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Reaction of Rice Genotypes to False Smut with Reference to the Host Factors Favouring the Disease

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ABSTRACT

An experiment was conducted with 16 rice genotypes to evaluate their reaction to false smut disease and to identify the host factors that contribute to false smut infection by path coefficient analysis during *kharif* 2014-15. Per cent rice false smut incidence was assessed hill-wise, panicle-wise and grain-wise. The rice false smut (rfs) incidence significantly varied among the genotypes when rice false smut incidence was recorded hill-wise and grain-wise but not panicle-wise. The least grain-wise disease incidence (0.02%) was observed in NP 9381 and MTU 1061 genotypes while the highest was in MTU 1075 (0.286%). Symptom expression varied among the genotypes screened for false smut. The smut balls of NLR 34449, RNR 15048 and MTU 1010 were dark green in colour, smut balls were initially yellow, later they transformed into dark green in MTU 1121 and NP 9381, infected grains showed black colour powdery mass in some of the genotypes like NLR 3041, WGL 283, JGL 384, JGL 19621, MTU 1081, JGL 20171 and JGL 11470 and yellow colour smut balls were observed in genotypes of MTU 1071, MTU 1061, MTU 4870 and MTU 1075. Plant height was found to be significantly and positively associated with rfs incidence while five traits *viz.*, boot leaf length, boot leaf breadth, grain length, test weight and grains/panicle recorded non-significant positive association whereas productive tillers and grain breadth recorded negative association when rfs incidence was recorded grain-wise. Plant height in addition to chaffiness and chaffy grains/panicle had not only a positive significant correlation but also a direct positive (0.0914) effect along with the highest positive indirect effects *via* boot leaf length (0.0475) indicating that these two traits could be considered as indicatives for false smut proneness in rice genotypes. The residual effects in path coefficient analysis were the least in grain-wise disease assessment than hill-wise and panicle-wise and hence grain-wise estimation of false smut incidence on rice genotypes is more reliable.

Key words : False smut, Host factors and Rice genotypes.

Diseases are key limiting factors that affect rice production, which collectively reduce the yield by 10-15% in tropical Asia (Gianessi, 2014). More than 70 diseases caused by fungi, bacteria, viruses and nematodes were reported to affect rice. Among them, rice false smut caused by *Ustilaginoidea virens* (Cke.) Takahashi is an important emerging disease of rice in all major rice cultivars and hybrids. False smut was earlier considered to be disease of lesser economic importance due to its minor occurrence. However, during recent years it has started occurring in higher proportion on high yielding rice cultivars particularly on hybrids and causing significant yield losses under favourable weather conditions. According to Singh *et al.* (2012), rfs, once considered as a minor disease, is gaining importance as a major disease with 61.20 % incidence and 14.18 % yield loss in late transplanted paddy fields.

Host plant resistance has been successfully exploited in the management of several crop diseases. Resistance genotypes are either deployed for direct cultivation if they possess desirable agronomic traits or used as donors for use in resistance breeding programmes. Variation in reaction to false smut was reported by several workers. Kapse *et al.* (2012) reported rfs incidence of 3-12% in seven out of 25 varieties with the maximum in MTU 1010. Upadhyay and Singh (2013) reported that maximum yield loss was in hybrid rice PA6444 (20%) followed by Samba Mahsuri (16.7%), Jalmagana (6.4%), Sarju 52 (5.0%) in semi deep water and deep water areas while the lowest damage was in Jallahari (4.4%)

and Madhukar (4.3%). Lore *et al.* (2013) recorded the lowest disease in inbred cultivars, PR113 and PR114 and the highest disease incidence in two hybrids NPH 369 and NPH 909. Some host morphological characters were found to have a strong association with diseases incidence. Plant height and flag leaf length/ breadth ratio (Singh and Singh, 2005) were found to have significantly positive correlation with false smut incidence. The present study was carried out to assess the variation with reference to reaction to false smut in different rice genotypes that were morphologically distinct and to identify the host morphological characters that directly and indirectly contribute to false smut proneness.

MATERIAL AND METHODS

Rice genotypes were evaluated for false smut reaction in *kharif* 2014-2015 at the APRRI & RARS, Maruteru, West Godavari district located at 26.38° N latitude and 81.44° E longitude and 5.0 m above MSL. Soils are typical deltaic alluvials and clay loams. Annual rain fall in this location is 900 to 1150 mm.

Fifteen genotypes were screened by infector row technique, with the susceptible check variety MTU 1075 planted a week before test genotypes on all sides of the experimental plot, for their reaction to false smut. Each genotype was planted in four rows with a row length of 2.25 m at 15 cm inter row and 15 cm inter hill distance.

Spore suspension (1 x 10^6 ml^{-1}) obtained by crushing smut balls collected and stored in the previous year was used for artificial inoculation by spraying on genotypes at booting stage of the crop.

