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Identification of the Morphological Characters Influencing the Infestation Rate of Yellow Stem Borer

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Resistnce of twenty one aus and eleven aman varieties of rice to yellow stem borer (YSB) infestation in relation to their morphological characters were determined. Different morphological characters varied significantly among test varieties. In aus season stem diameter, leaf number, flag leaf length and width, 2nd leaf length and width and life duration of rice plant induced YSB infestation but greater plant height, increased tiller number and leaf macro hairs reduced the infestation rate. The combined influence of these ten independent variables on YSB infestation was 64 percent. In aman season the correlation values indicated that wider stem, increased tiller number, greater flag leaf length and width and wider 2nd leaf induced higher infestation. On the other hand, longer plant, more leaf number, the greater 2nd leaf length, more leaf hairs and increased life duration of plant decreased YSB infestation rate. The combined influence of these seven independent variables on YSB infestation was 85 percent. These findings are indicative of the existence of potential sources of resistance in different rice varieties. Incorporation of such resistance factors in commercial rice varieties will be of immense importance in preventing losses by YSB and in reducing YSB population cumulatively.

Key words**:** Rice variety, YSB infestation rate, Morphological characters, Resistance, Quantitative relationship.

Introduction

Rice stem borers have been recognized as important rice pests. They are endemic to Southern Asia and the monophagous yellow rice stem borer (YSB), *Scirpophaga incertulas* (Walker), is the most important borer species in Bangladesh. It causes 5-10% damage to the rice crop with about 60% damage in case of severe outbreak (Jepson 1954; Catling and Islam 1981). The larval stage of YSB feeds on sheaths and bore into the rice stem causing dead hearts and white heads. At present, the use of insecticides is the only practical way to control stem borers. Insecticides, however, have limitations: they are expensive, require repeated applications and sometimes have undesirable side effects. Considering the intensity of the borer problem, other avenues of control must also be exploited. The use of insect-resistant varieties is one approach.

The growth and development of yellow stem borers have been reported to be affected by different morphological characters of plants. The size of the stalk was positively correlated with the degree of stem borer infestation (Pawar *et al* 1959; Ghosh 1960) wide and longer leaves, large number of tillers per hill and tallness rendered plants more susceptible to stem borers (Okamoto and Abe 1958; IRRI 1964 and 1965; Israel 1967; Khan *et al* 1991). Pathak *et al* (1971) observed that susceptibility to stem borers was positively correlated with plant height, width and length of flag leaf, size of the culm, glabrous leaf blades, and looseness of the leaf sheaths around the plant stem. Even after its hairs were artificially rubbed off, TKM6, a hairy variety not-preferred for oviposition, was still not preferred by the moths. Plant height, stem diameter, tiller density, length and width of flag leaf and glabrous surface of the leaf were positively correlated with number of egg laid (Lukefahr *et al* 1965; Patanakamjorn and Pathak 1967; Islam 1991). Resis-tant varieties exhibited non-preference mechanism of resistance (Riaz *et al* 1993). Borer population was affected by age of the plant, variety and soil fertility level (Pathak 1967c). Early maturity varieties develop few white heads (Lippold and Karim 1970). Viajante and Saxena (1988) observed fewer dead hearts in younger plants than in plant at 34, 40 and 46 days after sowing (DAS); dead heart count declined sharply at 52 DAS.

In Bangladesh, several modern varieties, locally improved varieties and local varieties have been screened against stem borers, but very little emphasis has been laid on the morphological characters of plants that impart host resistance.

Work on determination of correlation matrix, regression equations and path coefficient analysis for rice pests and affecting plant characters is absent in Bangladesh. Such types of large approaches are practiced on a large scale by agronomists and plant breeders (Khaleque *et al* 1978; Amin 1979).

This experiment was, therefore, conducted to find out the interreltionship between yellow rice stem borer infestation and the plant morphological characters affecting the borer infestation.

