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Genetic Diversity of Farmers' Varieties of Rice (*Oryza sativa* L.) with Special Orientation to Lodging Characteristics

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Abstract

Lodging status of rice is an important consideration for determination of grain yield and acceptability of the genotype among the rice farming community. In this communication, 59 local genotypes of rice were screened for lodging tolerance under three different cultivation environments. Boichi and Seshaphal were found to be highly lodging tolerant under all the three situations. Majority of the local genotypes were reported to be susceptible to lodging. The numbers of highly susceptible local genotypes towards lodging were 55, 29 and 15 at irrigated, drought created by spraying potassium iodide (KI) under irrigated condition and normal terminal drought environments, respectively. Lodging was more frequent in irrigated condition than the normal terminal drought condition or drought situation created by spraying of KI along with normal irrigation. The mean reduction in yield was more in the drought situation created by spraying of KI along with normal irrigation (20.62%) than the normal terminal drought (18.66%). The average lodging susceptibility also reduced in normal terminal drought condition (3.58) as compared to the drought situation created by spraying of KI along with normal irrigation (6.32). It has been reported that in most of the cases lodging caused remarkable yield loss.

Keywords: Rice (*Oryza sativa* L.); Local genotypes; Potassium Iodide; Lodging score

Introduction

Rice is a primary food source for more than two third of the world's population that account for ~21% of global calorie intake [1]. Nearly 75% of the global rice production comes from irrigated ecosystem that covers around 55% of the total cropped rice area. Rain-fed upland and rain-fed lowland contributed only 21% of the total production from 34% of the cropped area.

Lodging is the state of permanent displacement of the stems from their upright position. It is induced by external forces like wind, rain or hail. Lodging is often not distributed uniformly throughout an affected field but maybe scattered over certain sections or spots. Lodging is a serious obstacle in crop production. Lodging disturbs the ripening process, decreases crop yield, and causes poor grain quality [2]. Lodging is one of the factors causing grain yield reduction by up to 50% in rice, especially for rice in high-yielding environments [3]. Occurrence of lodging is common in tall traditional genotypes of rice. The causes of lodging are many under normal weather parameters, over-luxuriant growth due to excessive nitrogen application, high planting density and well irrigated fields [4]. In a lodged plant community, the normal canopy structure is destroyed, leading to reduced photosynthetic ability and dry matter accumulation [5]. Severe lodging prevents the transport of water, nutrients, and assimilates through the xylem and phloem, resulting in a reduction in assimilates for grain filling [6]. *In situ* germination may occur in lodged plants as a result, lodging could cause great losses in both grain yield and quality.

Mechanical strength is largely dependent on the chemical and biochemical components of the cell wall [7-9]. Generally, lignin and cellulose, which are the main biochemical components of plant tissues, particularly in the vascular bundles, are closely associated with culm mechanical strength [10]. Cellulose usually constitutes 20-30% or 40-90% of the dry weight of primary or secondary walls, respectively, varying with the cell type [11]. Moreover, lignin can be incorporated into the cell wall to enhance its mechanical strength.

Considering the importance of lodging in relation to grain yield in rice lodging score was recorded to standardize the status of 59 local genotypes of rice in respect to lodging tolerance or susceptibility.

Materials and Methods

Experimental materials

The experimental materials consisted of 59 local genotypes of rice collected mainly from northern parts of West Bengal and Assam in India was used in this study. Thirty nine rice genotypes were non-aromatic and 30 genotypes were aromatic.

Experimental site and design

The field experiment was carried out at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India during *Kharif* season of 2014 and 2015. The experimental field is situated at 26°19′86″ N latitude and 89°23′53″ E longitude, at an elevation of 43 meter above mean sea level. Single seedling per hill of 30 days old were transplanted in four lines of 5 m long in each set and in each genotype in Randomized Block Design with two replications. The row to row distance were 25 cm and plant to

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plant were 20 cm. In each plot a uniform plant stand was maintained and standard agronomic practices compatible to the humid tropic of Tarai Zone were followed to obtain good crop stand. Transplanting was done during the second week of July 2014 and 2015.

Experimental situation and method

The field experiments were conducted in three different sets. i) Irrigated condition- standing water was maintained from 20 days after transplanting to grain filling stage by providing rain water or by water supplementation as and when required. ii) Artificial drought condition- was created at reproductive stage just before anthesis by application of 0.6% potassium iodide (KI) solution as outlined by Blum et al. [12,13], Regan et al. [14] and Tyagi et al. [15]. This set of experiment was irrigated as when required. iii) Natural terminal drought stress condition- crops were transplanted under rain-fed condition and no supplementary irrigation was applied. During reproductive stage, the field was drained out to allow them dry and for stress to develop. Withdrawal of monsoon in Terai Zone of Cooch Behar usually takes place during first fortnight of October, whereas local genotypes of rice flower during second fortnight of October to first fortnight of November. Thus, if there is no supplementary irrigation after withdrawal of monsoon, the crop fetch terminal drought.