The number of tillers in ten hills of each genotype was counted and mean number of tillers $hill^{-1}$ was calculated. Plant height was recorded for ten randomly selected plants in each genotype. Plant height was measured from the base of the plant to the tip of the top most leaf (boot leaf) of the boot leaf at flowering and the mean plant height was calculated. Length of 10 randomly selected flag leaves was measured from base to tip of the flag leaf and the mean flag leaf length was calculated. Breadth at the broadest point of 10 randomly selected flag leaves was measured and the mean flag leaf breadth was calculated. Randomly selected 50 grains from the bulk lot of each plot of each replication were taken for recording grain length. Randomly selected 50 grains from the bulk lot of each plot of each replication were taken for recording grain breadth. Grain length and breadth were measured by the Grain Analyser version 4.0. One thousand grains were counted from a random sample for each genotype from a composite sample drawn from the net plot yield, weighed and expressed as 1000 grain (Test) weight in g. Number of grains in 15 panicles of each genotype was counted and mean number of grains/ panicle was calculated.

Fifteen panicles were randomly selected from each genotype for recording data on grain discolouration and chaffiness and per cent grain discolouration and chaffiness was calculated by using following formula

$$\text{Per cent grain discolouration} = \frac{\text{Number of discoloured grains}}{\text{Total number of grains}} \times 100$$

$$\text{Per cent chaffiness} = \frac{\text{Number of chaffy grains}}{\text{Total number of grains}} \times 100$$

Observations on disease incidence (hill, panicle and grain wise) were taken at grain maturity stage of rice crop for 16 genotypes and disease incidence was calculated by counting the total number of infected plants in each genotype.

Per cent disease incidence was calculated by using the following formula:

$$\text{Per cent disease incidence hill wise} = \frac{\text{Number of hills showing infection}}{\text{Total number of hills}} \times 100$$

$$\text{Per cent disease incidence panicle wise} = \frac{\text{Number of panicles with infection}}{\text{Total number of panicles}} \times 100$$

$$\text{Per cent disease incidence grain wise} = \frac{\text{Number of infected grains/panicle}}{\text{Total number of grains/panicle}} \times 100$$

The phenotypic correlation coefficients were worked out to determine the degree of association of a character with rice false smut incidence by using covariance technique as per Falconer (1964).

Phenotypic coefficients of correlation (r_p)

$$= r(x_i x_j)_p = \frac{Cov(x_i x_j)_p}{\sqrt{V(x_i)_p \times V(x_j)_p}}$$

Where,

$r(x_i x_j)_z$ = Phenotypic correlation between i^{th} and j^{th} characters

$Cov(x_i x_j)_p$ = Phenotypic covariance between i^{th} and j^{th} characters

$V(x_i)_p$ and $V(x_j)_p$ = Phenotypic variance of i^{th} and j^{th} characters, respectively.

Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values at (n-2) degrees of freedom at 5% and 1% level where 'n' denotes the number of paired observations used in the calculation.

Path coefficient analysis was performed by using the correlation coefficients to know the direct and indirect effects of the component characters on rice false smut as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

Path coefficients were obtained by solving the simultaneous equations which express the basic relationship between correlations and path coefficients.

The equations are as follows:

$$r_{1,y} = P_{1,y} + r_{1,2} P_{2,y} + r_{1,3} P_{3,y} + \ldots + r_{1,k} P_{k,y}$$
$$r_{2,y} = r_{2,1} P_{1,y} + P_{2,y} + r_{2,3} P_{3,y} + \ldots + r_{2,k} P_{k,y}$$
$$r_{k,y} = r_{k,1} P_{1,y} + r_{k,2} P_{2,y} + r_{k,3} P_{3,y} + \ldots + r_{k,k} P_{k,y}$$

Where,

$r_{1,y}$ to $r_{k,y}$ = Correlation coefficients between independent characters

$r_{1,2}$ to $r_{k-1,k}$ = Correlation coefficients between all possible combinations of independent characters

$P_{1,y}$ to $P_{k,y}$ = Direct effects of characters 1 to k on character y

The residual effect was computed by using the formula

$$R = 1 - (P_{1,y}\, r_{1,y} + P_{2,y}\, r_{2,y} + P_{3,y}\, r_{3,y} + \ldots\ldots)^{1/2}$$

Where,

R = Residual effect

$P_{1,y}$ = Direct effect of independent character '1' on dependent character 'y'

$r_{1,y}$ = Correlation coefficient of independent character '1' on dependent character 'y'

