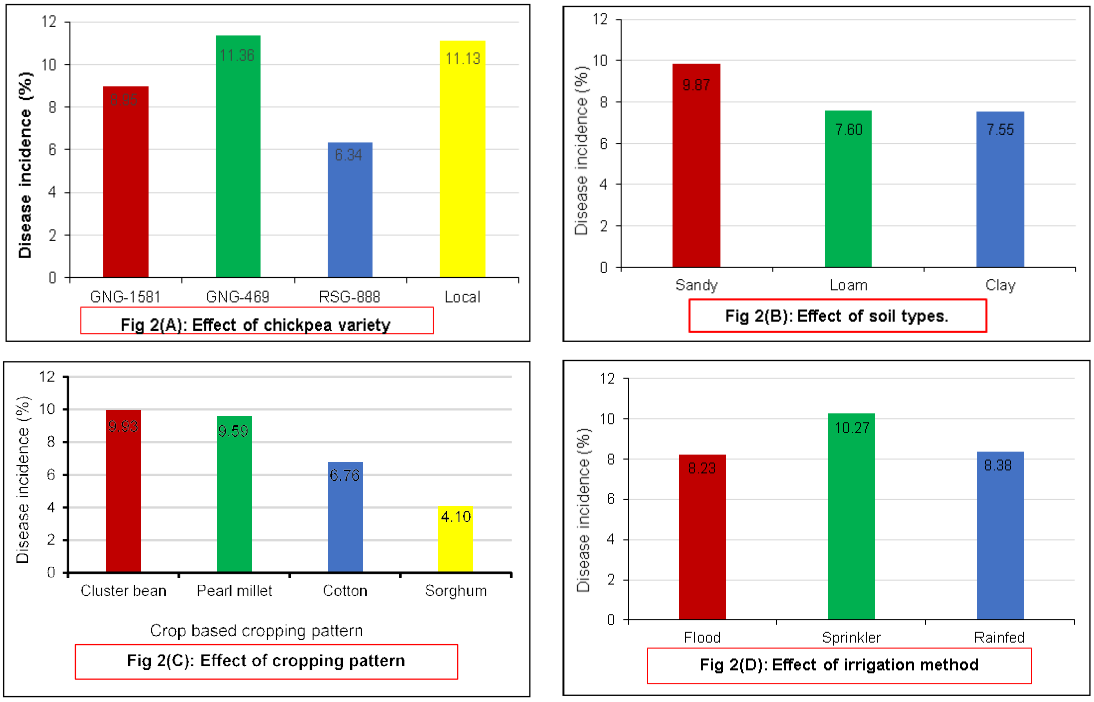

Fig 2: Effect of different parameters on per cent incidence of dry root rot of chickpea in Rajasthan.

soybean, sorghum and mungbean in sandy soils was also reported (Dhingra and Sinclair, 1973; Collins *et al.,* 1991; Hooda and Grover, 1990). Higher incidence of the disease in sandy soils might be attributed to the less competitive saprophytic ability of the pathogen at high moisture holding capacity associated with heavy soils like clay (Umamaheshwari, 1991) and reduction in the germination of sclerotia of *M. phaseolina* at high moisture holding capacity (Ali and Ghaffar, 1991).

CONCLUSION

Dry root rot of chickpea incited by *Macrophomina phasolina* (Tassi) Goid. is an important disease in arid and semi-arid region of Rajasthan. Occurrence and distribution of the dry root rot was observed as an important disease in Jaisalmer, Jodhpur, Jhunjhunu, Churu and Bikaner districts of Rajasthan. However, the dry root rot disease was found almost in all the chickpea growing areas. The maximum disease incidence was observed in plants at flowering and podding stages in the months of February and March when temperature starts rise up. The dry root rot disease incidence was varied from location to location and variety to variety. Comparatively deshi/local varieties were found to be more susceptible to *M. phaseolina* infection as compared to improved varieties. Variation was also observed among the soil types, sandy soils were more conducive to soil borne pathogen. The maximum disease incidence was recorded in cluster bean, pearl millet and cotton-based cropping pattern as compared to sorghum-based cropping pattern. Results also indicated that the disease incidence was more in sprinkler system of irrigation as compared to flood method and rainfed conditions. Chickpea grown after clusterbean and bajra crop in sandy soil mainly in Jaisalmer, Jhunjhunu and Churu under irrigated conditions was observed more susceptible to *M. phaseolina*. So, chickpea growing farmers of this region should use certified seed of improved varieties, proper seed treatment before sowing, must follow crop rotation and maintain suitable soil moisture for long duration to minimize disease inoculum levels.

ACKNOWLEDGEMENT

The authors are grateful to the Department of Plant Pathology, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner for providing facilities to conduct this research and survey. The authors are also grateful to all those who helped for providing useful information during survey.

REFERENCES

Ahmed, Q. and Mohammad, A. (1986). Losses in yield due to Rhizoctonia root rot of chickpea in Bihar. Indian Phyto--pathology. 39: 590-592.

Ali, F. and Ghaffar, A. (1991). Effect of water stress on rhizosphere microflora and root infection of soybean. Pakistan Journal of Botany. 23: 135-139.

Anonymous. (2017-18a). Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare, Govt. of India, New Delhi. 2018. www.agricoop.nic.in.