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Materials and Methods

This study was carried out from February 1992 to December 1994 in aus and aman seasons with twenty one varieties, *viz*. TKM6, TN1, IR8, IR29, BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR12, BR14, BR15, BR16, BR20, BR21, Dular, Gomvir, Hashikalmi and Purbachi in Aus and eleven varieties, *viz*. TKM6, TN1, BR4, BR10, BR11, BR22, BR23, Kalizira, Nizersail, Pajam and Tulsimala in Aman sesons. The plant were grown in the field. The experiments were laid out in RCBD with 3 replications. Date was assigned to the main plot and variety was in the split plot for all plant characters excepting stem diameter and leaf macro hairs. For stem diameter and leaf macro hairs, the experiments were laid out following the principles of factorial experiments in RCBD with three replications by assigning date to the main plot, stem place/leaf side in the split-plot and stem position/leaf place and variety in the split-plot. Seedlings were spaced at 25x15 cm in plots of $10m^2$. The ages of the seedling were 30 and 40 days in Aus and Aman seasons respectively. The individual plot was provided at the rate of 135 kg urea, 90 kg TSP., 70 kg MP, 11 kg zinc sulphate and 60 kg gypsum per hectare. Data were recorded at 40, 70 and 100 days after transplanting (DAT). Tests of correlation coefficient between percentage of YSB larval infestation and each morphological character of rice cultivars such as plant height (cm), number of tillers per hill, number of leaf per tiller, stem diameter (mm) just above soil level and 2 inch above soil level (both flat and edge to edge diameter), length (cm) and width of flag leaf (mm), length (cm) and width (mm) of 2^{nd} leaf and hairiness (number of macro hairs per sq cm) of the second leaf from the top and life duration were done independently. Stem diameter was recorded with the help of slide Calipers and Screw Gauge. Number of hairs was counted from dorsal and ventral sides of the leaves by binocular microscope using net micrometer in the eyepiece. Data were recorded from basal, middle and top portion of the leaves. Percentage of YSB infestation was calculated by using Onate's formula.

The number of leaf hairs and percentage of YSB infestation data were transformed by logarithm and square root transformation to eliminate discrepancy in calculation. Data of YSB infestation under field condition were subjected to analysis of variance. Means were separated by Duncan's Multiple Range Test (DMRT) (Duncan 1951). Simple linear correlation and multiple regression coefficients between the borer infestation and those of the various morphological characters were calculated. Path coefficient analysis for various plant characters, which influence YSB infestation, was done as per Deway and Lu (1959).

Results and Discussion

Average plant morphological character values and percentage of yellow stem borer (YSB) infestation in different years in aus and aman seasons varied significantly among varieties and are presented in Table 1 and 2. Correlation and regression coefficient analyses were carried out on the basis of these average plant character values and percentage of YSB infestation. In aus season the highest plant height, stem diameter, number of tiller, number of leaf, length of flag leaf, width of flag leaf, length of 2^{nd} leaf, width of 2^{nd} leaf, number of leaf hair, life duration and percentage of YSB infestation were observed in the rice varieties TKM6, BR8, BR3, TKM6, BR9, Gomvir, Dular, BR1, IR8 and TN1, respectively (Table 1). On the other hand lowest plant height, stem diameter, number of tiller, number of leaf, length of flag leaf, width of flag leaf, length of 2^{nd} leaf, width of 2^{nd} leaf, number of leaf hair, life duration and percentage of YSB infestation were observed in the rice varieties BR8, TKM6, BR6, Gomvir, BR1, TKM6, BR1, TKM6, Hashikalmi, Hashikalmi and BR8 respectively.

In aman season the highest plant height, stem diameter, number of tiller, number of leaf, length of flag leaf, width of flag leaf, length of 2^{nd} leaf, width of 2^{nd} leaf, number of leaf hair, life duration and percentage of YSB infestation were observed in the rice varieties TKM6, Pajam, TN1, BR23, BR22, BR4, Kalizira, BR11, BR22, BR10 and TN1, respectively (Table 2). On the other hand lowest plant height, stem diameter, number of tiller, number of leaf, length of flag leaf, width of flag leaf, length of 2^{nd} leaf, width of 2^{nd} leaf, number of leaf hair, life duration and percentage of YSB infestation were recorded in the rice varieties BR11, TKM6, BR11, TKM6, BR11, TKM6, BR11, TKM6, Tulsimala, TKM6 and Nizersail, respectively.

Quantitative relationship

Aus season. Information on correlation coefficient is particularly useful for direct selection. Yellow stem borer infestation rate was found positively correlated with the stem diameter (0.403), number of leaf (0.282), length of flag leaf (0.137), width of flag leaf (0.342), length of 2^{nd} leaf (0.219), width of 2^{nd} leaf (0.323) and life duration (0.404) but negatively correlated with plant height (-0.025), tiller number (-0.228) and number of leaf hair (-0.153) (Table 3). These results indicate that stem diameter, number of leaf, length of flag leaf, width of flag leaf, length of 2^{nd} leaf, width of 2^{nd} leaf and life duration induce higher stem borer infestation, where as plant height, tiller number and leaf hair reduce the infestation rate. Yellow stem borer infestation had an insignificant correlation with all other plant characters.