RESULTS AND DISCUSSION

Rice false smut (rfs) incidence significantly varied among the genotypes except in panicle-wise data. The lowest hill-wise incidence was recorded in genotype NP 9381 (7.12%), which was on a par with the incidence in genotypes, RNR15048 (9.40%), MTU 4870 (11.16%), MTU 1121 (19.62%), MTU 1071 (20.87%), MTU 1061 (20.89%), JGL 19621 (21.55%), MTU1010 (23.12%) and JGL 384 (23.86%), while it was 58.02% in MTU 1075 (check). However, in panicle-wise data, maximum incidence was recorded in MTU 1075 (16.12%) and minimum in RNR 15048 (1.51%); in other genotypes it ranged from 3.44 - 10.55%. In case of grain-wise data, the least disease incidence (0.02%) was observed in NP-9381 and MTU 1061 genotypes which was on a par with incidence in all other genotypes except NLR 3041 (0.075%) and MTU 1075 (0.286%) (Table 1). Although differences in smut incidence and severity on cultivars grown in the same sites or localities have been reported, Ou (1985) opined that these differences appeared to be from different maturity dates instead of true varietal resistance. Kumari and Kumar (2015) also found variation in false smut reaction in rice genotypes with the incidence in the range of 5.00 - 48.76%.

The symptom expression varied among the genotypes screened for false smut reaction. The smut balls of NLR 34449, RNR 15048 and MTU 1010 were dark green in colour (Plate 1) whereas in MTU 1121 and NP 9381 smut balls were initially yellow, later they transformed into dark green (Plate 2). In genotypes NLR 3041, WGL 283, JGL 384, JGL 19621, MTU 1081, JGL 20171 and JGL 11470 black colour powdery mass was present on infected grains (Plate 3). Yellow colour smut balls were observed in genotypes of MTU 1071, MTU 1061, MTU 4870 and MTU 1075 (Plate 4).

Correlation between morphological characters of rice genotypes and false smut incidence

Among the host characters studied, chaffy grains/panicle (0.5165**) and per cent chaffiness (0.3960*) had significant positive association with disease when rfs incidence was assessed hill-wise. Similarly with panicle level incidence also chaffy grains/panicle (0.5918**) and per cent chaffiness (0.5712**) had recorded significant positive

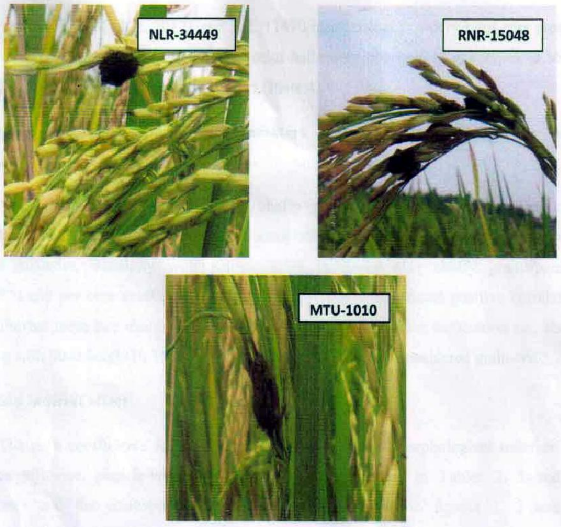

Plate 1. Varieties showing symptoms of dark green colour smut balls.

Plate 2. Varieties showing smut balls that were initially yellow and later turned into dark green.

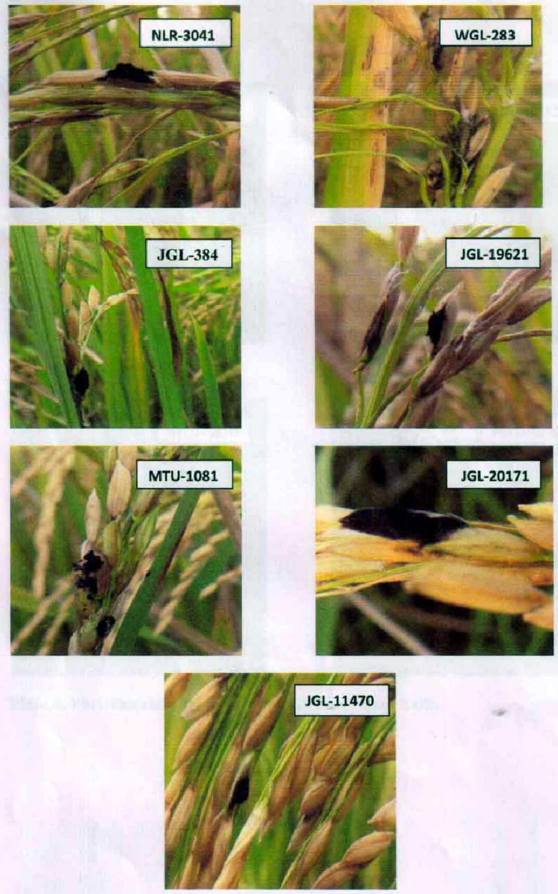

Plate 3. Varieties showing symptoms of black spores on surface of infected grains.

