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Varietal reaction of non-senescent sorghums to the pathogens causing root and stalk rot of sorghum in India

(*Keywords: Fusarium moniliforme, F. moniliforme* var. *subglutinans, F. oxysporum, F. semitectum, Macrophomina phaseolina*, non-senescence, India)

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Abstract. Twenty-five non-senescent sorghum genotypes were screened for stalk rot reaction against the five stalk rot pathogens inoculated individually by the toothpick inoculation method under field conditions. Five genotypes (Q 101, Q 102, Q 103, Q 104 and PQ 54) were found resistant (<5% plants lodged) against all the five stalk rot pathogens. More greener leaf area at physiological maturity, confirmed the resistance in the non-senescent sorghum genotypes. E 36–1, a stalk rot-resistant genotype, showed resistance against all the pathogens except *Fusarium moniliforme*. There was strong positive correlation between all the stalk rot disease evaluation parameters.

1. Introduction

Root and stalk rot of sorghum [Sorghum bicolor (L.) Moench] is a complex disease caused by a group of pathogens, *viz. Macrophomina phaseolina* (Tassi.) Goid., *Fusarium moniliforme* Sheldon., *F. moniliforme* var. *subglutinans* Reink & Woll., *F. semitectum, F. oxysporum, F. chlamydosporum, Colletotrichum graminicola, Acremonium strictum, Periconia circinata* and *Pythium* spp. in different geographical regions of the world (Trimboli and Burgess, 1982; Reed *et al.*, 1983; Mughogho and Pande, 1984; Khune *et al.*, 1985; Tangonan and Quimoi, 1985). In India, *M. phaseolina, F. moniliforme, F. moniliforme* var. *subglutinans* were identified as major pathogens involved in sorghum stalk rot complex (Mughogho and Pande, 1984). Many of the sorghum varieties, and recently released high-yielding sorghums in particular, are susceptible to stalk rot disease (Shekar *et al.*, 1987). The phenomenon of green leaf retention after the grain has reached physiological maturity has been termed non-senescence (Duncan, 1977). Rosenow (1980) attributed the non-senescent character in sorghums to the ability to resist stalk rot disease. Evangilista and Tangonan (1990) have screened some non-senescent sorghums in the Philippines and found some lines resistant to stalk rot disease. Bramel-Cox and Claflin (1989) have screened for resistance to *M. phaseolina* and *F. moniliforme*, employing a toothpick inoculation method. In the present investigation 25 non-senescent sorghum lines were screened for varietal reaction individually against each of the stalk rot pathogens by the toothpick inoculation method under field conditions. The objective of the present investigation is to study the role and importance of individual stalk rot pathogens in the pathogenesis and reaction of non-senescent sorghum lines to the stalk rot pathogens individually. This will help towards a better understanding of the stalk rot disease complex.

2. Materials and methods

Twenty-five non-senescent sorghum lines obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), were sown in a split-plot design in two replications of 4 m plots in deep vertisols at Rangapuram, Khammam District, Andhra Pradesh on 10 October 1988. Row-to-row spacing was 0·50 m and plant-to-plant distance was 10–15 cm. Basal dose of N:P:K (40:40:40) was applied at the time of sowing and topdressing (40 kg N) was done at 30 d.a.e. Carbofuran at 40 kg/ha was applied to prevent shoot fly attack. When the crop is at boot leaf stage the plants were inoculated by the toothpick inoculation method (Hsi, 1961).

Wooden toothpicks were boiled in water for 2 h and about 40 toothpicks were carefully introduced into a 25 × 3 cm Corning test tube. 5 ml of potato dextrose broth was poured into each test tube and autoclaved at 15 p.s.i. for 20 min. After cooling, discs of the test fungi grown on potato dextrose agar (PDA) were cut and placed on the tips of the toothpicks and incubated at 30°C for 7 days. The fungi grew all over the toothpick. A 1 mm hole was drilled between the first and second node of each sorghum plant and the toothpick was carefully inserted into the hole.