Table 1

Average plant character values and yellow stem borer (YSB) infestation of selected rice varieties of different ages and seasons resistant and susceptible to yellow stem borer (BAU Farm, Aus)

Variety (No.21)	Plant height (cm)	Stem diameter (mm)	Tiller number	No.of leaf	Length of flag leaf (cm)	Width of flag leaf (mm)	Length of 2nd leaf (cm)	Width of 2nd leaf (mm)	No.of leaf hair (sq.cm)	Life duration (days)	% YSB infestation
TKM6	88.21 a	4.51 b	9.83 a	4.16 bc	38.48 a	9.76 b	34.64 a	7.73 c	121.90 a	108.5 hi	6.16 ab
TN1	69.45 d-g	6.40 a	7.44 bcd	4.33 abc	28.05 ab	9.34 b	33.21 ab	8.97 abc	19.31 e	123.5 de	10.0 a
IR8	67.77 efg	6.59 a	7.56 bcd	4.59 ab	24.36 b	11.52 ab	33.94 a	9.16 ab	48.52 c	132.3 a	7.07 ab
IR29	66.94 fg	5.43 ab	8.02 bcd	4.48 ab	25.16 b	11.14 ab	30.07 ab	9.22 a	33.87 d	108.2 i	6.32 ab
BR1	61.53 g	5.35 ab	8.71 abc	4.42 abc	23.61 b	9.62 b	28.45 b	8.26 abc	128.10 a	113.3 g	5.66 b
BR2	72.44 b-g	6.12 ab	8.75 abc	4.57 ab	30.14 ab	9.64 b	33.09 ab	8.42 abc	7.12 gh	118.8 f	6.88 ab
BR3	62.63 g	6.23 a	8.58 a-d	4.79 a	24.27 b	10.76 ab	30.62 ab	8.46 abc	76.68 b	129.2 ab	9.03 ab
BR6	71.80 b-g	6.29 a	7.01 cd	4.47 ab	24.09 b	9.63 b	31.59 ab	8.39 abc	19.40 e	108.3 i	6.58 ab
BR7	73.94 a-g	6.04 ab	7.92 bcd	4.45 abc	32.88 ab	10.24 ab	32.60 ab	8.31 abc	9.53 fg	121.7 ef	6.90 ab
BR8	61.10 g	6.83 a	7.60 bcd	4.69 a	24.05 b	10.99 ab	31.97 ab	7.77 bc	31.78 d	122.0 ef	5.15 b
BR9	84.33 a-d	6.35 a	7.19 cd	4.36 abc	33.31 ab	12.53 a	34.09 a	8.88 abc	35.48 d	118.3 f	7.88 ab
BR12	67.31 fg	5.66 ab	8.51 a-d	4.29 abc	23.65 b	10.18 ab	30.62 ab	8.30 abc	97.89 ab	127.5 bc	6.08 ab
BR14	74.74 a-g	6.81 a	7.63 bcd	4.48 ab	30.18 ab	11.71 ab	33.08 ab	9.39 a	8.39 gh	123.0 de	8.31 ab
BR15	70.25 c-g	5.93 ab	8.13 a-d	4.35 abc	29.50 ab	10.64 ab	31.96 ab	8.46 abc	22.90 e	124.7 cde	6.32 ab
BR16	69.85 c-g	5.30 ab	7.80 bcd	4.45 abc	25.99 b	10.16 ab	31.25 ab	8.33 abc	98.13 ab	126.8 bcd	6.72 ab
BR20	81.32 af	6.25 a	9.15 ab	4.34 abc	31.04 ab	11.47 ab	33.03 ab	8.65 abc	6.38 h	112.7 g	5.46 b
BR21	85.30 abc	5.98 ab	6.76 d	4.38 abc	32.30 ab	10.71 ab	32.97 ab	8.70 abc	32.22 d	103.8 j	6.41 ab
Dular	83.15 a-e	5.50 ab	7.35 bcd	4.18 bc	27.98 ab	9.72 b	34.85 a	8.81 abc	22.61 e	102.5 jk	6.16 ab
Gomvir	86.62 ab	5.56 ab	7.25 cd	4.15 bc	29.69 ab	10.40 ab	34.95 a	8.91 abc	13.89 f	110.5 ghi	6.39 ab
Hashikalmi	85.16 a-d	5.26 ab	7.33 bcd	3.96 c	28.51 ab	9.41 b	33.25 ab	8.51 abc	1.03 i	99.2 k	5.38 b
Purbachi	64.89 g	5.52 ab	7.20 cd	4.35 abc	27.54 ab	11.61 ab	31.15 ab	9.21 a	19.68 e	112.3 gh	6.03 b
Probability	0.01	0.01	0.01	0.05	0.01	0.05	0.01	0.05	0.01	0.01	0.05
S.E.	3.651	0.3836	0.4163	0.1461	2.576	0.6998	1.071	0.4099	0.03416	0.9942	1.147
DAT											
40	59.15 b	6.02 b	6.67 b	4.20 b	*31.96 a	*11.18 a	34.6 b	7.58 b	50.70 a	**114.83	5.62 b
70	78.82 a	6.91 a	8.68 a	3.94 c	**31.28 a	**10.26 b	36.97 a	8.14 b	30.71 b	***118.24	4.69 b
100	83.28 a	4.77 c	8.32 a	5.04 a	***21.72 b	***10.16 b	25.78 c	10.11 a	-	-	9.82 a
Probability	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01	NS	0.01
S.E.	1.38	0.145	0.1574	0.05521	0.9737	0.2645	0.4046	0.1549	0.032	0.6513	0.4334