Plate 4. Varieties showing symptoms of yellow smut balls.

Table 1. False smut incidence in rice genotypes (*kharif* 2014-2015).

S. No	Genotypes	Disease incidence Hill wise (%)	Disease incidence Panicle wise (%)	Disease incidence Grain wise (%)
1	MTU 1121	19.62(26.18)	5.59(13.46)	0.052(1.27)
2	NLR 34449	25.43(30.28)	6.86(15.13)	0.032(0.98)
3	RNR 15048	9.40(17.36)	1.51(7.04)	0.028(0.95)
4	NLR 3041	33.86(35.51)	10.55(18.63)	0.075(1.56)
5	NP 9381	7.12(15.41)	4.87(11.19)	0.020(0.70)
6	WGL 283	29.96(33.01)	4.85(12.65)	0.036(1.08)
7	JGL 384	23.86(28.84)	6.02(13.78)	0.039(1.10)
8	JGL 19621	21.55(27.55)	4.02(11.45)	0.046(1.22)
9	MTU 1081	33.68(34.42)	5.38(13.34)	0.034(1.05)
10	JGL 20171	26.06(30.65)	5.01(12.75)	0.048(1.23)
11	JGL 11470	27.32(30.82)	5.14(12.83)	0.038(1.12)
12	MTU 1010	23.12(28.63)	3.71(10.97)	0.032(1.02)
13	MTU 1071	20.8726.48)	4.37(12.02)	0.034(1.04)
14	MTU 1061	20.89(27.17)	4.84(12.68)	0.020(0.78)
15	MTU 4870	11.16(18.78)	3.44(10.22)	0.022(0.82)
16	MTU 1075	58.02(49.64)	16.12(23.55)	0.286(3.02)
	S. Em $\pm$	4.82	2.67	0.23
	CD ($P \leq 0.05$)	14.54	NS	0.70
	CV (%)	23.68	28.49	27.59

Figures in parentheses are arc sine transformed values

correlation values. Further these two characters also had high significant positive association *i.e.*, above 0.5 along with plant height (0.3510*) when disease incidence was considered grain-wise.

Direct and indirect effect

The path coefficients for direct and indirect effects of morphological traits on rfs incidence hill-wise, panicle-wise and grain-wise are presented in Tables 2, 3 and 4, respectively and the corresponding path diagrams are given in figures 1, 2 and 3, respectively.

Hill-wise: When rfs incidence was considered hill-wise, per cent chaffiness, which recorded positive significant association, had negative direct effect (-0.3324). The positive correlation of per cent chaffiness with disease incidence had a negative direct effect due to indirect effect of per cent chaffiness on disease incidence *via* grains/panicle (0.0876), grain length (0.0464) and grain breadth (0.0089). These results indicate that the genotypes which recorded high values for grains/panicle, grain length and grain breadth could be more prone to false smut infection.

While the other character chaffy grains/ panicle which had positive significant correlation also had recorded high positive direct effect indicating that measurement of this character could directly indicate the probable incidence of smut on rice genotypes. Along with positive direct effect it also had high positive indirect effect *via* per cent chaffiness (0.8783) and per cent discolouration (0.4171) indicating that percent chaffiness and per cent discolouration are also indicatives for smut incidence on rice genotypes (Table 2 and Fig. 1).

Panicle-wise: When the smut incidence was recorded at panicle level, both the characters *viz.*, per cent chaffiness and chaffy grains/panicle, which had positive correlations with disease incidence, also had positive direct effects. In case of per cent chaffiness along with its direct positive effect, it had a high level of positive indirect effect *via* chaffy

Table 2. Phenotypic path coefficient matrix showing direct and indirect effects of morphological traits on rice false smut incidence (hill-wise).

