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Study of effect of irrigation schedules on post-flowering stalk rot of maize (*Zea mays* L.) caused by *Fusarium verticillioides*

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ABSTRACT

Soil moisture plays an important role in disease development in most of the field crops. It regulates soil micro-flora and their types including pathogens. Post flowering stalk rot in maize is caused by *Fusarium verticillioides* is one important diseases of maize which reduces its yield and economic value. In present study, maize plants were grown in sick plots and soil moisture was regulated at grain filling stage with three different irrigation schedules viz. I1 (Local practice - irrigation once in every 15 days), I2 (additional one irrigation during the grain filling stage), I3 (Stress during and after the grain filling stage). These irrigation schedules were studied for their effect on disease incidence and crop yield. Among them, I3 irrigation schedule exhibited high average disease rating of 7.36 and percent stalk rot was 42.66 (at 70 DAS) followed by I1 irrigation schedule with average disease rating of 5.76 and percent stalk rot of 20.33 (at 70 DAS). I2 irrigation schedule showed significantly superior results with least of average disease rating (3.43) and percent stalk rot (9.66 at 70 DAS). Total lodging percent was calculated at 85 DAS that varied similarly i.e., 26.66 (I3 schedule) followed by 23.33 (I1 schedule) and 12.66 (I2 schedule). Other yield parameters like number of cobs per plant, cob length, cob diameter, grains per cob and their test weight were also studied.

INTRODUCTION

Maize (*Zea mays* L.) also known as Queen of Cereals belongs to the grass family poaceae. It is widely distributed throughout out the world in tropical and subtropical climate. In India, it is the third most important crop after rice and wheat and has high food and economic values. It is predominantly cultivated in Kharif season in Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, Maharashtra, Bihar, Uttar Pradesh, Madhya Pradesh and Gujarat states (India Maize Summit, 2014). Its production is limited by many biotic and abiotic constraints including the fungal diseases. Total 65 diseases were reported in India and among them 13 were identified as major diseases that affect crop yields (AICRP Report, 2017). Among these,post-flowering stalk rot caused by Fusarium verticillioides was frequently reported as major disease of maize in most of the regions that reduce crop yield significantly. As per the report of AICRP (2014), the estimated loss due to post-flowering stalk rot of maize is 38 % of the total yield in a year. These days most of the commercially grown cultivars of maize had shown high level of disease susceptibility during the grain filling stage (Khokhar, 2014a), disease severity was found greater in those areas comes under rain fed conditions (Williams et al, 2008) or drought conditions (Pascale et al., 1997). Severity of this disease was reported high in warm weather during the grain filling stage (Miller, 1994).

Fungicides like tebuconazole, bavistin, mancozeb, etc. were reported as suitable control agents in disease management of stalk rot of maize (Honmane, 2007; Khokhar et al., 2014b; Singh et al., 2003). However, high dosage of chemical fungicides has been associated with several consequences related to pollution in environment that may responsible for hazardous effects on health of human, cattle and other animals. Biocontrol agents are good alternatives and safer but difficult to use. Beside them, cultural practices are more convenient and liked by majority of farmers in India which can be used to manage plant diseases like post-flowering stalk rot of maize. Regulation of soil moisture in field by irrigation practices is one important factor that not only controls the plant growth but also modify virulence of pathogens.

In present study, three irrigation schedules viz. I1 (Local practice - irrigation once in every 15 days), I2 (additional one irrigation during the grain filling stage), I3 (Stress during and after the grain filling stage) were tested on maize crop grown in a sick plot infested with virulent F. *veticillioides*.

MATERIALS AND METHODS

Virulent *F. verticillioides* (Sacc.) Nirenberg (ITCC Catalog number 7452) was obtained from Indian Type Culture Collection, Division of Plant Pathology, Indian Agriculture Research Institute, New Delhi. The culture was revived on Potato Dextrose Agar (PDA) plate at 25 ± 1°C and stored in PDA slants at 4°C in a refrigerator. The pathogenicity of fungus was tested on maize Vipin 760 under controlled environment in a poly house. The suitable day of artificial inoculation was also estimated. The field experiment was conducted in Uttaranchal College of Agricultural Sciences, Uttaranchal University, Dehradun, India. Seeds of selected variety of maize were sown during late Kharif season (May 2017) in natural sandy loam soil (Sand:Silt:Clay, 6:3:1 ratio) with N, P, K and organic carbon of 327, 13, 189 Kg/ha and 1.23%, respectively, with a spacing of 60 cm × 20 cm. After germination of seeds, seedlings were allowed to grow up to grain filling stage under normal growth conditions. The effect of soil moisture on the disease incidence and yield parameters of the crop at the grain filling stage was studied using three different irrigation schedules, I1 (Local practice with irrigation once in every 15 days), I2 (additional irrigation during grain filling stage) and I3 (Stress during grain filling stage). The experiment was carried out with three replications in randomized block design. The soil of experimental field was infested with spores of *F. verticillioides* before seeds were sown and plants at flowering stage (after 50% of flowering) were inoculated with toothpicks having mycelial growth of fungal pathogen by a method described by Young (1943) with some modifications. The disease incidence and yield parameters were recorded at maturity of the crop at 70 days after sowing (DAS) and 85 DAS, respectively. For disease incidence, the average disease rating was calculated using a 0 – 9 rating scale (0 represented no disease and 9 represented highest disease rating) based on number of infected internodes. Percent stalk rot at 70 DAS was calculated by formula,

