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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(1): 185-194

www.thepharmajournal.com
Received: 06-11-2022
Accepted: 13-01-2023

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Biochemical factors imparting resistance to sorghum rust (*Puccinia purpurea* cooke)

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DOI: https://doi.org/10.22271/tpi.2023.v12.i2c.18434

Abstract
An experiment was conducted to study the different biochemical constituents imparting resistance and susceptibility to rust of sorghum disease caused by *Puccinia purpurea* Cooke. For this, five rust resistant (R) and five rust susceptible (S) genotypes of sorghum were inoculated at 30 days after sowing (DAS) and studied at both 30 days after inoculation (DAI). Reduction in the chlorophyll a, chlorophyll b, total chlorophyll, soluble protein, reducing sugar, non reducing sugar, total sugar and phenol contents was found in inoculated S genotypes as compared with inoculated R genotypes. The total phenol content and enzymatic activities *viz*., peroxidase and polyphenol oxidase were decreased in R as well as S genotypes when challenged with sorghum rust, while increased levels of phenol, peroxidase and polyphenol oxidase activity were found more in R genotypes than S genotypes.

Keywords: Sorghum rust, rust resistance, biochemical constituents, chlorophyll, peroxidase and polyphenol oxidase

Introduction
Sorghum (*Sorghum bicolor* L.) is one of the most important grain and fodder crop grown worldwide for food security and believed to be originated from Africa, Nile valley, Central India and has spread through the warmer parts of India, China, South and East Asia and Southern Europe. It ranks fifth after wheat, maize, rice and barley in the list of world's important cereal crop globally and second after maize in sub-Saharan Africa.
The crop suffers by many more fungal, bacterial and viral diseases *viz*., leaf blight [*Exherohilu mturcicum*] formerly, *Helminthos poriumturcicum*, Downey mildew [*Sclerospora sorghi*], crazy top [*Sclerospora macrospora*], Zonate leaf spot [*Gloeocercospora sorghi*], grey leaf spot [*Cercospora sorghi*] mycoplasma. Among these diseases rust of sorghum *Puccinia purpurea* Cooke is becoming a serious problem in *Rabi* sorghum. It occurs in warmer regions. In India, it occurs in all the states. Severe rust infection also contributes to lodging by reducing leaf area and increasing plant stress (Ryley *et al.* 2002) [33]. The pathogen form scattered purple, red and flecks on both side of infected leaves and is highly susceptible lines, the flecks may coalesce to form blister like dark reddish brown pustules (Bandyopadhyay 2000; Thakur *et. al.* 2007) [7, 41].
The rust disease was considered to be minor but now a days it is becoming a major one. Rust is particularly problematic in late-sown crops (White *et al.*, 2012) [19] with yield losses up to 65% resulted from the impact on panicle exertion and grain fill under environmental conditions favourable for early rust development (Bandyopadhyay, 2000) [7]. The disease was noticed in high intensity during *Rabi* 2012-13 in the field of the All India Coordinated Sorghum Improvement Project, MPKV, Rahuri.
In order to minimize losses caused by rust, cultivation of resistant cultivars is one of the cheaper and suitable options over the use of chemicals. Therefore, identification of resistant sources and the factors imparting resistance to rust are needed to be studied thoroughly. Comparative studies on biochemical constituents in R and S genotypes of sorghum during pathogenesis has often helped in understanding the nature and mechanism of used as basis for identification of R genotypes. Now, a little information is available regarding factors imparting rust resistance and their activities. The present study attempts to identify the biochemical factors which help in identification of traits responsible for resistance to rust of sorghum.

Materials and Methods
Estimation of biochemical components such as chlorophyll (chlorophyll 'a', chlorophyll 'b' and total chlorophyll) content, sugar content (reducing sugar, non reducing sugar and total

sugar) total phenols, peroxidase activities and polyphenol activities was carried out in five rust resistant (RSV2390, RSV2394, RSV2395, RSV2393 and RSV2383) and five rust susceptible (RSV2388, RSV2381, RSV2400, P. Anuradha and M 35-1) genotypes of sorghum. An experiment was carried out during 2018-19 at the Department of Plant Pathology and Agriculture Microbiology, Mahatma Phule Krishi Vidyapeeth, Rahuri under the controlled glass house condition. Seed of the each genotype were sown in the plastic pots. All the plants were inoculated at the 4 to 5 leaf stage with an inoculum concentration of Urediniospores (*Puccinia pupurea*) and incubated at 20-25 °C under high RH (> 90%) for 24 hoursafter 30 days of sowing (DAS) (Karunakar*et al.*, 1996) [25]. Simultaneously, similar sets of all the five genotypes were sown in pots separately under rust free environment in another glasshouse for comparison. Rust severity was recorded at 60 days after sowing (DAS) using '0 to 9 scale' suggested by Mayee and Datar (1986) [14]. Further per cent disease index (PDI) was calculated using the formula given by Wheeler (1969) [24].

Sampling for biochemical studies was done at 30 days after inoculation (DAI) from both the sets. Standard procedures were followed for estimation of different biochemical constituents from the leaf portion i.e. chlorophyll content (Arnon, 1949) [2], soluble protein by the method of Lowry *et al.* (1951) [24], reducing sugars by Nelson Somogyi"s method (Somogyi, 1952) [38], total sugars by Thimmaia (2004) [42], total phenols by using Folin-Denis reagent as described by Swain and Hills (1959) [40], peroxidase activity and polyphenol oxidase activity (Kumar and Khan, 1982) [12]. Non reducing sugar was calculated by subtracting reducing sugars from total sugars.

