Proc. Indian natn. Sci. Acad. **B47** No. 4 pp. 574–580 (1981)

Growth Stages in Pearl Millet [*Pennisetum typhoides* (Stapf & Hubb.)] and Susceptibility to Infection of Downy Mildew Pathogen (*Sclerospora graminicola* (Sacc.) Schroet.)

S SUBRAMANYA, K M SAFEEULLA, H S SHETTY and H S PRAKASH
Downy Mildew Research Laboratory, University of Mysore, Manasagangotri, Mysore 570006

(Received 15 December 1980)

The growth pattern of the main stalk and different types of tillers in pearl millet is defined into vegetative, panicle initiation, panicle development and grain drying phases. The main stalk and tillers of pearl millet plants were artificially inoculated at different growth phases using pearl millet downy mildew pathogen (*Sclerospora graminicola*) to determine the susceptible growth phase of the plant. The main stalk of the plant was susceptible to downy mildew up to 26 days from emergence. However, the differentiating primary, secondary and tertiary tillers became infected and remained susceptible to downy mildew for a longer period. High degree of susceptibility of main stalk to downy mildew was noticed in plants when inoculated at 9-day-old stage but such plants died prematurely without producing earheads. Most of the plants in which the main stalk was inoculated 2 weeks after emergence, produced malformed earheads. Malformed earheads were also produced from the infected tillers. Susceptibility of pearl millet crop throughout its growth phases due to continued emergence of tillers and its significance in the epidemiology of the disease is discussed.

Key Words: **Growth stages, *Pennisetum typhoides*, Susceptibility, Downy mildew infection**

Introduction

Pearl millet is an important food and fodder crop of arid and semi-arid tropics. The downy mildew or green ear disease caused by *Sclerospora graminicola* is a limiting factor in the pearl millet production. The degree of infection has been related to the growth phases of the crop and age of the tissues in many cereal diseases (Leu & Chu 1959, Bronnimann 1968, Dalmacio & Exconde 1969, Cooke & Jones 1970, Kajiwara 1975). Such studies, which are of prime importance, have not been conducted in relation to the downy mildew disease of pearl millet. That the pearl millet plants are susceptible to downy

mildew infection at the earlier stages of plant growth and the degree of susceptibility decreased with the increase in the age of the plants, is the common experience of the downy mildew research workers. In contrast to this view, our investigations demonstrate that pearl millet plant is susceptible to downy mildew infection throughout its growth stage on account of the emergence of tillers.

In the recent investigation growth pattern of the main stalk and tillers of the pearl millet plant and its relation to the susceptibility to downy mildew disease has been carried out and the results are discussed in this paper.

Materials and Methods

Tillering and panicle development in pearl millet

Pearl millet seeds (Cv. HB_3) were sown in a disease-free plot in three replicates during the June-September season of 1979. The crop was manured fifteen days after emergence of seedlings and irrigated suitably when required. Observations were made once in three days on the extent of tillering and the timings of various growth phases in the main stalk and the tillers as described in the tables 3 and 4. The stages of panicle initiation in the main stalk and different types of tillers were identified according to the criteria described by Maiti and Bisen (1976).

Artificial inoculation of the plants

Pearl millet plants (Cv. HB_3) were grown in a 12 × 6 m plot, free from soil borne inoculum of *S. graminicola* by sowing at specified intervals. In addition, the crop was isolated from nearby pearl millet fields at least by 500 m to avoid air-borne inoculum if any. All the plants were inoculated by dropping water suspension of zoospores into the leaf whorls. The zoospore inoculum was adjusted to 3×10^3/ml by following the procedures of Safeeulla (1976). The weather parameters were monitored continuously on the day of inoculation using a thermohygrograph located in a Stevenson Screen, a Taylor's dew meter and an automatic rain gauge. Inoculations were carried out up to 67 days after emergence of the plants.

Disease incidence was assessed from 6 days after inoculation up to 16 days. Infection of the main stalk and the tillers were recorded separately.

Observations

Tillering and panicle development in pearl millet

The pearl millet plants studied consisted of a main stalk (MS) which produced distinct types of tillers viz., primary tiller (PT), secondary tiller (ST), tertiary tiller (TT) and quarternary tiller (QT). These could be distinguished from each other based on their place of origin and age of the plants during their emergence as shown in table 1.