Percent stalk rot at 70 DAS= [(Number of plants infected / Total number of plants observed) x100]

Similarly, total lodging percent at 85 DAS was calculated by formula,
lodging percent at 85 DAS= [(Number of plants lodged / Total number of plants observed) x100]

Different yield parameters such as number of cobs per plant, cob length, cob diameter, number on grains per cob and, test weight were also recorded.

Statistical Analysis

Statistical analyses were performed using SPSS 16.0 (SPSS Inc). Pearson correlation analysis was used to determine the correlation between different parameters of disease incidence and yield. The level of significance between the data was taken at $P < 0.05$.

RESULTS AND DISCUSSION

Soil moisture plays an important role on disease development in various crops. *F. verticillioides* is a soil fungus survives at moderate temperature and moisture easily colonizes all underground parts of host plants and causes various rot and wilt diseases. Pathogenicity of this fungus was studied by evaluating disease incidence and yield parameters on a variety of maize Vipin 760 also grown locally in an experimental field with different irrigation schedule.

In present study, selected variety of maize was found susceptible for stalk rot at all growth stages with disease rating varied from 4 to 7. However, disease rating was higher after flowering stage at 55 DAS. Plants developed symptoms 10 days after toothpick inoculation.

Effect of irrigation schedules on disease incidence

Average Disease Rating

The average disease rating was calculated by observing number of infected internodes progressed after toothpick inoculation of fungal pathogen. It was found significantly higher in I3 irrigation schedule (7.36) and lower I2 irrigation schedule (3.43) as compared to I1 irrigation schedule (5.76) with lower incidence of post-flowering stalk rot (Table -1).

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Percent talk Rot at 70 DAS

Percent stalk rot expressed severity of disease caused by a pathogen. It was found that percent stalk rot at 70 DAS was significantly higher in I3 irrigation schedule (42.66) and lower in I2 irrigation schedule (9.66) as compared to the I1 irrigation schedule (20.33) at 70 DAS. (Table–1).

Total lodging percent at 85 DAS

Similar results were obtained when total lodging at 85 DAS was calculated after use of each irrigation schedule (Table-1). Results from above tests showed that irrigation schedule in maize field can affect the incidence of post-flowering stalk rot in host plants. Different irrigation schedules had different roles on pathogenicity of *F. verticillioides*.

Disease incidence was increased when water stress in soil increased by poor irrigation schedule (I3) and yield of maize crop suppressed significantly. Alternatively, one additional irrigation (I2) significantly improved moisture in soil during post flowering stage of maize crop which changed the micro-climate of field and soil environment. This suppressed the virulence of *F. verticillioides* and lowered disease incidence. Similar work was done by Seetharama et al. (1987) on sorghum charcoal rot caused by *Macrophomina phaseolina* where stress after flowering stage resulted in higher disease incidence and reduced yields. Miller (1994) observed that severity of post-flowering stalk rot in cereals was greater in warm weather especially during the grain filling stage of the crop. Mohamed (1991) reported that the severity of this disease is increased when the maize plans are grown in sandy soil.

Effect of irrigation schedules on the yield parameters

Different yield parameters like number of cobs per plant, cob length, cob diameter, grains per cob and test weight were tested (Table-2). The plants that were given with an additional irrigation (I2) during grain filling stage significantly showed superior yield parameters. Among three different irrigation schedule number of cobs per plant remain the similar, however other parameters varied. Cob diameter was recorded significantly higher in I2 irrigation schedule (11.40 cm) and lower in I3 irrigation schedule (8.93 cm) as compared to I1 irrigation schedule (10.23 cm). Cob length was recorded from I2 irrigation schedule which was significantly higher (19.3) cm when the plants were given with an additional irrigation during the grain filling stage whereas the lowest cob length was recorded from I3 irrigation schedule (15.56) as compared to I1 irrigation schedule(18.56).

Significantly higher number of grains was produced in plants given I2 irrigation schedule (281.66 grains) and less number of grains were produced in I3 irrigation schedule (258.66 grains) as compared to I3 irrigation schedule (258.66 grains). Similarly test weights were varied with different irrigation schedule. Test weight was significantly higher when plants were given I2 irrigation schedule (222.33 gm) and lower in I3 irrigation schedule (182 gm) as compared to I1 irrigation schedule (204 gm).

Providing an additional irrigation to the crop at grain filling stage not only decreases the disease incidence but also positively improves the yield parameters like cob length, cob diameter, number of grains per cob and, test weight. Similar work was done by Khokhar et al, 2014 in maize and found that water stress at flowering stage significantly reduces the yield of crop and increases the severity of post-flowering stalk rot.