At physiological maturity, total plants and number of lodged plants were counted and percentage lodging was calculated. Leaf senescence was visually rated on a 1–5 scale (where 1 = all leaves were green and 5 = more than 50% leaves were senesced). All the plants were uprooted, the stalks were split open (Masterhazy, 1979) and stalk rot disease parameters were evaluated as follows: the number of plants with soft stalks were counted and the spread of fungus across the nodes from the point of inoculation was measured as the number of nodes crossed. Infection of roots was measured as mean root infection on a 1–5 scale (where 1 = all roots healthy and 5 = more than 50% of roots infected or killed).

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Table 1. Correlations among the stalk rot disease parameters

Disease parameters	Lodging (%)	Mean no. nodes crossed	Mean root infection	Leaf senescence rating
Soft stalks (%)	0·9532***	0·9126***	0·7216***	0·6589***
Lodging (%)		0·8376***	0·6243***	0·6243***
Mean no. nodes crossed			0·8569***	0·7659***
Mean root infection				0·8939***

Degrees of freedom = 24.
Correlation coefficients at 5% = 0·388, and at 1% = 0·496.
*** Significant at $P < 0·001$

Table 2. Analysis of variance among different treatments

Source of variation	Mean sum of squares and levels of significance				
	Soft stalks (%)	Lodging (%)	Mean no. nodes crossed	Mean root infection	Leaf senescence rating
Fungi	2083·49*	1989·65*	112·407*	0·731n.s.	1·267n.s.
Genotypes	1424·94***	1692·88***	24·175***	8·87***	6·648***
Fungi genotypes	238·80***	240·58***	15·33***	0·71***	0·465***
LSD (0·05%)	8·494	7·605	1·646	0·89	0·902

* = Significant at $P = 0·05$; *** = highly significant at $P < 0·001$; n.s. = not significant.

3. Results

The parameters of stalk rot evaluated against 25 non-senescence sorghum lines were percentage soft stalk, percentage lodging, mean number of nodes crossed, mean root infection and leaf senescence. Strong significant positive correlations were found to exist between the five disease parameters (Table 1).

Analysis of variance revealed that there was significant variation among the five stalk rot fungi involved in stalk rot disease development for three parameters (percentage lodging, percentage soft stalks and mean number of nodes crossed). Highly significant variations ($P<0·001$) existed among the 25 non-senescent genotypes (Table 2). Interactions between the fungi and the genotypes in this experiment also showed highly significant variation.

Five genotypes (Q 101, Q 102, Q 103, Q 104 and PQ 54) had low mean percentage lodging (<5%) against all the five stalk rot pathogens and these genotypes also had more green leaf area rated as mean leaf senescence score of less than 4 (Tables 3 and 4). Five genotypes, *viz.* Q 101, Q 102, Q 103, IS 12675 and PQ 66, inoculated with *M. phaseolina* were free from lodging, whereas Q 104 had only 2·5% lodging. Among these, the Q numbers had low percentage lodging compared with the other four fungal pathogens. All these lines had low leaf senescence ratings except IS 12675, which had a leaf senescence score of 4·5. E 36–1, a known resistant line (Pande and Karunakar, 1992), developed little disease on inoculation with all the stalk rot pathogens except against *F. moniliforme*. PQ 54 was resistant against *F. moniliforme* var. *subglutinans, F. oxysporum, F. semitectum* and *M. phaseolina* inoculation. PQ 56 and PQ 58 were resistant against *F. moniliforme, F. oxysporum* and *F. semitectum*, and PQ 56 also remained resistant against *M. phaseolina*. M 35–1 and BJ 111 showed less lodging when inoculated with *F. moniliforme* var. *subglutinans, F. oxysporum* and *F. semitectum*, whereas Annegeri 1 remained resistant against *M. phaseolina, F. moniliforme* var. *subglutinans* and *F. semitectum*. Released var. SPV 86 and PQ 61 showed tolerance to *F. moniliforme, F. moniliforme* var. *subglutinans* and *F. semitectum*.