*Aus season, 92; **Aus season, 1993; ***Aus season, 1994

Table 2

Average plant character values and yellow stem borer (YSB) infestation of selected rice varieties of different ages and seasons resistant and susceptible to yellow stem borer (BAU Farm, Aman)

Variety (No.21)	Plant height (cm)	Stem diameter (mm)	Tiller number	No.of leaf	Length of flag leaf (cm)	Width of flag leaf (mm)	Length of 2nd leaf (cm)	Width of 2nd leaf (mm)	No.of leaf hair (sq.cm)	Life duration (days)	% YSB infestation
TKM6	94.78 a	4.97 c	12.95 a	3.87 ab	29.82	7.48 c	39.79 bc	7.34 c	117.30 b	128.5 c	5.20 b
TN1	76.04 bc	5.99 abc	13.08 a	4.01 ab	28.82	11.70 ab	35.91 cd	9.98 ab	7.70 f	143.5 b	10.09 a
BR4	82.68 ab	6.49 ab	10.71 ab	4.13 ab	26.81	13.16 a	43.63ab	9.79 ab	77.09 c	144.0 b	5.19 b
BR10	83.13 ab	5.51 bc	12.41 ab	3.86 ab	23.29	11.45 ab	36.33 cd	10.26 a	111.50 b	154.2 a	3.79 b
BR11	65.41 c	5.55 bc	9.48 b	3.82 b	20.94	12.57 ab	32.36 d	10.55 a	19.89 d	141.5 b	4.69 b
BR22	78.66 abc	6.16 ab	10.50 ab	3.96 ab	32.03	12.57 ab	36.36 cd	9.65 abc	161.50 a	142.7 b	5.33 b
BR23	81.89 ab	6.52 ab	11.31 ab	4.11 ab	22.90	11.58 ab	39.93 bc	8.82 abc	14.08 e	142.3 b	4.40 b
Kalizira	93.63 a	5.94 abc	11.55 ab	4.30 a	23.92	9.59 abc	47.75 a	8.63 abc	130.32 ab	145.7 b	3.80 b
Nizersail	91.23 ab	5.63 bc	11.73 ab	4.01 ab	30.22	10.67 abc	43.03 ab	8.83 abc	115.12 b	143.7 b	3.65 b
Pajam	82.05 ab	6.75 a	10.78 ab	4.07 ab	28.46	11.68 ab	40.03 bc	9.39 abc	117.80 b	143.5 b	4.48 b
Tulsimala	91.65 ab	5.67 abc	11.17 ab	4.14 ab	28.26	9.15 bc	41.71 bc	7.84 bc	0.00 g	145.7 b	3.77 b
Probability	0.01	0.05	0.05	0.05	NS	0.05	0.01	0.01	0.01	0.01	0.01
S.E.	3.886	0.3314	0.9629	0.1366	3.441	1.135	1.370	0.5329	0.02528	1.294	0.8147
DAT											
40	70.02 b	7.15 a	10.14 b	3.85 b	*30.76 a	*14.94 a	40.93 a	8.77 b	99.00 a	**144.09	3.58 b
70	89.64 a	5.61 b	11.95 ab	3.96 b	**24.98 b	**9.04 b	38.16 b	9.65 a	59.60 b	***142.30	3.28 b
100	91.56 a	5.01 b	12.18 a	4.27 a	***24.85 b	***9.18 b	40.03 ab	9.14 ab	-	-	7.97 a
Probability	0.01	0.01	0.01	0.01	0.05	0.01	0.05	0.05	0.01	NS	0.01
S.E.	2.029	0.1731	0.5028	0.07135	1.797	0.5928	0.7155	0.2783	0.011	0.63456	0.4254