Results and Discussion

Severity of sorghum in different soybean genotypes: Rust severity assessed at 60 DAS on all the genotypes revealed that it differed significantly as far as genotypes, crop growth stages (days) and their interaction are concerned. The genotypes RSV2390, RSV2394, RSV2395, RSV2393 and RSV2383 showed highly resistant reaction to rust. However, maximum rust severity was recorded in RSV2388, RSV2381, RSV2400, P. Anuradha and M 35-1 at 60 DAS (Table 1).

Biochemical studies

Infection by pathogen brings about lot of changes in respiratory pathway and photosynthesis which are the vital processes taking place in the plant leading to wider fluctuation in biochemical components. This in turn alters the resistance of the host. Some studies on biochemical components in resistant and susceptible sorghum genotypes were carried out as described in material and methods and the results are presented here under. Biochemical analysis in resistant and susceptible sorghum genotypes was carried out 60 days after sowing (DAS) i.e. 30 days after inoculation (DAI) to understand their role in resistance or susceptibility of rust pathogens.

Chlorophyll

The results on chlorophyll 'a', chlorophyll 'b' and total chlorophyll content as influenced by rust analyzed at 30 DAI are presented in Tables 2 and fig 1,2 & 3. In general, levels of Chlorophyll content were higher at 30 DAI in healthy plants but lower under inoculated condition. Per cent decrease in all the three chlorophyll components over healthy leaf and R genotypes was observed in both R and S genotypes after inoculation.

The data on chlorophyll 'a' indicated that it was high in healthy plants, but decreased under inoculated condition. The chlorophyll 'a' differed significantly among the resistant and susceptible genotypes. The genotype RSV2395 recorded highest chlorophyll 'a' in healthy stage (1.693 mg/g fresh wt.) and also in inoculated stage (1.587 mg/g fresh wt.) followed by genotype RSV2381 in healthy condition. However, the lowest chlorophyll content was recorded in the genotype RSV2393 under inoculated condition (0.659 mg/g fresh wt.). The mean chlorophyll 'a' was more in the resistant genotypes, at both healthy and inoculated condition than in susceptible genotypes. It was also noted that there was decrease in the per cent mean chlorophyll 'a' in inoculated condition over healthy in both resistant genotype (9.78%) and susceptible genotypes (13.04%).

In case of chlorophyll 'b' and total chlorophyll, same genotype RSV2395 recorded highest chlorophyll 'b' (0.511 mg/g fresh wt.) and also total chlorophyll (2.204 mg/g fresh wt.) in healthy stage and decreases in inoculated condition. However, the lowest chlorophyll 'b' was recorded in the genotype P. Anuradha under inoculated (0.112 mg/g fresh wt.) and lowest total chlorophyll content was found in genotype RSV2393 (0.775 mg/m fresh wt. The mean chlorophyll 'b' and total chlorophyll was more in the resistant genotypes, at both healthy and inoculated condition and decreases in susceptible genotypes. It was also noted that there was decrease in the per cent mean chlorophyll 'b' at inoculated condition over healthy in both resistant and susceptible genotypes i.e. 46.95% and 47.68%, respectively and in case of total chlorophyll it was 17.81% and 19.73%, respectively. Total chlorophyll content is presented in table 2 and fig 1

The study revealed that chlorophyll a, chlorophyll b and total chlorophyll contents were decreased due to the foliar infection by *Puccinea purpurea* in sorghum. In case of chlorophyll 'a', mean chlorophyll content was 1.167 mg/g fresh wt. in healthy and 1.048 mg/g fresh wt. in inoculated condition. In case of chlorophyll 'b' mean chlorophyll content in healthy was 0.354 mg/g fresh wt. and 0.242 mg/g fresh wt. in inoculated and 1.521 mg/g fresh wt. in healthy and 1.281 mg/g fresh wt. in inoculated in case of total chlorophyll.

The phenomenon of reduction of chlorophyll has been reported by many workers attributing to various reasons. Amongst them, Ellis *et al.*, 1981 reported decrease in chlorophyll content due to infection in several host pathogen systems and Heath, 1974 reported a change in the ultra-structure of chloroplast in rusted cowpea leaves. Balasubramaniam (1981) [6] studied the chlorophyll content and mineral composition of downy mildew affected chlorotic leaves of sorghum and found reduction in content of chlorophyll 'a' and chlorophyll 'b' content. Benagi (1995) [9] studied the effect of late leaf-spot disease on chlorophyll content in different groundnut varieties and reported substantial loss of chlorophyll in susceptible varieties than that of partially resistant varieties. Jyosthana *et al.* (2004) [18] reported that the total chlorophyll content was higher in healthy leaves than inoculated leaves with *Phaeoisariopsis personata* and also observed that the chlorophyll content was higher in resistant cultivar and low in susceptible groundnut cultivar. Ponmourugan and Baby (2007) [31] observed that the

chlorophyll content was more in healthy leaves than the *Phomopsis* infected leaves of tea plants. They also observed that the chlorophyll content was slight more in tolerant than susceptible cultivar. Mesta *et al.* (2009) [26] reported that the chlorophyll content decreased due to the infection of *Alternaria helianthi*. The rate of decrease was more in susceptible genotypes than resistant genotypes.

Sugars content

The results in respect of reducing sugars, non reducing sugars and total sugars as influenced by rust disease recorded are given in Table 3 and Fig 4, 5 & 6. The results revealed that significant difference existed among the genotypes. There was decrease in reducing sugars, non reducing sugars and total sugars observed under infected condition in all the resistant and susceptible sorghum genotypes than in healthy.