Lodging was most severe (26·92% lodging) with inoculation by *M. phaseolina*, followed by *F. moniliforme* (20·19%), *F. moniliforme* var. *subglutinans* (16·15%), *F. oxysporum* (16·06%) and *F. semitectum* showing the least (7·79%). *M. phaseolina* and *F. moniliforme* produced highest percentage lodging on susceptible check CSH 6. Among the 25 non-senescent sorghum genotypes, eight genotypes showed less than 10% lodging with *M. phaseolina*, and nine genotypes with *F. moniliforme*, 12 with *F. oxysporum*, 13 with *F. moniliforme* var. *subglutinans* and 19 with *F. semitectum*. Low lodging, and a reduced ability to cause lodging in most of the genotypes by *F. semitectum*, suggests it is not a major cause stalk rot disease. Leaf senescence rating was generally low in several of the resistant genotypes.

4. Discussion

The most promising plant trait that is positively correlated with stalk rot resistance, and is increasingly used as a selection criterion, is the non-senescence character expressed as leaf and plant death rating. Comfort (1956) has described senescence as a decrease in viability with an increase in vulnerability. Rosenow (1980) and Pande *et al.* (1989) have also found negative correlation between

Table 3. Percentage lodging in 26 sorghum genotypes inoculated with pure cultures of Macrophomina phaseolina, Fusarium moniliforme, F. moniliforme *var.* subglutinans, F. oxysporum *and* F. semitectum *by the toothpick method of inoculation under field conditions*

Genotype	MP	FM	FMS	FO	FS	Mean
Q 101	0·0	0·0	0·0	0·0	0·0	0·0
Q 102	0·0	0·0	0·0	0·0	0·0	0·0
Q 103	0·0	5·0	2·5	5·0	0·0	2·5
Q 104	2·5	0·0	0·0	0·0	0·0	0·5
IS 176	65·0	20·0	55·0	0·0	15·0	31·0
IS 181	45·0	45·0	27·5	15·0	30·0	32·5
IS 2404	22·5	15·0	0·0	15·0	15·0	13·5
IS 2954	20·0	15·0	20·0	0·0	10·0	13·0
IS 9377	35·0	40·0	20·0	30·0	7·5	26·5
IS 12675	0·0	0·0	30·0	15·0	7·5	10·5
IS 18696	50·0	60·0	20·0	25·0	15·0	34·0
IS 18739	40·0	20·0	10·0	20·0	17·5	21·5
E 36-1	15·0	25·0	7·5	7·5	0·0	11·0
M 35-1	25·0	25·0	10·0	7·5	5·0	13·5
BJ 111	30·0	30·0	15·0	10·0	0·0	17·0
BJ 112	50·0	30·0	35·0	20·0	10·0	27·0
Annegeri 1	15·0	35·0	10·0	35·0	0·0	19·0
SPV 86	30·0	15·0	0·0	25·0	0·0	14·0
PQ 51	40·0	7·5	20·0	20·0	10·0	19·5
PQ 54	7·5	15·0	0·0	0·0	0·0	4·5
PQ 56	10·0	0·0	25·0	0·0	0·0	7·0
PQ 58	30·0	0·0	20·0	0·0	0·0	10·0
PQ 60-2	40·0	20·0	25·0	35·0	7·5	25·5
PQ 61	27·5	7·5	0·0	40·0	10·0	17·0
PQ 66	0·0	15·0	7·5	30·0	10·0	12·5
CSH 6	100·0	80·0	60·0	62·5	47·5	70·0
Mean	26·9	20·2	16·2	16·1	7·8	17·4
SE (±)	4·53	4·57	3·00	3·91	3·08	4·96
CV (%)	16·1	20·2	15·4	20·5	27·7	28·5

MP = *Macrophomina phaseolina*; FM = *Fusarium moniliforme*; FMS = *F. moniliforme* var. *subglutinans*; FO = *F. oxysporum*; FS = *F. semitectum*.

plant lodging and non-senescence. Our results have also indicated significantly low positive correlation between lodging and leaf senescence rating (0·6243 at $P<0·001$).