*Aman season, 92; **Aman season, 1993; ***Aman season, 1994

Table 3
Correlation matrix between rice plant characters and YSB infestation rate (BAU Farm, Aus). Average of 40, 70 and 100 DAT

Characters	Stem diameter	Tiller number	Number of leaf	Length of flag leaf	Width of flag leaf	Length of 2nd leaf	Width of 2nd leaf	Number of leaf hair	Life duration	YSB infestation
Plant height	-0.312	-0.082	-0.607**	0.765**	-0.266	0.777**	0.153	-0.251	-0.592**	-0.025
Stem diameter		-0.339	0.576**	-0.245	0.644**	0.066	0.154	-0.485*	0.497*	0.403
Tiller number			-0.095	0.211	-0.330	-0.181	-0.483*	0.520*	0.184	-0.228
Number of leaf				-0.473*	0.260	-0.346	-0.170	-0.124	0.454*	0.282
Length of flag leaf					-0.177	0.639**	-0.087	-0.151	-0.302	0.137
Width of flag leaf						-0.030	0.434*	-0.370	0.429*	0.342
Length of 2nd leaf							0.278	-0.424	-0.214	0.219
Width of 2nd leaf								-0.445*	-0.177	0.323
Number of leaf hair									0.231	-0.153
Life duration										0.404

*P<0.05; **P<0.01

The estimated correlation coefficients among rice stem borer infestation and tested plant characters were partitioned into direct and indirect effects and have been presented by path coefficient analysis in Table 4. The direct effect of plant height on YSB infestation was positive (0.138) but its indirect effects via stem diameter, number of leaf, length of 2nd leaf, number of leaf hair and life duration were negative which makes the correlation coefficient between plant height and YSB infestation to be negative. The indirect effects of plant height via tiller number, length and width of flag leaf, width of 2nd leaf was positive. Stem diameter had a positive direct effect (0.187) and its indirect effects via tiller number, number of leaf, width of 2nd leaf and life duration were positive and via plant height, length and width of flag leaf, length of 2nd leaf, number of leaf hair were negative and negligible. The direct effects of tiller number on YSB infestation were negative and of higher in magnitude (-0.332). Its indirect effects via length and width of flag leaf, length of 2nd leaf, number of leaf hair and life duration were positive but via plant height, stem diameter, number of leaf and width of 2nd leaf were negative and negligible except the values of width of 2nd leaf. Number of leaf had a positive direct effect (0.438) but its indirect effects via plant height, length of flag leaf, width of flag leaf, width of 2nd leaf, number of leaf hair were negative and comparatively higher than its positive indirect effects via stem diameter, tiller number, length of 2nd leaf and life duration. Although length of flag leaf exerted maximum positive direct influence (0.734) on YSB infestation its indirect effects via stem diameter, tiller number, number of leaf, length and width of 2nd leaf, number of leaf hair and life duration were negative which minimized the correlation coefficient between length of flag leaf and YSB infestation to be insignificant. Its indirect effects via plant height and width of flag leaf were positive and negligible. On the other hand width of flag leaf had a negative direct effect (-0.308), whereas its indirect effects via stem diameter, tiller number, number of leaf, length and width of 2nd leaf, life duration were positive which makes the correlation coefficient between width of flag leaf and YSB infestation to be positive. Its indirect effects via plant height, length of flag leaf and number of leaf hair were negative and negligible. The direct effects of length of 2nd leaf was negative (-0.236). Its indirect effects via plant height, stem diameter, tiller number, length and width of flag leaf and width of 2nd leaf were positive but via number of leaf, number of leaf hair and life duration were negative. Its highest positive indirect effects via length of flag leaf made the correlation coefficients between length of 2nd leaf and YSB infestation to be positive. Width of 2nd leaf had positive direct

Table 4
Path coefficient analysis of plant characters influencing YSB infestation (BAU Farm, Aus). Average of 40, 70 and 100 DAT