Genotype RSV2390 recorded the highest reducing sugars in both at healthy condition (14.93 mg/g fresh weight) and inoculated stage (12.960 mg/g fresh wt.) followed by RSV2393 in healthy and in inoculated stage. However, the lowest was recorded in the genotype RSV2400 at healthy (6.399 mg/g fresh wt.) and in infected condition (5.077 mg/g fresh wt.). The mean reducing sugars was more in the resistant genotypes, at both healthy and inoculated condition when compared with mean reducing sugars of susceptible genotypes. Also it was noted that there was decrease in the per cent mean reducing sugar at inoculated condition over healthy in both resistant and susceptible genotypes (16.97% and 18.16% respectively).

Decrease in the non-reducing sugars content was observed under infected condition in all the resistant and susceptible sorghum genotypes. During investigation it was found that, RSV2393 recorded the highest non reducing sugars in both at healthy condition (23.515 mg/g fresh weight) and inoculated stage (21.236 mg/g fresh wt.) followed by genotype RSV2395 in both healthy and in inoculated stage. However, the lowest was recorded in the genotype P. Anuradhaat healthy (10.740 mg/g fresh wt.) and in infected condition (9.242 mg/g fresh wt.).The mean non reducing sugars was more in the resistant genotypes, at both healthy and inoculated condition when compared with per cent mean non reducing sugars of susceptible genotypes. It was also noted that there was decrease in the per cent mean of non-reducing sugar content at inoculated condition over healthy in both resistant and susceptible genotypes (10.31% and 18.48%, respectively).

Decrease in the total sugars content was observed under infected condition in all the resistant and susceptible sorghum genotypes. Genotype RSV2393 recorded the highest total sugars in both at healthy condition (35.683 mg/g fresh weight) and inoculated stage (31.429 mg/g fresh wt.) followed by genotype RSV2395 in both healthy and in inoculated stage. However, the lowest was recorded in the genotype P. Anuradha at healthy (19.037 mg/g fresh wt.) and in infected condition (16.048 mg/g fresh wt.)**.** The mean total sugars was more in the resistant genotypes, at both healthy and inoculated condition when compared with per cent mean total reducing sugars of susceptible genotypes. It was also noted that there was decrease in the per cent mean of total reducing sugar content at inoculated condition over healthy in both resistant and susceptible genotypes (12.69% and 18.36%, respectively)

Sugars acts as precursor for synthesis of phenolics, phytoalexins, lignin and cellulose which play an important role in defense mechanism of plants against invading pathogens. Generally, high levels of total sugars, reducing sugars and non-reducing sugars in the host plants are stated to be responsible for disease resistance. Difference in sugar level between resistant and susceptible genotypes was due to inherent character of the genotypes. It was observed that there was decrease in the reducing sugar content in the resistant and susceptible genotypes which was ranging from 3.06 to 30.55 per cent in case of non reducingsuagar, 6.66 to 28.64 percent in case of total sugar and 9.07 to 23.58 per cent.

These results are in conformity with Naik (1979) [27] reported that in rust resistant genotype of sorghum, the quantity of reducing sugar was more at all stages of crop growth than the moderately resistant and susceptible genotype. Jalinder (1983) [17] observed the reduction of total and reducing sugar in *Pucciniagraminis* f. sp. *tritici* affected stem and leaf sample of wheat. Basarkar *et al.* (1988) [8] reported that downy mildew susceptible sorghum varieties contained less of total and non-reducing sugars than the multiple resistant cultivars *viz*., SB 2413 and SB 2415. Kalappanavar and Hiremath (2000) [20] stated that the multiple foliar disease resistant sorghum genotypes possessed higher content of sugar as compared to susceptible ones.

Soluble proteins content

The observations on soluble protein as influenced by rust disease recorded at different stages are presented in Table 4 and Fig 7 It was evident that significant difference existed among the genotypes. Decrease in soluble protein was observed under infected condition in all the resistant and susceptible sorghum genotypes. Genotype RSV2383 recorded the highest soluble protein in both at healthy condition (49.79 mg/g fresh weight) and inoculated condition (42.90 mg/g fresh wt.) followed by genotype RSV2390 in healthy and in inoculated stage. However, the lowest was recorded in the genotype M35-1 at healthy (27.44 mg/g fresh wt.) followed by genotype RSV 2388 in infected condition (22.21 mg/g fresh wt.)**.**

The mean soluble protein was more in the resistant genotypes, at both healthy and inoculated condition when compared with mean soluble protein of susceptible genotypes. Also it was noted that there was decrease in the per cent mean soluble protein at inoculated condition over healthy in both resistant and susceptible genotypes (17.78% and 21.95%, respectively).Mean soluble protein content was more in resistant genotypes than the susceptible genotypes. In general, it was noticed that decrease in the soluble protein content in response to foliar infection crop growth ranging from 25.23 to 14.98 per cent. The rate of decrease in the soluble protein content in response to rust disease infection was more in susceptible genotypes.

Results on protein content in different resistance and susceptible sorghum genotypes as influenced by rust disease are in agreement with Arjunan *et al.* (1976) [3] reported changes in protein content in sorghum leaves infected by *Helminthos poriumturcicum* Pass. The protein content in healthy and infected leaves was 0.31 and 0.39 per cent, respectively in ten days old plant and 0.24 and 0.02 per cent, respectively in 60 days old plants. Kalappanavar and Hiremath (2000) [20] reported that the multiple foliar disease resistant sorghum genotype possessed higher protein content compared to those of susceptible genotype. Sunkad and Kulkarni (2006) [39] recorded more protein content in resistance and moderately resistant Vatrieties of groundnut

than susceptible one. Hosagoudar and Chattannavar (2008) reported that the protein content was more in healthy leaves than infected leaves of cotton genotypes as influenced by the *Xanthomonas axonopodis pv. malvacearum.* Pawar*et al.* (2012) [17] observed that the healthy leaves of both resistant and susceptible genotypes showed more protein content than grey mildew infected leaves of each genotype in cotton.