The values of yield parameters were varied with severity of post-flowering stalk rot and significant Pearson correlation was found with it (Table-3). Negative values of correlation coefficient showed inverse effect of disease incidence on various yield parameters. Number of cobs in experimental plants almost remained similar.

From the present investigation, it was evident that one additional irrigation at grain filling stage significantly reduced the incidence and severity of post-flowering stalk rot of maize. It decreased percent stalk rot around four times and average disease rating and total lodging percent each over two times than water stress, respectively. It is assumed that addition irrigation improves nutrient absorption from the soil that enhance synthesis of sucrose and starch and other carbon compounds which improves development and maturation of kernels and other parts of the plants (Anjum et al., 2011). In addition, it improves systemic resistance in plants that reduce disease incidence. Khokhar et al. (2014a) reported that the population of F. verticillioides decreased in the soil when the soil moisture increases. So an additional irrigation during the grain filling stage increases soil moisture which may reduce the population of pathogenic fungi in the soil and hence, reduce the disease incidence. It was also reported earlier that moisture stress in the plants makes them susceptible to various pests and diseases. The susceptibility of maize to F. verticillioides is directly influenced by temperature and osmotic stress (Conrath et al., 2002).

Table 1: Effect of different irrigation schedules on the incidence of post-flowering stalk rot of maize .

S No	Treatments	Average Disease Rating	Percent Stalk Rot at 70 DAS	Total Lodging Percent at 85 DAS
I1	Crop (Inoculated) + Local practice	5.76	20.33	23.33
I2	Crop (inoculated) + One additional irrigation during grain filling stage	3.43	9.66	12.66
I3	Crop (inoculated) + Stress during grain filling stage	7.36	42.66	26.33
	SEm±	0.122	2.037	1.217
	CD at 5%	0.491	8.211	4.907

Table 2: Effect of different irrigation schedules on the disease incidence and yield parameters of maize.

Treatments	No of cobs per plant	Cob length (cm)	Cob diameter (cm)	Grains per cob	Test weight (gm)
I1	2	18.56	10.23	266.33	204
I2	2	19.3	11.40	281.66	222.33
I3	2	15.56	8.93	258.66	182
SEM	0.00	0.288	0.107	1.122	1.575
CD at 5%	0.00	1.162	0.432	4.524	6.351

Table 3: Correlations between different parameters of disease incidence and yield.

		Average Disease rating	Percent Stalk Rot at 70DAS	Total Lodging percent at 85DAS	Cob length	Cob diameter	Grains/cob	Test weight
Average Disease rating	Pearson Correlation	1	0.935	0.929	-0.851	-0.925	-0.913	-0.937
	Sig. (2-tailed)		0.000	0.000	0.004	0.000	0.001	0.000
	N	9	9	9	9	9	9	9
Percent Stalk Rot at 70DAS	Pearson Correlation	0.935	1	0.820	-0.963	-0.960	-0.861	-0.955
	Sig. (2-tailed)	0.000		0.007	0.000	0.000	0.003	0.000
	N	9	9	9	9	9	9	9
Total Lodging at 85DAS	Pearson Correlation	0.929	0.820	1	-0.719	-0.883	-0.731	-0.791
	Sig. (2-tailed)	0.000	0.007		0.029	0.002	0.025	0.011
	N	9	9	9	9	9	9	9
Cob length	Pearson Correlation	-0.851	-0.963	-0.719	1	0.927	0.774	0.919
	Sig. (2-tailed)	0.004	0.000	0.029		0.000	0.014	0.000
	N	9	9	9	9	9	9	9
Cob diameter	Pearson Correlation	-0.925	-0.960	-0.883	0.927	1	0.813	0.942
	Sig. (2-tailed)	0.000	0.000	0.002	0.000		0.008	0.000
	N	9	9	9	9	9	9	9
Grain per cob	Pearson Correlation	-0.913	-0.861	-0.731	0.774	0.813	1	0.920
	Sig. (2-tailed)	0.001	0.003	0.025	0.014	0.008		0.000
	N	9	9	9	9	9	9	9
Test weight	Pearson Correlation	-0.937	-0.955	-0.791	0.919	0.942	0.920	1
	Sig. (2-tailed)	0.000	0.000	0.011	0.000	0.000	0.000	
	N	9	9	9	9	9	9	9

CONCLUSION

Post-flowering stalk rot of maize caused by *F. verticillioides* is an important disease India. It not only reduces crop yields but also contaminates maize products with fumonisins which poses a high risk of cancer and other chronic diseases in its consumers. The pathogen survives in the seed in dormant states and starts the infection from the seedling stage. Hot and humid conditions, sandy soil, water stress at post-flowering stage increases the severity of the stalk rot caused by *F. verticillioides*.

The present experiment revealed that providing an additional irrigation during the grain filling stage significantly decreased the disease incidence and improved yields. Therefore, an additional irrigation can be considered during this stage.

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