Characters	Indirect effects through										
	Plant height	Stem diameter	Tiller number	Number of leaf	Length of flag leaf	Width of flag leaf	Length of 2nd leaf	Width of 2nd leaf	Number of leaf hair	Life duration	Total Correlation with borer infestation
Plant height	**0.138**	-0.058	0.027	-0.265	0.561	0.082	-0.183	0.013	-0.063	-0.368	-0.025
Stem diameter	-0.043	**0.187**	0.112	0.251	-0.180	-0.198	-0.016	0.103	-0.122	-0.308	0.403
Tiller number	-0.011	-0.063	**-0.332**	-0.041	0.155	0.102	0.043	-0.325	0.130	0.115	-0.228
Number of leaf	-0.084	0.107	0.031	**0.436**	-0.347	-0.080	0.082	-0.114	-0.031	0.282	0.282
Length of flag leaf	0.106	-0.046	-0.070	-0.206	**0.734**	0.054	-0.151	-0.059	-0.038	-0.188	0.137
Width of flag leaf	-0.037	0.120	0.109	0.113	-0.130	**-0.308**	0.007	0.292	-0.093	0.267	0.342
Length of 2nd leaf	0.108	0.012	0.060	-0.151	0.469	0.009	**-0.236**	0.187	-0.106	-0.133	0.219
Width of 2nd leaf	0.021	0.029	0.160	-0.074	-0.064	-0.134	-0.066	**0.672**	-0.111	-0.110	0.323
Number leaf hair	-0.035	-0.091	-0.172	-0.054	-0.111	0.114	0.100	-0.299	**0.251**	0.144	-0.153
Life duration	-0.082	0.093	-0.061	0.198	-0.222	-0.132	0.051	-0.119	0.058	**0.621**	0.404

Residual effect is the square root of: 0.3566452; N.B: Bold figures are the direct effects.

effects (0.672) but its total indirect effects via number of leaf, length and width of flag leaf, length of 2nd leaf, number of leaf hair and life duration were negative and higher than its total indirect effects via plant height, stem diameter and tiller number which minimized the correlation coefficients between width of 2nd leaf and YSB infestation to be insignificant. Although the direct effects of number of leaf hair was positive, its indirect effects via plant height, stem diameter, tiller number, number of leaf, length of flag leaf and width of 2nd leaf were negative and made the correlation coefficients between number of leaf hair and YSB infestation negative. Its indirect effects via width of flag leaf, length of 2nd leaf and life duration were positive and negligible. Although life duration had higher positive effects its total negative indirect effects via plant height, tiller number, length and width of flag leaf and width of 2nd leaf were higher than its total positive indirect effects via stem diamter, number of leaf, length of 2nd leaf and number of leaf hair which minimized correlation coefficients between life duration and YSB infestation to be insignificant.

The regression coefficients between average percentage of YSB infestation and plant height (0.0169), stem diameter (0.3480), number of tiller (-0.4612), number of leaf (2.7674), width of flag leaf (-0.3313), length of 2nd leaf (-0.1507), number of leaf hair (0.0070) and life duration (0.0707) were found insignificant excepting length of flag leaf (0.2012) and width of 2nd leaf (1.3157) which were found to be significant at 5% level of probability (Appendix). The above mentioned ten independent variables in the model together explained 64% variation in the dependent variable but none of the partial b (regression coefficient) were statistically significant except X_5, (length of flag leaf) and X_8 (width of 2nd leaf) which have significant ($P<0.05$) and positive influence on the dependent variable. There were more variables not included in the model, which explained about 36% of the variability of the dependent variable. The proposed model is:

$$Y = -22.59 + 0.0169X_1 + 0.3480X_2 - 0.4612X_3 + 2.7674X_4 + 0.2012X_5$$
$$(0.0672)\ (0.7033)\ (0.3645)\ (1.8807)\ (0.0999)$$

$$- 0.313X_6 - 0.1507X_7 + 1.3157X_8 + 0.0070X_9 + 0.0707X$$
$$(0.0354)\ (0.2749)\ (0.5590)\ (0.0090)\ (0.0432)$$

Figures in parentheses below the regression coefficients show the standard errors of the estimated value.

Aman season. The yellow stem borer infestation rate was positively correlated with stem diameter (0.087), tiller number (0.398), length of flag leaf (0.267), width of flag leaf

Table 5
Correlation matrix between rice plant characters and YSB infestation rate (BAU Farm, Aman). Average of 40, 70 and 100 DAT