Total phenol

Results of the study on total phenols as influenced by rust disease recorded in Table 4 and Fig 8 Decrease in the total phenols was observed under infected condition in all the resistant and susceptible sorghum genotypes. Genotype RSV2383 recorded the highest total phenols in healthy condition (0.911 mg/g fresh weight) and in at inoculated stage (0.842 mg/g fresh wt.) followed by RSV2394 in healthy and in inoculated stage. However, the lowest was recorded in the genotype RSV2400 at healthy (0.521 mg/g fresh wt.) and P. Anuradha in infected condition (0.413 mg/g fresh wt.).

The mean total phenols was more in the resistant genotypes, at both healthy and inoculated condition while compared with per cent mean total phenols of susceptible genotypes. It was noted that, there was decrease in the total phenols at inoculated condition over healthy in both resistant and susceptible (17.93% and 28.15%, respectively). High concentration causes an instant lethal action by a general tanning effect while, low concentration causes gradual effect on the cellular constituent of the parasite. If the concentration does not occur at toxic level, the inhibition will be obviously slow.

There is significant positive correlation between phenolic content and disease resistance. In this study, lower levels of phenols were observed in diseased plant at both the stages of all susceptible genotypes. It was also observed that decrease in phenol content ranged from 8.141 to 29.47 per cent. Mean phenol content in healthy genotypes was 0.610 mg/g fresh wt. where as in inoculated genotypes it was 0.499 mg/g fresh wt. The rate of decrease in the total phenol content in response to the rust disease infection was more in susceptible as compared to healthy ones.

Similar results were obtained by Anahosur *et al.* (1985) [2] found higher level of phenolics in resistant sorghum genotypes to *Macrophomina phaseolina* (Maubl) Ashby than in susceptible ones. Shree and Reddy (1986) [11] reported that healthy hybrids (CSH 6 and 148) resistant to *Helminthos poriumturcicum* Pass. contained comparatively large amounts of total phenols than in the susceptible cultivars Swarna and Neerujola. Kalappanavar and Hiremath (2000) [20] reported that multiple foliar disease resistant sorghum genotypes recorded higher content of phenols as compared to susceptible ones.

Peroxidase activity

The observations on peroxidase activity as influenced by rust disease recorded in Table 4 and Fig 9. The results revealed that significant difference existed among the genotypes. There was an increase in the peroxidase activity was observed under infected condition in all the resistant and susceptible sorghum genotypes. The genotype RSV2390 recorded the highest peroxidase activity in healthy condition (4.12 units/mg/g fresh wt.) and increases in inoculated stage (4.61 units/mg/g fresh wt.) followed by RSV2383 in both healthy and in inoculated stage. However, the lowest was recorded in the genotype RSV2400 at healthy (2.82 units/mg/g fresh wt.) and genotype M35-1 in infected condition (3.28 units/mg/g fresh wt.)

It was noted that there was increase in the per cent mean peroxidase activity at inoculated condition in both resistant and susceptible genotypes (19.34% and 11.83% respectively) Peroxidase oxidizes phenolics to highly toxic quinines and hence, has been assigned a role in disease resistance. The increased activity of peroxidase was observed in resistant and susceptible genotypes which was ranged from 7.89 to 29.62 per cent. Mean peroxidase content in healthy genotype was 3.395 units/g fresh wt. whereas 4.045 units/g fresh wt. in inoculated condition.

These results were in agreement with Gowda *et al.* (1989) [8] who reported peroxidase and polyphenol oxidase activity in downy mildew resistant (DMRS 1 and DL 3) and susceptible (DMS 652) sorghum cultivars in ten days old seedlings inoculated with *Peronosclerospora sorghi* (Weston) Shaw. The activity of both the enzymes were analysed at 15, 30 and 60 hr after inoculation. They found that peroxidase activity was very low in healthy leaves of all the three sorghum lines. Inoculation with *P. sorghi* increased the peroxidase activity to varying degrees in all the three sorghum lines with the highest increase in DL-3. Also, Velazhahan and Krishnaveni (1994) [44] observed higher activities of peroxidase and polyphenol oxidase in the resistant cultivar (No 179) of sunflower than the susceptible cultivar (EC 68414) following infection with *P. helianthi.* Pawar *et al.* (2012) [17] observed that the healthy leaves of resistant and susceptible cotton plant exhibited less polyphenol oxidase activity and peroxidase activity as compared to infected leaves of cotton as influenced by grey mildew disease.

Polyphenol oxidase activity

The data on polyphenol oxidase activity as influenced by rust disease recorded at different stages are presented in Table 4 and Fig 10. There was increase in the polyphenol oxidase activity which observed under infected condition in all the resistant and susceptible sorghum genotypes. The genotype RSV2383 recorded the highest polyphenol oxidase activity in inoculated condition (0.091 units/g fresh wt.) followed by RSV2390 in inoculated stage (0.090 units/mg/g fresh wt.) followed by RSV2395 in inoculated condition. However, the lowest wasre corded in the genotype in both at P. Anuradha healthy (0.044 units/g fresh wt.) followed by genotype M 35-1 (0.050 units/g fresh wt.) in healthy condition.

The mean polyphenol oxidase activity was more in susceptible genotype as compared to resistant genotypes and mean polyphenol oxidase activity in healthy genotypes were 3.359 units/g fresh wt. and 4.045 units/g fresh wt. in inoculated condition. Also it was noted that there was increase in the per cent mean polyphenol oxidase activity at inoculated condition in both resistant and susceptible genotypes (18.18% and 19.50%, respectively).