Mughogho and Pande (1984) reported resistance in non-senescent sorghum lines, but found that their non-senescent character varied in the genotypes from location to location, depending on the pathogen population, variability and moisture stress level. Evangilista and Tangonan (1990) screened 31 non-senescent sorghum genotypes in the Philippines and found that most of the Q numbers, E 36–1, PQ 60–2, SPV 86, BJ 111, PQ 76 and CSH 6 were resistant to stalk rot. Shekar *et al.* (1987) reported hybrids CSH 5 and CSH 6 to be highly susceptible. In the present study CSH 6 has been used as a susceptible check and showed very high lodging against all the five pathogens. Pande and Karunakar (1992) conducted a multilocational testing of these non-senescent lines under receding soil moisture conditions and found Q 101, Q 102, Q 103, Q 104 and E 36–1 to be resistant in all locations under receding soil moisture condition and natural pathogen population. CSH 6 was used as a susceptible check and had maximum lodging. The variation in the reaction of CSH 6 is due to the pathogen variability in the Philippines, where stalk rot was reported to be caused by *F. moniliforme*, *Colletotrichum graminicola* and *Rhizoctonia bataticola* (*M. phaseolina*) (Tangonan and Quimoi, 1985). Our results also establish the resistance in Q 101, Q 102, Q 103 and Q 104, which has been found to be resistant against all five stalk rot pathogens individually. Another resistant line, E 36–1, has shown some disease against *F. moniliforme* and *M. phaseolina*. Pande and Karunakar (1992), in their study of fungal succession in E 36–1, found that *F. moniliforme* and *M. phaseolina* colonized the roots and stalks at different plant growth stages, but lodging did not occur due to the non-senescence character and strong stalk in this c.v. Bramel-Cox and Claflin (1988) screened breeding progenies against *M. phaseolina* and *F. moniliforme* using the toothpick method of inoculation, and found this method to be useful in screening for resistance.

The present investigation reveals the level of resistance in these non-senescent sorghum lines to all five stalk rot pathogens. This knowledge will help in understanding the genetics of resistance and usage in resistance breeding to the stalk rot disease complex.

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Table 4. Leaf senescence rating (1–5 scale) in 26 sorghum genotypes inculated with pure cultures of Macrophomina phaseolina, Fusarium moniliforme, F. moniliforme *var.* subglutinans, F. oxysporum *and* F. semitectum *by the toothpick method of inoculation under field conditions*

Genotype	MP	FM	FMS	FO	FS	Mean
Q 101	3·0	3·5	3·5	4·0	3·0	3·4
Q 102	3·0	3·5	3·0	4·0	3·5	3·4
Q 103	3·0	3·5	3·2	4·0	3·5	3·4
Q 104	3·2	3·2	3·0	3·0	3·5	3·2
IS 176	5·0	4·2	5·0	4·7	4·7	4·7
IS 181	5·0	5·0	5·0	4·7	5·0	4·9
IS 2404	5·0	4·2	4·7	4·2	4·7	4·6
IS 2954	5·0	4·5	5·0	5·0	5·0	4·9
IS 9377	5·0	5·0	5·0	5·0	5·0	5·0
IS 12675	4·5	4·0	5·0	5·0	5·0	4·7
IS 18696	5·0	5·0	5·0	5·0	5·0	5·0
IS 18739	5·0	5·0	5·0	5·0	5·0	5·0
E 36-1	4·0	4·2	5·0	4·2	4·7	4·2
M 35-1	5·0	4·7	4·0	5·0	5·0	4·9
BJ 111	5·0	5·0	5·0	5·0	5·0	5·0
BJ 112	5·0	5·0	5·0	5·0	4·5	4·9
Annegeri 1	4·5	4·5	5·0	4·7	4·5	4·5
SPV 86	4·7	4·7	4·2	5·0	4·5	4·6
PQ 51	5·0	4·5	4·2	5·0	5·0	4·9
PQ 54	5·0	5·0	4·0	5·0	4·5	4·3
PQ 56	4·5	3·5	4·2	4·0	4·5	4·3
PQ 58	5·0	3·0	5·0	4·5	4·5	4·4
PQ 60-2	5·0	4·5	5·0	4·5	5·0	4·9
PQ 61	5·0	5·0	4·0	5·0	5·0	4·8
PQ 66	3·5	4·5	4·5	5·0	5·0	4·5
CSH 6	5·0	5·0	5·0	5·0	5·0	5·0
Mean	4·5	4·3	4·5	4·6	4·6	4·5
SE (±)	0·39	3·4	0·34	0·29	0·56	0·32
CV (%)	3·3	7·9	2·8	2·4	4·5	7·0