Characters	Stem diameter	Tiller number	Number of leaf	Length of flag leaf	Width of flag leaf	Length of 2nd leaf	Width of 2nd leaf	Number of leaf hair	Life duration	YSB infestation
Plant height	-0.268	-0.499	-0.286	0.364	-0.784	0.791**	-0.838**	-0.359	-0.171	-0.391
Stem diameter		-0.400	0.598*	-0.017	0.632*	0.189	0.322	-0.035	0.300	0.087
Tiller number			-0.427	0.278	-0.548	-0.136	-0.357	0.051	-0.126	0.398
Number of leaf				-0.774**	0.441	0.205	0.363	-0.280	0.403	-0.223
Length of flag leaf					-0.209	0.135	-0.366	0.392	-0.343	0.267
Width of flag leaf						-0.389	0.881**	-0.088	0.459	0.210
Length of 2nd leaf							-0.563	0.274	0.017	-0.385
Width of 2nd leaf								-0.067	0.546	0.282
Number of leaf hair									-0.043	-0.325
Life duration										-0.190

*P<0.05; **P<0.01

(0.210) and width of 2nd leaf (0.282) but negatively correlated with plant height (-0.391), number of leaf (-0.223) length of 2nd leaf (-0.385), number of leaf hair (-0.325) and plant life duration (-0.190) (Table 5). In this season also yellow stem borer infestation had an insignificant correlation with all plant characters. These correlation coefficient values revealed that stem diameter, tiller number, length and width of flag leaf and width of 2nd leaf induced higher stem borer infestation. On the other hand plant height, number of leaf, length of 2nd leaf, number of leaf hair and life duration decreased the infestation rate. In some cases, the differences in correlation values in aus and aman season may be due to environmental changes.

The estimated correlation coefficients among yellow stem borer infestation and tested plant characters were partitioned into direct and indirect effects and have been presented by path coefficient analysis in Table 6. Path analysis revealed that plant height, stem diameter, tiller number, width of flag leaf, width of 2nd leaf had positive direct effects and number of leaf, length of flag leaf, length of 2nd leaf, number of leaf hair and life duration had negative direct effects on YSB infestation. Although plant height exerted maximum positive direct effects its indirect effects via stem diameter, length and width of flag leaf, length and width of 2nd leaf and number of leaf hair were negative and higher than the total positive indirect effects of tiller number, number of leaf and life duration, which made the correlation coefficients between plant height and YSB infestation negative and insignificant. The indirect effects of stem diameter via plant height, tiller number, number of leaf, length of 2nd leaf and life duration were negative and considerable which minimized the correlation coefficient between stem diameter and YSB infestation to be insignificant, though its indirect effects via length and width of flag leaf, width of 2nd leaf and number of leaf hair were positive. The direct effects of tiller number on YSB infestation were negligible. Its indirect effects via plant height, number of leaf and life duration were positive and stem diameter, length and width of flag leaf, length and width of 2nd leaf and number of leaf hair were negative. Although leaf number had the highest negative direct effect its total positive indirect effects via stem diameter, length and width of flag leaf, width of 2nd leaf and number of leaf hair minimized the correlation coefficient between leaf number and YSB infestation, though its indirect effects via plant height, tiller number, length of 2nd leaf had negative direct effects. Correlation coefficient between length of flag leaf and YSB infestation was insignificant because the

Table 6
Path coefficient analysis of plant characters influencing YSB infestation (BAU Farm, Aman). Average of 40, 70 and 100 DAT

Characters	Indirect effects through										
	Plant height	Stem diameter	Tiller number	Number of leaf	Length of flag leaf	Width of flag leaf	Length of 2nd leaf	Width of 2nd leaf	Number of leaf hair	Life duration	Total Correlation with borer infestation
Plant height	**3.972**	-0.455	0.058	0.857	-0.780	-0.962	-0.181	-2.632	-0.488	0.322	-0.391
Stem diameter	-1.037	**1.701**	-0.046	-1.794	0.037	0.776	-0.043	0.012	0.047	-0.566	0.087
Tiller number	1.930	-0.680	**0.116**	1.282	-0.595	-0.673	-0.031	-1.119	-0.070	0.237	0.398
Number of leaf	-1.106	1.017	-0.050	**-3.000**	1.658	0.542	-0.047	1.140	0.382	-0.758	-0.223
Length of flag leaf	1.410	-0.030	0.032	2.322	**-2.143**	-0.257	-0.031	-1.150	-0.533	0.646	0.267
Width of flag leaf	-3.036	1.075	-0.064	-1.324	0.448	**1.227**	0.089	2.538	0.120	-0.865	0.210
Length of 2nd leaf	3.062	0.321	0.016	-0.616	-0.288	-0.478	**-0.229**	-1.768	-0.373	-0.033	-0.385
Width of 2nd leaf	-3.246	0.548	-0.041	-1.090	0.785	0.993	0.129	**3.139**	0.092	-1.027	0.282
Number leaf hair	1.389	-0.059	0.006	0.841	-0.839	-0.108	-0.063	-0.212	**-1.362**	0.082	-0.325
Life duration	-0.662	0.511	-0.015	-1.208	0.735	0.564	-0.004	1.713	0.059	**-1.883**	-0.190