Results of the present study, on polyphenol oxidase activity in different resistance and susceptible sorghum genotypes as influenced by rust disease are in agreement with Gupta *et al.* (1992) [9]. They observed that the polyphenol oxidase activity was relatively more in tolerant cultivars than susceptible cultivars in groundnut as influenced by leaf spot pathogen. Velazhahan and Krishnaveni (1994) [44] observed higher activities of peroxidase and polyphenol oxidase in the resistant cultivar (No 179) of sunflower than the susceptible cultivar (EC 68414) following infection with *P. helianthi.* In infected leaves of the susceptible cultivar there was an

increase in peroxidase activity but the ratio of peroxidase activity decreased during the later period of infection. Pawar *et al*. (2012) [17] observed that the healthy leaves of resistant and susceptible cotton plant exhibited less polyphenol oxidase activity and peroxidase activity as compared to infected leaves of cotton as influenced by grey mildew disease.

Table 1: Screening of sorghum genotypes in glasshouse to rust disease.

SN.	Genotype	Rust Disease(PDI)	Grade	Category
Resistant genotypes				
1	RSV2383	0.88	1	R
2	RSV2390	1.00	1	R
3	RSV2393	0.88	1	R
4	RSV2394	0.40	1	R
5	RSV2395	0.88	1	R
Susceptible genotypes				
6	RSV2381	72.44	9	HS
7	RSV2388	72.44	9	HS
8	RSV2400	65.33	9	HS
9	P. Anuradha	59.11	9	HS
10	M 35-1	75.11	9	HS

Table 2: Chlorophyll ‘a’, ‘b’ and total chlorophyll content in different resistance and susceptible sorghum genotypes as influenced by rust disease rust disease.

Genotypes	Chlorophyll (mg/g fresh weight)								
	Chlorophyll ‘a’			Chlorophyll ‘b’			Total Chlorophyll		
	Healthy	Inoculated	% Dec. over healthy	Healthy	Inoculated	% Dec. over healthy	Healthy	Inoculated	% Dec. over healthy
Resistant genotypes									
RSV2390	1.009	0.982	2.75	0.293	0.163	79.18	1.302	1.145	13.65
RSV2394	1.317	1.261	4.44	0.383	0.246	55.90	1.700	1.507	12.83
RSV2395	1.693	1.587	6.66	0.511	0.370	38.11	2.204	1.957	12.60
RSV2393	0.878	0.659	33.22	0.253	0.190	33.16	1.131	0.775	45.98
RSV2383	1.057	0.934	13.16	0.313	0.224	39.94	1.370	1.158	18.34
Mean A	1.191	1.085	9.78	0.351	0.239	46.95	1.542	1.309	17.81
Susceptible genotypes									
RSV2388	1.043	0.910	14.61	0.494	0.346	42.82	1.537	1.256	22.37
RSV2381	1.344	1.147	17.18	0.410	0.233	75.82	1.753	1.380	27.08
RSV2400	1.340	1.253	6.92	0.392	0.353	10.95	1.731	1.606	7.80
P. Anuradha	0.985	0.824	19.54	0.204	0.112	82.14	1.189	0.936	27.03
M 35-1	1.003	0.921	8.83	0.290	0.168	72.82	1.293	1.089	18.70
Mean B	1.143	1.011	13.04	0.358	0.242	47.68	1.501	1.253	19.73
Mean A + B	1.167	1.048	11.41	0.354	0.240	47.31	1.521	1.281	18.77
SE+	0.031	0.024	--	0.004	0.004	--	0.033	0.021	--
CD at 5%	0.091	0.071	--	0.012	0.012	--	0.098	0.063	--
Cv %	4.62	4.02	--	1.99	3.058	--	3.80	2.93	--

Table 3: Reducing, non-reducing and total sugar content in resistance and susceptible sorghum genotypes as influenced by rust disease.

Genotypes	Sugar (mg/g fresh weight)								
	Reducing sugar			Non reducing sugar			Total sugar		
	Healthy	Inoculated	% Dec. over healthy	Healthy	Inoculated	% Dec. over healthy	Healthy	Inoculated	% Dec. over healthy
Resistant genotypes									
RSV2390	14.93	12.960	15.23	16.902	14.872	13.65	31.836	27.832	14.39
RSV2394	11.62	9.743	19.21	18.907	16.877	12.03	30.522	26.620	14.66
RSV2395	10.81	9.170	17.88	23.080	21.050	9.64	33.890	30.220	12.14
RSV2393	12.17	10.193	19.38	23.515	21.236	10.73	35.683	31.429	13.54
RSV2383	11.62	10.203	13.84	21.419	20.082	6.66	33.034	30.285	9.07
Mean A	12.228	10.454	16.97	20.765	18.823	10.31	32.993	29.277	12.69
Susceptible genotypes									
RSV2388	8.299	6.357	30.55	12.222	10.249	19.25	20.521	16.605	23.58
RSV2390	8.850	7.687	15.13	14.712	13.014	13.05	23.562	20.701	13.82
RSV2400	6.399	5.077	26.05	14.308	12.278	16.53	20.707	17.355	19.32
P. Anuradha	8.297	6.807	21.89	10.740	9.242	16.21	19.037	16.048	18.62
M35-1	8.256	8.010	3.06	13.600	10.572	28.64	21.856	18.582	17.62
Mean B	8.020	6.787	18.16	13.117	11.071	18.48	21.136	17.858	18.36
Mean A +B	10.124	8.620	17.56	16.941	14.947	14.39	27.064	23.567	15.52
SE+	0.197	0.187	--	0.373	0.369	--	0.569	0.416	--
CD at 5%	0.582	0.553	--	1.102	1.089	--	1.679	1.228	--
Cv. %	3.378	3.767	--	3.821	4.280	--	3.643	3.060	--

Table 4: Protein content, total phenol content, Peroxidase activity and Polyphenol oxidase activity in different resistance and susceptible sorghum genotypes as influenced by rust disease.