The growth pattern of the main stalk and different types of tillers in pearl millet can be classified into following four growth phases:

1. Vegetative phase (GS1)—Seedling emergence to panicle initiation.
2. Panicle initiation phase (GS2)—Panicle initiation to initiation of floral parts in the panicle.
3. Panicle development phase (GS3)—Flag leaf emergence to initiation of grain drying.
4. Grain drying phase (GS4)—Initiation of grain drying to harvest.

Each tiller behaved as an individual plant and exhibited all the four growth phases. The duration of these growth phases in the main stalk and tillers has been presented in table 2.

Table 1 *Classification of tillers of pearl millet*

Name of the tiller	Place of origin on the plant	Age of the plant at the time of their emergence
Primary tiller	Sub-soil nodes of the main stalk	21
Secondary tiller	Aerial nodes of the main stalk	45–48
Tertiary tiller	Aerial nodes of the primary tiller	58–75
Quaternary tiller	Aerial nodes of the main stalk and the existing tillers	80–90

The results of the comparative studies on panicle initiation, panicle development and grain drying phase of the main stalk and the tillers has been summarised in tables 3 and 4. The development of the spikelet primordia in the panicle of main stalk was acropetal. At the later stages, the sequence of developmental stage followed regular protogynous pattern. Also it was significant to note that all earheads of a plant did not mature at a time.

Artificial inoculation of the plant

The weather data of the day of inoculation revealed that the environment was highly suitable for infection to occur. The slight intermittent showers and high relative humidity (over 95%), with optimum temperature (21–23°C) in the night and early morning hours provided conditions conducive to zoospore infection. In general the inoculated plants showed downy mildew symptoms a week after inoculation.

The results of the inoculation of plants of different ages has been summarised in table 5. The main stalk of the plant was susceptible up to 26 days, from emergence, to infection by zoospores. Inoculation of the main stalk more than 26-day-old was not successful in causing disease. The primary tillers which were highly susceptible to infection at the earlier stages of development, became resistant with the increase in age. Inoculation of the primary tillers on 26th day after emergence, resulted in 69.64% disease while only 3.57% of the primary tillers were infected when inoculated 40 days after plant emergence. Inoculation of primary tillers, more than 42-day-old, failed to cause disease. But emerging secondary and tertiary tillers remained susceptible to infection up to 67 and 65 days respectively (table 5).

Maximum main stalk infections occurred when they were 9-day-old and no earhead malformation resulted from such diseased plants due to seedling death. When 16-day-old plants were inoculated, 36.2% plants showed systemic infection among which 46.4% produced maformed earheads. However, most of the infected plants produced malformed earheads when they were inoculated 26 days after emergence. Primary tillers inoculated on 26 and 33 days after emergence produced 63.05% and 86.57% malformed earheads respectively. On the

Table 2 *Duration of the growth stages of main stalk and tillers of pearl millet*

Name of the organ	Growth phase after emergence (in days)*			
	GS1	GS2	GS3	GS4
Main stalk	0–18	18–36	36–59	59–85
Primary tiller	20–32	32–47	47–69	69–85
Secondary tiller	45–52	52–65	65–85	—
Tertiary tiller**	65–72	—	—	—
Quaternary tiller**	80–	–	—	—

*The crop is harvested 85 days after sowing

**No synchrony was observed in the origin and development of the tertiary and quaternary tillers

Table 3 *Comparison of panicle initiation in main stalk, primary tiller and secondary tiller of pearl millet*

Developmental stages**	Morphology of the panicle	No. of days required to attain the stage by the panicle of*		
		MS	PT	ST
2	Initiation of the panicle meristem	20	34	54
3	Initiation of the spikelet at the base of the panicle meristem	23	X	55
4	Completion of the spikelet primordium up to the tip of the panicle meristem	24	37	56
5	Formation of the floret primordium at the base of the panicle	26	39	58
6	Initiation of glumes	X	X	X
7	Initiation of lemma and palea	28	X	60
8	Initiation of stamens	28	40	61
9	Completion of initiation of stamen up to the tip of the panicle	30	42	63
10	All floral parts initiated	32	43	64

*No synchrony was observed as to the origin of tertiary and quaternary tillers. Hence analysis of panicle initiation was not conducted

**Developmental stages of panicle initiation is based on Maiti and Bisen (1976)

XData not available

Table 4 *Comparison of panicle development and grain drying phases in main stalk, primary tiller and secondary tiller of pearl millet*