Anonymous. (2017-18b). DoA, Department of Agriculture, Govt. of Rajasthan, Jaipur, www.krishi.rajasthan.gov.in.

Collins, D.J., Wyllie, T.D. and Anderson, S.H. (1991). Biological activity of *Macrophomina phaseolina* in soil. Soil Biology and Biochemistry. 23: 495-496.

Cruz Jimenez. (2011). Influences of soils, nutrition and water relations upon charcoal rot disease processes in Kansas. M.Sc. Thesis, Kansas State University, Kansas.

Dhingra, O.D. and Sinclair, J.B. (1973). A location of *Macrophomina phaseoli* on soybean plants related to cultural characteristics and virulence. Phytopathology. 63: 934-936.

Dhingra, O.D. and Sinclair, J.B. (1977). An Annotated Bibliography of *M. phaseolina* 1905-1975. Universidade Federal Vicosa, Brazil. pp. 277.

Dhingra, O.D., Sinclair, J.B. (1975). Survival of *Macrophomina phaseolina* sclerotia in soil: Effect of soil moisture, carbon: nitrogen ratio, carbon sources and nitrogen concentrations. Phytopathology. 65: 236-240.

Garrett, K.A., Dendy, S.P., Frank, E.E., Rouse, M.N. and Travers, S.E. (2006). Climate change effects on plant disease: Genomes to ecosystems. Annual Review of Phytopathology. 44: 489-509.

Ghosh, R., Sharma, M., Telangre, R. and Pande, S. (2013). Occurrence and distribution of chickpea diseases in central and southern parts of India. American Journal of Plant Sciences. 4: 940-944.

Gupta, R.N., Gupta, J.S. and Sharma, B.L. (1983). Studies on wilt and root rot incidence of *Cicer arietinum* of Madhya Pradesh. Indian Phytopathology. 36: 82-84.

Hooda, I. and Grover, R.K. (1990). Environmental factors affecting control of *Macrophomina phaseolina* by fungicides on mungbean. Plant Disease Research. 5: 25-33.

Horsfall, J.G. and Cowling, E.B. (1978). Plant Disease: An Advanced Treatise, Volume II: How Disease Develops in Populations. Chapter 6: Pathometry: The measurement of plant disease. Academic Press, New York. 120-136 pp.

Kaiser, W.J., Danesh, D., Okhovat, M. and Mossahebi, H. (1968). Diseases of pulse crops (edible legumes) in Iran. Plant Disease Reporter. 52: 687-689.

Meyer, W.A., Sinclair, J.B. and Khare. M.N. (1973). Biology of *Macrophomina phaseoli* in soil studied with selective media. Phytopathology. 63: 613-620.

Mihail, J.D. (1989). *Macrophomina phaseolina*: Spatio-temporal dynamics on inoculum and of disease in a highly susceptible crop. Phytopathology. 79: 848-855.

Mihail, J.D. (1992). *Macrophomina*. In: Methods for Research on Soilborne Phytopathogenic Fungi. [Singleton, L.L., Mihail, J.D., Rush, C.M. (eds)], St. Paul, Minnesota: APS Press, pp. 134-136.

Mitra, M. (1931). Report of the imperial mycologist. Scientific Reports of the Agricultural Research Institute, Pusa, 1929-1930: 58-71.

Nene, Y.L., Sheila, V.K. and Sharma, S.B. (1996). A World List of Chickpea and Pigeonpea Pathogens, 5th edn, ICRISAT, Patancheru, 27 pp.

Padwick, G.W. (1948). Plant protection and food crops of India I. Plant pests and diseases of rice, wheat, sorghum and gram. Empire Journal of Experimental Agriculture. 16: 55-64.

Pande, S. and Sharma, M. (2010). Climate Change: Potential Impact on Chickpea and Pigeonpea Diseases in Rainfed Semi-arid Tropics (SAT). Presented in 5th International Food Legumes Research Conference (IFLRCV) and European Conference on Grain Legumes (AEP VII), April 26-30, Antalya, Turkey.

Pande, S., Sharma, M., Nagavardhini, A. and Rameshwar, T. (2012). High throughput phenotyping of chickpea diseases: Stepwise identification of host plant resistance. Information Bulletin No. 92 International Crops Research Institute for the Semi-Arid Tropics. Patancheru (A.P.) 56 pp.

Pandey, G. and Singh, R.B. (1990). Survey of root rot diseases of chickpea in Allahbad region. Current Nematology. 1: 77-78.

Sharma, M. and Pande, S. (2013). Unravelling effects of temperature and soil moisture stress response on development of dry root rot [*Rhizoctonia bataticola* (Taub.)] Butler in chickpea. American Journal of Plant Sciences. 4: 584-589.

Tripathi, N.N. and Sharma, B.K. (1983). Incidence of chickpea dry root rot (*Rhizoctonia bataticola*) in southern Harayana. International Chickpea Newsletter. 8: 22-23.

Umamaheshwari, C. (1991). Biological control of root rot of groundnut (*Arachis hypogaea* L.) caused by *Macrophomina phaseolina* (Maub.) Ashby. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, India. 93.

Westerlund, F.V., Jr-Cambell, R.N. and Kimble, K.A. (1974). Fungal root rots and wilt of chickpea in California. Phytopathology. 664: 432-436.