Character	Pl. ht	Pr. tl	Bl. l	Bl. b	GL	GB	TW	G/P	Ch %	Ch. g/P	Dis %	Di. h %
Pl. ht	**-0.0154**	0.0006	-0.0080	-0.0041	-0.0028	-0.0049	-0.0047	0.0017	-0.0049	-0.0048	0.0030	0.2171
Pr. tl	0.0031	**-0.0867**	-0.0153	-0.0259	0.0119	-0.0198	-0.0035	0.0138	-0.0063	-0.0097	0.0087	-0.1014
Bl. l	-0.0213	-0.0072	**-0.0410**	-0.0583	-0.0052	-0.0102	-0.0124	0.0196	-0.0118	-0.0121	0.0064	0.0455
Bl. b	-0.0190	-0.0216	-0.0498	**-0.0721**	-0.0104	0.0034	0.0060	0.0128	-0.0210	-0.0292	0.0080	0.1692
GL	0.0673	-0.0519	0.0475	0.0543	**0.3770**	0.0928	0.1912	-0.0718	-0.0526	-0.0512	-0.1593	0.2816
GB	0.0217	0.0158	0.0172	-0.0032	0.0170	**0.0690**	0.0499	-0.0227	-0.0018	-0.0071	-0.0279	-0.0031
TW	0.0126	0.0017	0.0125	-0.0034	0.0209	0.0298	**0.0412**	-0.249	0.0042	-0.0010	-0.0087	0.0780
G/P	-0.0247	-0.0347	-0.1043	-0.0388	-0.0415	-0.0716	-0.1315	**0.2178**	-0.0573	-0.0234	0.0340	0.1318
Ch %	-0.1059	-0.0242	-0.0961	-0.0966	0.0464	0.0089	-0.0338	0.0876	**-0.3324**	-0.3047	-0.1549	0.3960*
Ch. g/P	0.2995	0.1073	0.2835	0.3878	-0.1302	-0.0990	-0.0236	-0.1028	0.8783	**0.9581**	0.4171	0.5165**
Dis %	-0.0008	-0.0004	-0.006	-0.0004	-0.0017	-0.0016	-0.0008	0.0006	0.0019	0.0017	**0.0040**	0.1304
Di. h %	0.2171	-0.1014	0.0455	0.1692	0.2816	-0.0031	0.0780	0.1318	0.3960*	0.5165**	0.1304	

* and ** represent 5 and 1% level of significance, respectively. Bold and diagonal values indicate direct effects. Residual effect = 0.7120

Pl. ht- Plant height; GL- Grain Length; Ch %- Per cent chaffiness
Pr. tl- Productive tillers; GB- Grain Breadth; Ch. g/P- Chaffy grains per panicle
Bl. l- Boot leaf length; TW- Test weight; Dis %- Per cent discolouration
Bl. b- Boot leaf breadth; G/P- Grains per panicle; Di. h %- Per cent rice false smut incidence hill-wise

Table 3. Phenotypic path coefficient matrix showing direct and indirect effects of morphological traits on rice false smut incidence (panicle-wise).

Character	Pl. ht	Pr. tl	Bl. l	Bl. b	GL	GB	TW	G/P	Ch %	Ch. g/P	Dis %	Di. p %
Pl. ht	**0.1229**	-0.0044	0.0639	0.0323	0.0219	0.0387	0.0376	-0.0139	0.0392	0.0384	-0.0238	0.2662
Pr. tl	-0.0061	**0.1721**	0.0304	0.0515	-0.0237	0.0394	0.0070	-0.0274	0.0125	0.0193	-0.0172	0.2370
Bl. l	-0.1926	-0.0654	**-0.3707**	-0.2561	-0.0457	-0.0921	-0.1121	0.1775	-0.1072	-0.1097	0.0578	0.1312
Bl. b	0.0951	0.0951	0.1082	**0.2499**	0.3618	-0.0169	-0.0302	-0.0644	0.1052	0.1464	0.0403	0.3180
GL	-0.0008	0.0006	-0.0006	-0.0006	**-0.0045**	-0.0011	-0.0023	0.0009	0.0006	0.0006	0.0019	0.0387
GB	-0.0073	-0.0053	-0.0057	0.0011	-0.0057	**-0.0231**	-0.0167	0.0076	0.0006	0.0024	0.0093	0.0767
TW	0.0895	0.0119	0.0884	-0.0244	0.1483	0.2114	**0.2923**	-0.1765	0.0297	-0.0072	-0.0614	0.0997
G/P	-0.0228	-0.0321	-0.0963	-0.0358	-0.0383	-0.0661	-0.1215	**0.2011**	-0.0530	-0.0216	0.0314	-0.0269
Ch %	0.1323	0.0302	0.1200	0.1207	-0.0580	-0.0111	0.0422	-0.1093	**0.4151**	0.3805	0.1935	0.5712**
Ch. g/P	0.0493	0.0177	0.0467	0.0638	-0.0214	-0.0163	-0.0039	-0.0169	0.1445	**0.157**	0.0687	0.5918**
Dis %	0.0067	0.0034	0.0054	0.0038	0.0146	0.0139	0.0072	-0.0054	-0.0160	-0.0150	**-0.0344**	0.1853
Di. p %	0.2662	0.2370	0.1312	0.3180	0.0387	0.0767	0.0997	-0.0269	0.5712**	0.5918**	0.1853	