Developmental stages	Morphology of the panicle	Days required to attain the stage by the panicle of*		
		MS	PT	ST
GS3 1	Flag leaf emergence	36	47	65
2	Boot stage	38	49	66
3	Panicle emergence	40	57	69
4	Half bloom	42	53	X
5	Full bloom	43	54	71
6	50% anthesis	45	57	72
7	Kernel in watery ripe stage	47	63	76
8	Soft dough stage of the Kernel	51	68	79
9	Hard dough stage of the Kernel	57	72	79–81
GS4 1	Seed drying	57–85	72–85	83–95
2	Harvest	85–90	85–90	95–105

*No synchrony was observed as to the origin of tertiary and quaternary tillers and hence analysis of panicle development and grain drying phases was not conducted in such tillers

X Data not recorded

Table 5 *Age of pearl millet plant in relation to susceptibility to downy mildew infection and earhead malformation*

Age of the plant in days	Per cent infection of				% plants showing earhead malformation/ No. of diseased plants up to 85 days			
	MS	PT	ST	TT	MS	PT	ST	TT
9	42.15	—	—	—	0	—	—	—
16	36.20	—	—	—	46.49	—	—	—
26	16.07	64.64	—	—	99.00	63.05	—	—
33	0	25.34	—	—	0	86.57	—	—
37	0	5.88	—	—	0	100.00	—	—
40	0	3.57	—	—	0	100.00	—	—
42	0	0	—	—	0	0	—	—
48	0	0	42.10	—	0	0	32.42	—
54	0	0	14.28	—	0	0	65.13	—
60	0	0	6.25	—	0	0	25.60	—
63	0	0	0	12.15	0	0	0	0
65	0	0	8.33	8.33	0	0	17.17	0
67	0	0	1.14	0	0	0	0	0

MS=Main Stalk; *PT*=Primary Tiller; *ST*=Secondary Tiller; *TT*=Tertiary Tiller

other hand, all the infected primary tillers produced malformed earheads when the inoculation was made after 37 and, 40 days of emergence (table 5). Infecte d secondary tillers also produced the malformed earheads.

Discussion

Pearl millet is a tillering crop and the tillers are as important as the main stalk from the view point of yield. The previous works (Ayyangar et al. 1933, Cobby 1965, Burton & Powell 1968, Maiti & Bisen 1976) have been restricted to panicle initiation and development in the main stalk only. There is lack of information on the development of tillers and their panicle. In the present study the distinction among different types of tillers has been traced.

In Maiti and Bisen (1976) system of classification the authors have overlooked the distinction between the active phase of grain filling from the passive phase of grain drying, and hence a four phase system of classification of the growth pattern is proposed. Main stalk and tillers showed all the four growth phases viz., vegetative, panicle initiation, panicle development and grain drying phases. In this regard, each tiller behaves as an individual plant. The growth pattern of pearl millet thus varied from that of non-tillering cereals (Chiarappa 1970, Vanderlip & Reeves 1972).

Pearl millet is susceptible to infection by *S. graminicola* throughout its growth period on account of the continued emergence of the tillers (tables 1 and 5). The main stalk and the tillers are susceptible to the downy mildew infection in their vegetative phase and the degree of susceptibility reduces gradually as the main stalk or the tiller ages, indicating the possible build up of natural resistance. They become resistant as they cross half of the growth phase II, viz., panicle initiation. Similar observations were made by Leu and Chu (1959) who recorded 100% infection when one-week-old seedlings of maize were inoculated with *Sclerospora sacchari*, but no infection was observed on four-week-old plants. Dalmacio and Exconde (1969) who conducted histopathological studies on the ramification of the mycelium of *S. philippinensis* in maize opined that the resistance showed by four-week-old plants might be associated with the resistance of the cell walls of mature leaves which might not allow the entry of the pathogen. Kajiwara (1975) showed that 20-day-old plants developed resistance to *S. maydis*.

From the present study it is clear that later expression of the disease in the main stalk and the tillers generally produce malformed earheads. The degree of malformation varies from partial to complete. The seeds collected from such malformed earheads invariably contain seed-borne mycelium of *S. graminicola* in all parts of seed tissues and such seeds act as primary source of inoculum (Shetty et al. 1980). So care should be taken not to collect the seeds from malformed earheads.

A good crop of pearl millet is harvested within 85–90 days after sowing and contribution towards the yield is mainly from the earheads of the main stalk, primary tillers and some of the secondary tillers (Rangaswami Ayyangar et al. 1935). Eventhough, tertiary tillers do produce the earheads they do not set grains within the harvest period. Hence to protect the food crop of pearl millet from downy mildew, measures should be taken to prevent infection of the tillers at least of the primay and the secondary.