MP = *Macrophomina phaseolina*; FM = *Fusarium moniliforme*; FMS = *F. moniliforme* var. *subglutinans*; FO = *F. oxysporum*; FS = *F. semitectum*.

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References

BRAMEL-COX, P. J. and CLAFLIN, L. E., 1989. Selection for resistance to *Macrophomina phaseolina* and *Fusarium moniliforme* in sorghum. *Crop Science*, **29**, 1468–1472.

COMFORT, A., 1956. *The Biology of Senescence* (New York: Rinehart).

DUNCAN, R. R., 1977. Characteristics and inheritance of non-senescence in *Sorghum bicolor* (L.) Monech. Ph.D. thesis, Texas A&M University, College Station, Texas, USA.

EVANGILISTA, C. C. and TANGONAN, N. G., 1990. Reaction of 31 nonsenescent sorghum genotypes to stalk rot complex in Southern Philippines. *Tropical Pest Management*, **36**, 214–215.

HSI, D. C. H., 1961. An effective technique for screening sorghum for resistance to charcoal rot. *Phytopathology*, **51**, 340–341.

KHUNE, N. N., KURHEKAR, J. G., RAUT, J. G. and WANGIKAR, P. D., 1984. Stalk rot of Sorghum caused by *Fusarium moniliforme*. *Indian Phytopathology*, **37**, 316–317.

MASTERHAZY, A., 1979. Stalk splitting as a method for evaluating stalk rot of corn. *Plant Disease Reporter*, **63**, 227–231.

MUGHOGHO, L. K. and PANDE, S., 1984. Charcoal rot of Sorghum. In: *Sorghum Root and Stalk Rots, A Critical Review* (L. K. Mughogho and G. Rosenberg, Eds) (Patancheru: ICRISAT), pp. 11–23.

PANDE, S. and KARUNAKAR, R. I., 1992. Stalk rots. In *Sorghum and Millet Diseases: A Second World Review* (W. A. J. de Milliano, R. A. Frederiksen and G. D. Bengston, Eds) (Patancheru: ICRISAT), pp. 219–234.

PANDE, S., MUGHOGHO, L. K., SEETARAMA, N. and KARUNAKAR, R. I., 1989. Effects of nitrogen, plant density, moisture stress and artificial inoculation with *Macrophomina phaseolina* on charcoal rot incidence in grain sorghum. *Journal of Phytopathology*, **126**, 343–352.

REED, J. E., PARTRIDGE, J. E. and NORDQUIST, P. T., 1983. Fungal colonization of stalks and roots of grain sorghum during the growing season. *Plant Disease*, **67**, 417–420.

ROSENOW, D. T., 1980. Stalk rot resistance breeding in Texas. In *Sorghum Diseases, a World Review: Proceedings of the International Workshop on Sorghum Diseases* (R. J. Williams, R. A. Frederiksen, L. K. Mughogho and G. D. Bengston, Eds). Sponsored jointly by Texas A&M University (USA) and ICRISAT (Patancheru: ICRISAT), pp. 306–314.

SHEKAR, G., ANAHOSUR, K. H. and HEGDE, R. K., 1987. Evaluation of susceptibility of sorghum to charcoal rot infection. *Indian Phytopathology*, **40**, 406.

TANGONAN, N. G. and QUIMOI, T. H., 1985. Etiology of sorghum stalk rot complex in Mindanao. *Philippine Phytopathology*, **21**, 20–27.

TRIMBOLI, D. S. and BURGESS, L. W., 1982. The fungi associated with stalk and root rot of grain sorghum in New South Wales. *Sorghum Newsletter*, **25**, 105–106.