** represents 1% level of significance. Bold and diagonal values indicate direct effects. Residual effect = 0.7171

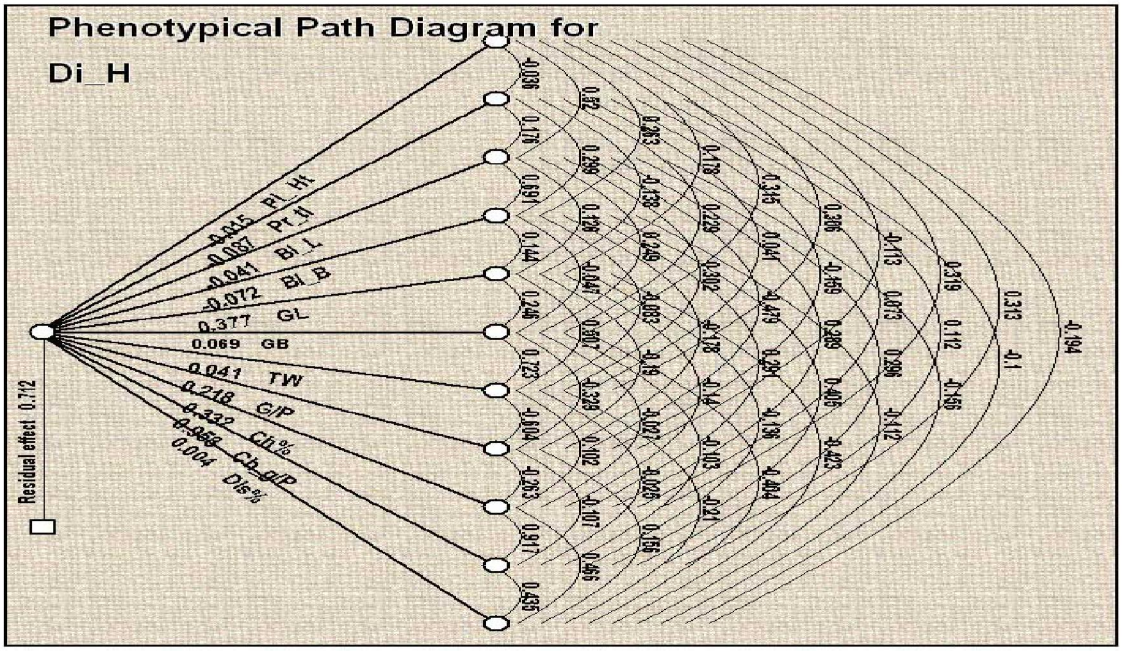

Fig. 1. Phenotypic path diagram showing association between some host morphological traits and hill wise per cent rice false smut incidence.

Pl. ht- Plant height	GL- Grain Length	Ch %- Per cent chaffiness
Pr. tl- Productive tillers	GB- Grain Breadth	Ch. g/P- Chaffy grains/panicle
Bl. l- Boot leaf length	TW- Test weight	Dis %- Per cent discolouration
Bl. b- Boot leaf breadth	G/P- Grains/Panicle	Di. h %- Per cent rice false smut incidence hill-wise