The attempts to control pearl millet downy mildew using seed dressing chemicals were serious failures until 1978 and this might be due to the difficulties in preventing the continued susceptibility of the plant to infection by air-borne sporangia. Recently successful control of pearl millet downy mildew was reported by Venugopal and

Safeeulla (1978) using a CIBA-GEIGY fungicide Ridomil (CGA 48988). Control of downy mildew was achieved up to 94.83%. Although, an average of 5.17% disease incidence was observed in pearl millet grown from Ridomil treated seeds (2 g/kg), the lower values of infection index (av. 2.30%), calculated by using the scale proposed for IPMDMN (International Pearl Millet Downy Mildew Nursery) suggest that disease appeared in the tertiary or quaternary tillers of the treated plants. Being a systemic fungicide, the chemical applied to the seeds before sowing, may be translocated acropetally (Urech et al. 1977) to the growing points such as shoot apices/floral primordia, which are highly susceptible for downy mildew infections may protect them against air-borne infections at least for about 35–45 days. With further increase in the age of the crop the concentration of the chemical may be reduced to low levels, which can no longer protect the growing points of emerging tertiary and quaternary tillers from air-borne infections. The involvement of a similar phenomenon has been observed in Black Shank disease of tobacco (Kannwischer & Mitchell 1978). This probably can account for both the high efficiency of Ridomil in controlling pearl millet downy mildew infections on one hand and for very low percentage of downy mildew incidence from plants raised from Ridomil-treated seeds.

References

Ayyangar S N R, Vijiaraghavan, Gomathinagam O and Pillai V 1933 Studies on *Pennisetum typhoides* (Rich.)—The pearl millet, Part I—Anthesis; *Indian J. agric. Sci.* **3** 688

Bronnimann A 1968 Zur Kenntnis Von *Septoria nodorum* Berk., dem Ereger der Spelzenbraune und Blattdurre des Weizens; *Phytopath. Z.* **61** 101–146

Burton G W and Powell J B 1968 Pearl millet breeding and cytogenetics; *Advan. Agron.* **20** 49–89

Chiarappa L (ed) 1970 Crop-loss assessment methods. *FAO Manual on the Evaluation and Prevention of Losses by Pests, Diseases and Weeds* (Rome)

Cobby L S 1965 An introduction to the botany of tropical crops; (London: Langman Press and Co. Ltd.)

Cooke B M and Jones D G 1970 The epidemiology of *Septoria tritici* and *S. nodorum* on spring wheat; *Trans. Br. mycol. Soc.* **54** 395–404

Dalmacio S C and Exconde O R 1969 Penetration and infection of *Sclerospora philippinensis* Weston on corn; *Philip. Agric.* **23** 35–52

Kajiwara T 1975 Some experiments on downy mildew of maize; *Trop. agric. Res. Ser.* **8** 121–124

Kannwischer M E and Mitchell D T 1978 The influence of a fungicide on the epidemiology of black shank of tobacco; *Phytopathology* **68** 1760–1765

Leu L S and Chu T L 1959 Transmission of downy mildew (*Sclerospora sacchari*) from sugarcane to maize and vice versa; *Rept. Taiwan Sugar Expt. Stn.* **20** 1–8

Maiti R K and Bisen S 1976 Studies on growth and Development of Panicles and Grains in two Contrasting Genotypes of Pearl Millet; in *Physiology of Sexual Reproduction in Flowering Plants* (New Delhi: Kalyani Publishers)

Rangaswami Ayyangar S N and Hariharan P V 1935 The tillers of pearl millet—*Pennisetum typhoides* Rich; *Madras agric. J.* **23** 474–477

Safeeulla K M 1976 Biology and control of downy mildews of pearl millet, sorghum and finger millet; Wesley Press, Mysore, India

Shetty H S, Mathur S B and Paul Neergaard 1980 *Sclerospora graminicola* in pearl millet seeds and its transmission; *Trans. Br. mycol. Soc.* **74** 127–134

Urech P A, Schwinn F and Jaub T 1977 CGA-48988, a novel fungicide for the control of late blight, downy mildews, and related soil borne diseases; *Proc. British Crop Protection Conference*

Vanderlip R L and Reeves H E 1972 Growth stages of sorghum, *Sorghum bicolor* (L.) Munch.; *Agron. J.* **64** 13–16

Venugopal M N and Safeeulla K M 1978 Chemical control of the downy mildews of pearl millet, sorghum and maize; *Indian J. agric. Sci.* **48** 537–539