Genotypes	Protein (mg/g fresh weight)			Total Phenol (mg/g fresh weight)			Peroxidase activity (Units/g fresh wt.)			Polyphenol oxidase activity (units/g fresh wt.)		
	Healthy	Inocu-lated	% Dec. over healthy	Healthy	Inocu-lated	% Dec. over healthy	Healthy	Inocu-lated	% Dec. over healthy	Healthy	Inocu-lated	% Dec. over healthy
Resistant genotypes												
RSV2390	39.96	33.72	18.51	0.590	0.501	17.834	4.12	4.61	10.63	0.075	0.090	16.67
RSV2394	31.51	26.42	19.28	0.676	0.556	21.535	3.07	3.98	22.86	0.071	0.087	18.39
RSV2395	36.14	31.09	16.24	0.614	0.509	20.609	3.62	3.93	7.89	0.073	0.089	17.98
RSV2393	31.46	26.23	19.95	0.647	0.507	27.619	3.79	4.87	22.18	0.063	0.083	24.10
RSV2383	49.79	42.90	16.07	0.911	0.842	8.141	3.92	5.57	29.62	0.078	0.091	14.29
Mean A	37.77	32.07	17.78	0.688	0.583	17.93	3.70	4.59	19.34	0.072	0.088	18.18
Susceptible genotypes												
RSV2388	29.19	22.21	31.41	0.548	0.423	29.47	3.68	4.05	9.14	0.057	0.068	16.18
RSV2381	29.35	23.44	25.23	0.524	0.416	25.99	2.98	3.59	16.99	0.056	0.069	18.84
RSV2400	30.00	25.47	17.78	0.521	0.408	27.73	2.82	3.32	15.06	0.053	0.067	20.90
P. Anuradha	29.07	23.96	21.32	0.530	0.413	28.33	2.94	3.26	9.82	0.044	0.053	16.98
M 35-1	27.44	23.86	14.98	0.539	0.417	29.21	3.01	3.28	8.23	0.050	0.066	24.24
Mean B	29.01	23.79	21.95	0.532	0.415	28.15	3.09	3.50	11.83	0.052	0.065	19.50
Mean A + B	33.39	27.93	19.86	0.61	0.499	23.04	3.395	4.045	15.58	2.124	2.153	18.84
SE+	0.720	0.555	--	0.018	0.010	--	0.001	0.002	--	0.055	0.081	--
CD at 5%	2.126	1.639	--	0.053	0.030	--	0.004	0.005	--	0.162	0.240	--
Cv. %	3.73	3.44	--	5.18	3.54	--	3.88	4.59	--	2.80	3.48	--

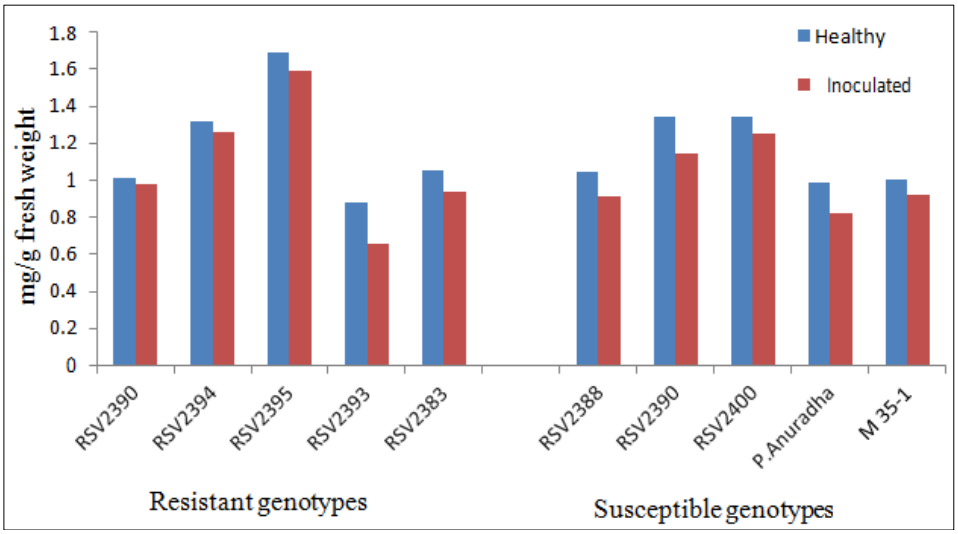

Fig 1: Chlorophyll 'a' in different resistant and susceptible sorghum genotypes as influenced by rust disease