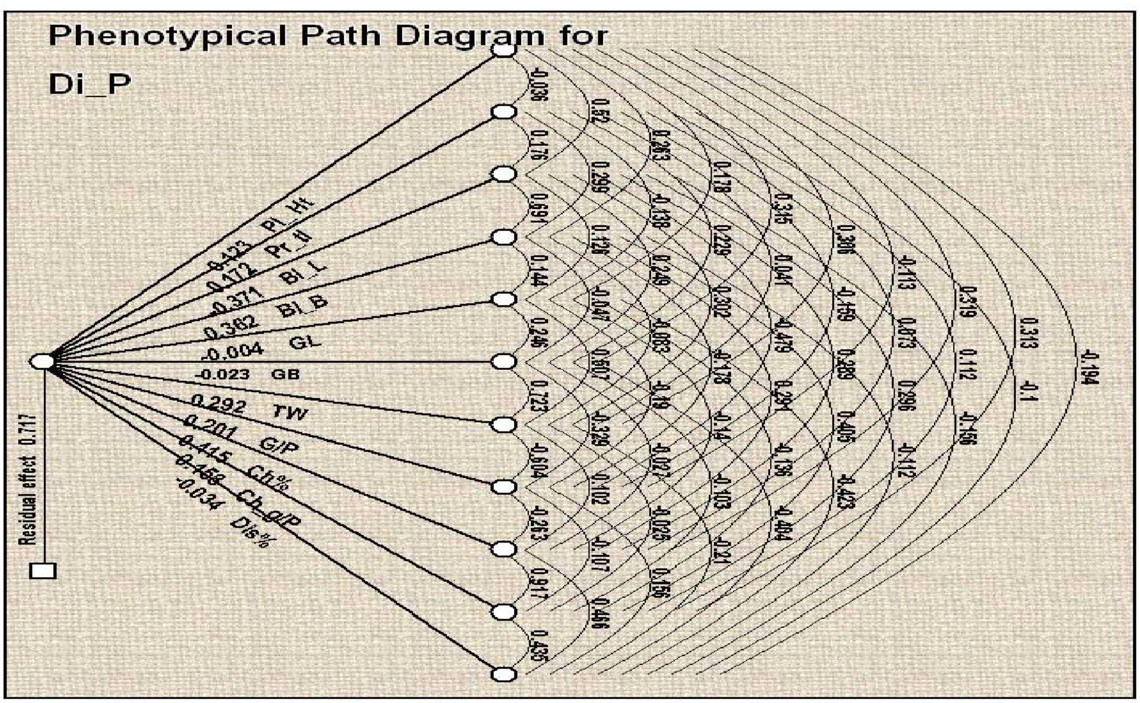

Fig. 2. Phenotypic path diagram showing association between some host morphological traits and panicle-wise per cent rice false smut incidence.

Table 4. Phenotypic path coefficient matrix showing direct and indirect effects of morphological traits on rice false smut incidence (grain-wise).

Character	Pl. ht	Pr. tl	Bl. l	Bl. b	GL	GB	TW	G/P	Ch %	Ch. g/P	Dis %	Di. g %
Pl. ht	**0.0914**	-0.0033	0.0475	0.0240	0.0163	0.0288	0.0280	-0.0104	0.0291	0.0286	-0.0177	0.3510*
Pr. tl	0.0024	**-0.0680**	-0.0120	-0.0203	0.0094	-0.0155	-0.0028	0.0108	-0.0050	-0.0076	0.0068	-0.0601
Bl. l	-0.1035	-0.0352	**-0.1993**	-0.1376	-0.0251	-0.0495	-0.0603	0.0954	-0.0576	-0.0590	0.0311	0.2196
Bl. b	0.1289	0.1466	0.3386	**0.4902**	0.0706	-0.0229	-0.0409	-0.0873	0.1425	0.1984	-0.0547	0.3190
GL	-0.0300	0.0231	-0.0211	-0.0242	**-0.1679**	-0.0413	-0.0852	0.0320	0.0234	0.0228	0.0709	0.1421
GB	-0.1593	-0.1158	-0.1258	0.0237	-0.1247	**-0.5064**	-0.3662	0.1664	0.0135	0.0523	0.2048	-0.0426
TW	0.3122	0.0416	0.3082	-0.0850	0.5169	0.7371	**1.0191**	-0.6156	0.1035	-0.0251	-0.2141	0.2177
G/P	-0.0644	-0.0906	-0.2721	-0.1012	-0.1082	-0.1868	-0.3433	**0.5683**	-0.1497	-0.0610	0.0886	0.0106
Ch %	0.1741	0.0398	0.1580	0.1588	-0.0763	-0.0146	0.0555	-0.1439	**0.5465**	0.5009	0.2547	0.5814**
Ch. g/P	-0.0125	-0.0045	-0.0119	-0.0162	0.0054	0.0041	0.0010	0.0043	-0.0367	**-0.0401**	-0.0175	0.5839**
Dis %	0.0117	0.0061	0.0094	0.0068	0.0256	0.0245	0.0127	-0.0094	-0.0282	-0.0264	**-0.0605**	0.2925
Di. g %	0.3510*	-0.0601	0.2196	0.3190	0.1421	-0.0426	0.2177	0.0106	0.5814**	0.5839**	0.2925	

* and ** represent 5 and 1% level of significance, respectively. Bold and diagonal values indicate direct effects. Residual effect = 0.5908

Pl. ht- Plant height; GL- Grain Length; Ch %- Per cent chaffiness
Pr. tl- Productive tillers; GB- Grain Breadth; Ch. g/P- Chaffy grains per panicle
Bl. l- Boot leaf length; TW- Test weight; Dis %- Per cent discolouration
Bl. b- Boot leaf breadth; G/P- Grains per panicle; Di. g %- Per cent rice false smut incidence grain-wise

grains/panicle indicating the *per se* measurement of per cent chaffiness and chaffy grains/panicle can be directly considered for estimation of smut incidence on panicles of rice genotypes.

While the other character chaffy grains/panicle which had a positive correlation with smut had a high positive indirect effect *via* per cent chaffiness also, again indicating that estimation of these two values can be used in assessing the smut incidence on rice panicles (Table 3 and Fig. 2).

Grain-wise: When smut incidence was assessed at grain level, plant height in addition to chaffiness and chaffy grains/panicle had positive significant correlation and also exhibited direct positive (0.0914) effect along with the highest positive indirect effects *via* boot leaf length (0.0475) indicating that these two traits *i.e.*, plant height along with boot leaf length also could be taken as indicatives for smut incidence on paddy grains. The trait per cent chaffiness had both positive direct effect (0.5465) and significant positive correlation and the highest positive indirect effect *via* chaffy grains/panicle (0.5009) (Table 4 and Fig. 3).