Residual effect is the square root of: 0.18772; N.B: Bold figures are the direct effects.

total positive indirect effects via plant height, tiller number, number of leaf and life duration were higher than the total negative effects via stem diameter, width of flag leaf, length and width of 2nd leaf and number of leaf hair. The indirect effects of width of flag leaf via plant height, number of leaf, life duration were negative and higher, which minimized the correlation coefficient between width of flag leaf and YSB infestation, though their indirect effects via stem diameter and width of 2nd leaf were positive and higher. The indirect effects via tiller number, length of flag leaf, length of 2nd leaf and number of leaf hair were negligible. The higher indirect effects of length of 2nd leaf via plant height were positive and via number of leaf and width of 2nd leaf were negative. On the other hand its indirect effects via stem diameter, tiller number was positive and via length and width of flag leaf, number of leaf hair and life duration were negative and negligible. Although width of 2nd leaf and higher positive direct effects its total negative indirect effects via plant height, tiller number, number of leaf, life duration were higher than the total indirect effects via stem diameter, length and width of flag leaf, length of 2nd leaf and number of leaf hair. This indirect effect minimized the correlation coefficient between width of 2nd leaf and YSB infestation to be insignificant. The direct effects of number of leaf hair were higher and negative but correlation coefficient between number of leaf hair and YSB infestation was insignificant because the total positive indirect effects via plant height, tiller number, number of leaf and life duration were higher than the total negative indirect effects via stem diameter, length and width of flag leaf and length and width of 2nd leaf. Although life duration had higher negative direct effect its total indirect effects via stem diameter, length and width of flag leaf, width of 2nd leaf and number of leaf hair were positive and considerably higher than the total negative indirect effects via plant height, tiller number, number of leaf and length of 2nd leaf, which minimized the correlation coefficient between life duration and YSB infestation to be insignificant.

In this aman season data case numbers (number of variety mean) were lesser in comparison with number of variables. For this reason only some important variables were taken for multiple regression analysis. The regression coefficients between average percentage of YSB infestation and plant height (-0.1638), stem diameter (0.8661), length of flag leaf (0.1932), width of flag leaf (-0.0003), number of leaf hair (-0.0069) and life duration (-0.0542) were found to be insignificant excepting number of tiller (1.3258) which was found

significant at 5% level of probability (Appendix IV). Seven above mentioned independent variables in the model together explained 85% variation in the dependent variable but none of the partial b (regression coefficient) were statistically significant except X_3 (number of tiller) which has significant ($P<0.05$) and positive influence on the dependent variable. There were more variables not included in the model, which explained about 15% of the variability of the dependent variable. The proposed model is:

$$Y=1.4826-0.1638X_1+0.8661X_2+1.3258X_3+0.1932X_4-0.0003X_5$$
$$(0.1142)\quad(1.2298)\quad(0.4797)\quad(0.1469)\quad(0.7295)$$
$$-0.0069X_6-0.0542X_7$$
$$(0.0087)\quad(0.0962)$$

Figures in parentheses below the regression coefficients show the standard errors of the estimated value.

In most of the cases the results of the present investigation supported the findings of previous workers. Their findings were as follows: Plants with wider and longer leaves, with wider and longer flag leaves, a large number of tillers per hill, higher diameter of the stalk/stem and pith and tall stature appreared more susceptible to stem borers (Pawar *et al* 1959; Ghosh 1960; IRRI 1964 and 1965; Israel 1967; Pathak *et al* 1971; Chaudhary *et al* 1984; Khan *et al* 1991). Resistant varieties possessed long, dense hairs and more spicules than susceptible varieties (Lukefahr *et al* 1965; Israel 1967). Resistant varieties had slender and tight leaf sheaths and susceptible varieties possessed loose leaf sheaths (Patanakamjorn and Pathak 1967; Padhi and Prakasa 1978). Borer populations were affected by age of the plant and variety and resistant varieties exhibited non-preference mechanism of resistance (Pathak 1967c; Lippold and Karim 1970; Viajante and Saxena 1988).

The results of the present findings are an indicative of the existence of potential sources of resistance in different rice varieties. Incorporation of such resistance factors in commercial rice varieties will be of immense importance in preventing losses by YSB and in reducing YSB population cumulatively.

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