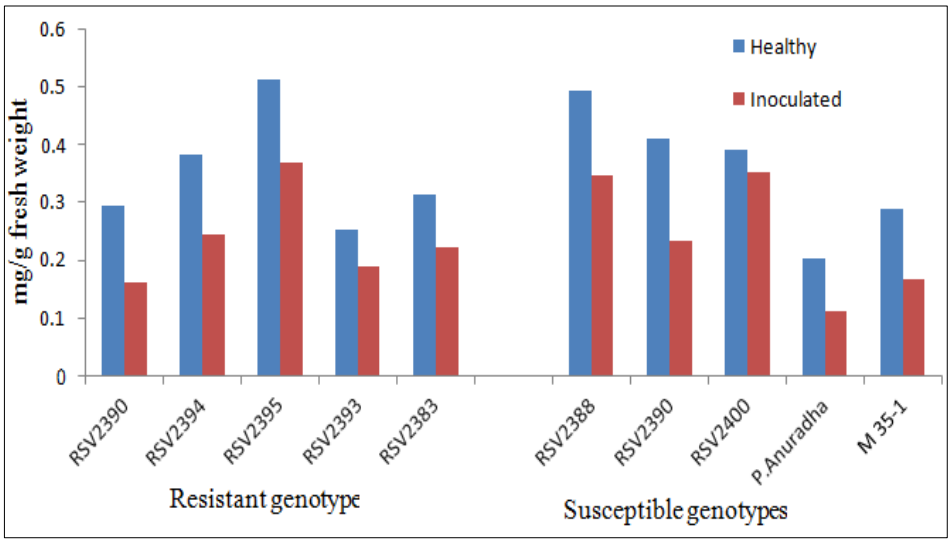

Fig 2: Chlorophyll 'b' in different resistant and susceptible sorghum genotypes as influenced by rust disease.

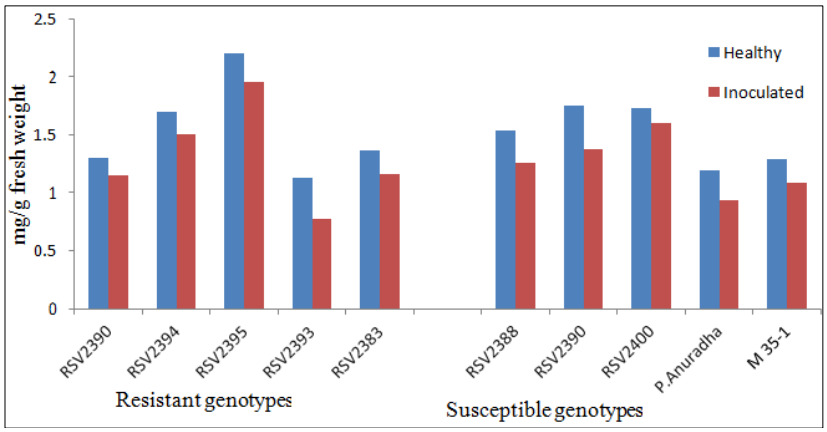

Fig 3: Total chlorophyll in different resistant and susceptible sorghum genotypes as influenced by rust disease.

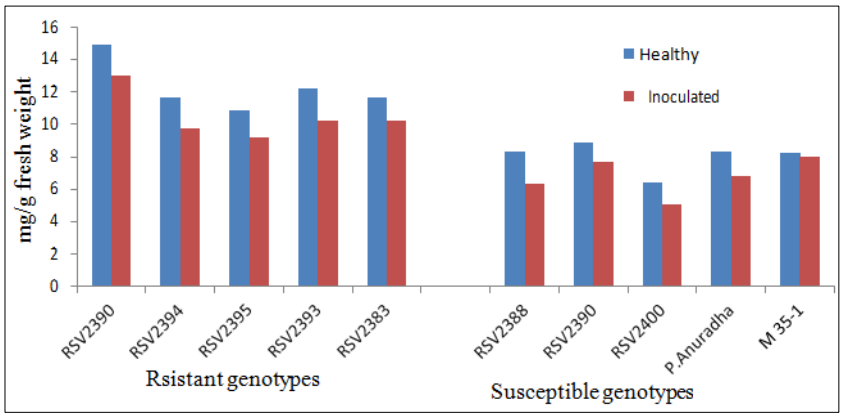

Fig 4: Reducing sugar in different resistant and susceptible sorghum genotypes as influenced by rust disease

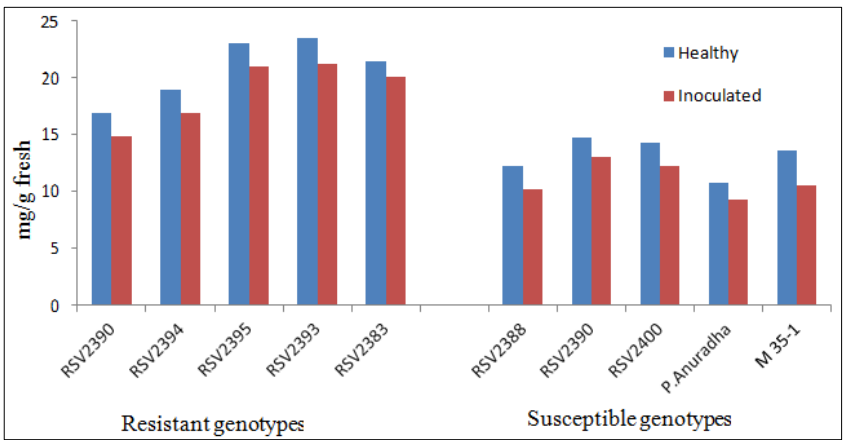

Fig 5: Non reducing sugar in different resistant and susceptible sorghum genotypes as influenced by rust disease.