The residual effects at the three levels indicate that estimation of smut incidence on paddy genotypes is more reliable when measured at grain level as it is showing the least residual effect (0.5908) compared to the other two levels *i.e.,* hill level (0.7120) and panicle level (0.7171).

Increase in chaffiness and decrease in test weight and panicle weight were found to commonly result due to false smut (Singh *et al.*, 1992; Hegde and Anahosur, 2000; Sinha *et al.*, 2003, Atia, 2004). However, chaffiness occurs after

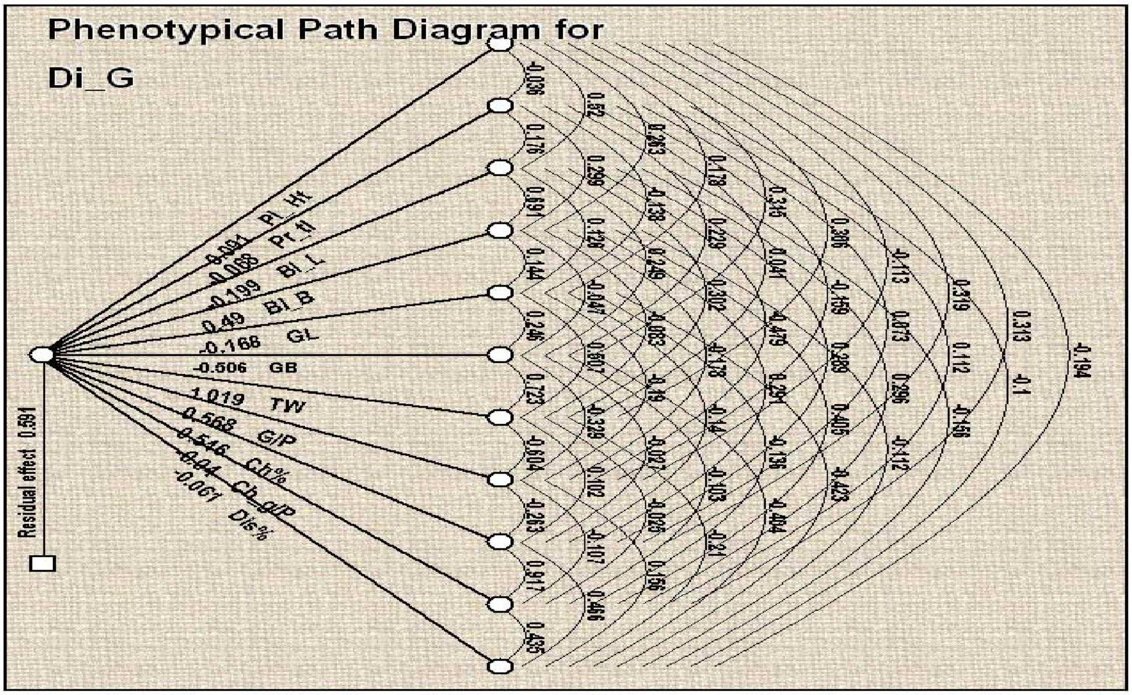

Fig. 3. Phenotypic path diagram showing association between some host morphological traits and grain-wise per cent rice false smut incidence.

Pl. ht- Plant height	GL- Grain Length	Ch %- Per cent chaffiness
Pr. tl- Productive tillers	GB- Grain Breadth	Ch. g/P- Chaffy grains/panicle
Bl. l- Boot leaf length	TW- Test weight	Dis %- Perc ent discolouration
Bl. b- Boot leaf breadth	G/P- Grains/Panicle	Di. g %- Per cent rice false smut incidence grain-wise

grain filling whereas rfs infection takes place at flowering *i.e.,* rfs infection predates chaffiness and hence could be the cause of the latter. *U. virens* infection was found to hinder fertilization of the florets but the number of genes governing grain filling related activities including seed storage proteins, starch metabolism and endosperm transcription factors (RISBZ1 and RPBF) were highly transcribed as if the ovaries were fertilized (Fan *et al*., 2015). This transcription probably enables the pathogen to hijack host nutrient reservoir by activation of grain filling network directing most of the photosynthates in to the infected grains and depriving the normal grains of their share leading them to become chaffy. Hence, chaffines should be a result rather than a contributing factor to false smut infection which therefore cannot be considered as indicative of false smut proneness.

In this study through path coefficient analysis, plant height was found to be positively correlated with rfs incidence at hill, panicle and grain level though significant only at grain level and had a direct influence along with indirect influence *via* boot leaf length. Hence, plant height and boot leaf length could be useful traits that to some extent could be considered as indicatives of false smut proneness in rice genotypes. Significant positive association of false smut incidence with plant height. Higher plant height and a longer boot leaf are more likely to intercept the air borne spores of the fungus thus leading to higher false smut incidence.

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