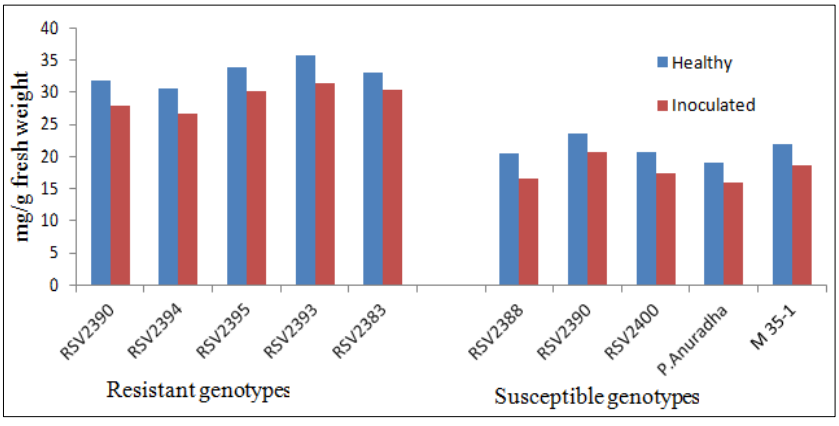

Fig 6: Total sugar in different resistant and susceptible sorghum genotypes as influenced by rust disease

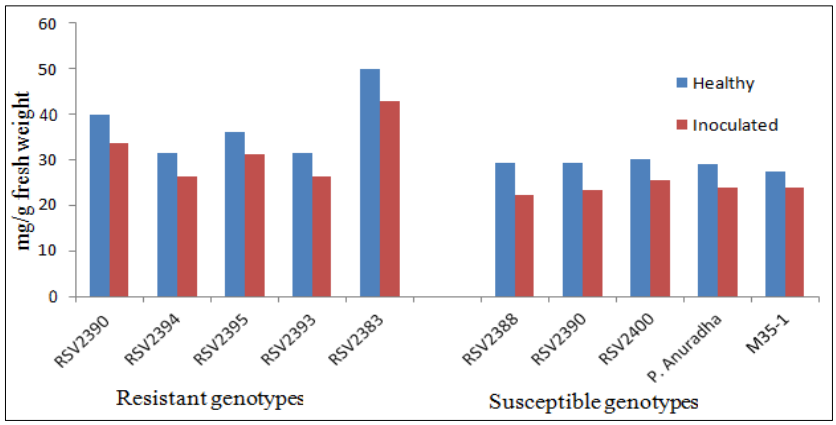

Fig 7: Soluble protein in different resistance and susceptible sorghum genotypes influenced by rust disease

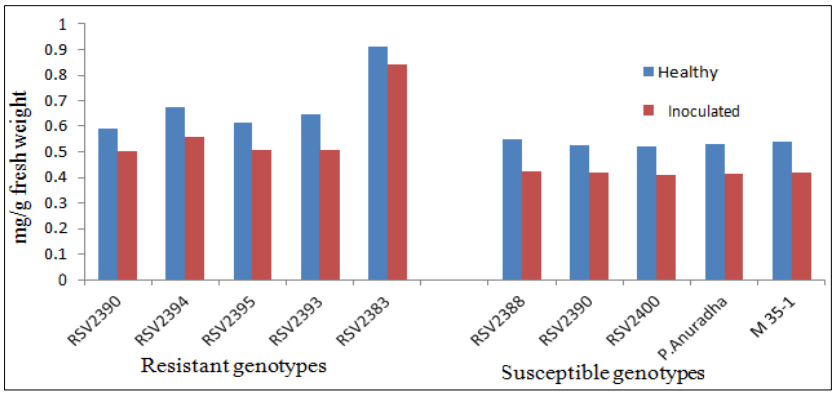

Fig 8: Total phenols in different resistant and susceptible sorghum genotypes as influenced by rust disease.

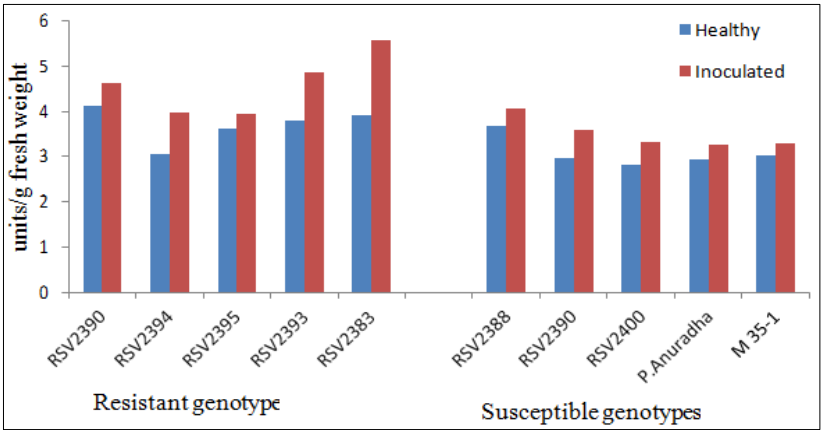

Fig 9: Peroxidase activity in different resistant and susceptible sorghum genotypes as influenced by rust disease

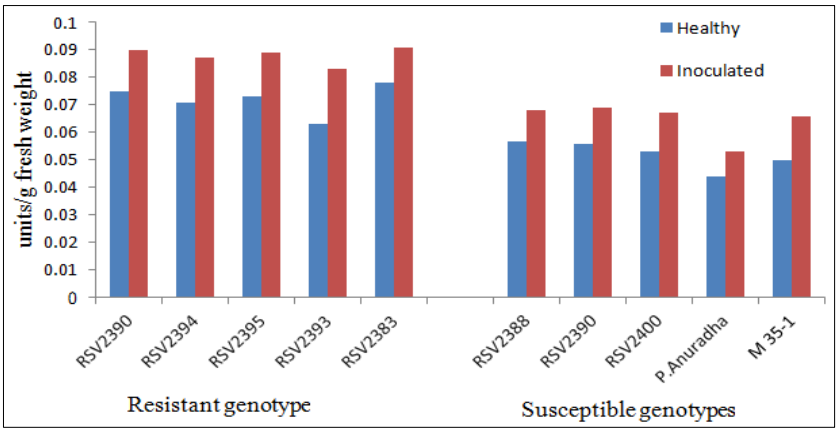

Fig 10: Polyphenol oxidase activity in different resistant and susceptible sorghum genotypes as influenced by rust disease

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