Data recording

Lodging severity at maturity was scored visually on a scale of 0-9 [16,17], where 0 was totally upright and 9 was totally lodged, and given in the Table 1. Panicles of ten plants from each replication were harvested and mean grain yield of single plant were measured in an electronic balance.

Score	Remarks	Classification
0	No plants are lodged	Highly lodging tolerant
1	Less than 20% plants are lodged	Moderately lodging tolerant
3	20-40% of plants are lodged	
5	41-60% of plants are lodged	Moderately lodging susceptible
7	61-80% of plants are lodged	
9	More than 80% of plants are lodged	Highly lodging susceptible

Statistical analysis

The experimental plan used was Randomized Blocks Design with 59 treatments (genotypes) per replication and two replications, in a total of 354 experimental units. Statistical analysis of data was conducted with absolute values. The data were analyzed using AgRes Statistical Software, (c) 1994 Pascal Intl Software Solutions, Version 3.01 to find out the variability of the experimental treatments. Mean reduction in yield at different stress situations were calculated using following formula:

$$\text{Reduction in yield (\%)} = \left[\frac{(\text{Mean yield in irrigated condition} \quad \text{Mean yield in stress condition})}{\text{Mean yield in irrigated condition}}\right] \times 100$$

Results and Discussion

Lodging score at irrigated condition

Lodging scores at irrigated condition were given in Table 2. No plants lodged in the plot of Boichi and Seshphal. As these genotypes remained standing even in the irrigated condition, those genotypes have been classified as *highly lodging tolerant*. Kagey showed less than 20% lodged plants. Thus, Kagey may be treated as *moderately lodging tolerant* under irrigated condition.

Genotype/variety	No. of genotypes	Remarks	Status
Boichi, Seshphal	02	No plants are lodged	Highly lodging tolerant
Kagey	01	<20% plants are lodged	Moderately lodging tolerant
-	00	20-40% of plants are lodged	
-	00	41-60% of plants are lodged	Moderately lodging susceptible
Jashyopa	01	61-80% of plants are lodged	
Badshabhog, Baigon Machua, Beto, Binni, Bitti, Bonnidhan, Bora, Dhyapa, Dubari Komal, Dudhekalam, Dudheswar MotaJaswa, Dudheswar, Fudugey, Garu Chakua, Ghee Bora, Gobindabhog, Hatidat Komal, Jhagrikartik, Jhapaka, Kabra, Kalakali, Kalodhyapa, Kalojeera, Kalojoha, Kalokhasa, Kalonunia, Kalshipa, Kaltury, Kashiya binni, Kataribhog, Kauka, Kharadhan, Khasa, Konkonijoha, Ladu, Lagidhan, Laldhyapa, Malshira, Mohanbhog, Munimannanri, Panikuthi shyamlal, PhoolPakri,Radhatilak, Radunipagal, Rampha, Sadamala, Satia, Sial Bhomra, Silathia Bora, Sitalkuchi, Tarapakri, Thuri, Tulaipanji, Tulsibhog, Tulsimukul.	55	>80% of plants are lodged	Highly lodging susceptible

Table 2: Lodging score at irrigated condition.

Jashyopa showed 61-80% lodged plants in irrigated condition and it is treated as *moderately lodging susceptible* under irrigated condition. Most of the genotypes were found to be *highly lodging susceptible* and more than 80% of plants of those local genotypes lodged under irrigated condition. There were 55 highly lodging susceptible local genotypes of rice under irrigated condition (Table 2).

Lodging score at drought created by spraying KI

Eight genotypes, namely Boichi, Hatidat Komal, Kagey, Mohanbhog, Radhatilak, Seshphal, Sitalkuchi and Thuri were highly tolerant to lodging under drought environment created by spraying KI and no plants of those were noticed to be lodged (Table 3). Less than 20% lodged plants were reported in Jhagrikartik, Khasa, Radunipagal and Rampha. Two genotypes, namely, Kharadhan and Silathia Bora showed 20-40% lodged plants. These six local genotypes were moderately lodging tolerant.

Boichi, Hatidat Komal, Kagey, Mohanbhog, Radhatilak, Seshphal, Sitalkuchi, Thuri	08	No plants are lodged	Highly lodging tolerant
Jhagrikartik, Khasa, Radunipagal, Rampha	04	Less than 20% plants are lodged	Moderately lodging tolerant
Kharadhan, Silathia Bora	02	20-40% of plants are lodged	
Bora, Dubari Komal, Sadamala, Satia, Tulsimukul	05	41-60% of plants are lodged	Moderately lodging susceptible
Badshabhog, Jashyopa, Kalodhyapa, Kauka, Sial Bhomra, Garu Chakua, Gobindabhog, Kataribhog, Konkonijoha, Laldhyapa, Malshira	11	61-80% of plants are lodged	
Baigon Machua, Beto, Binni, Bitti, Bonnidhan, Dhyapa, Dudhekalam, Dudheswar MotaJaswa, Dudheswar, Fudugey, Ghee Bora, Jhapaka, Kabra, Kalakali, Kalojeera, Kalojoha, Kalokhasa, Kalonunia, Kalshipa, Kaltury, Kashiya binni, Ladu, Lagidhan, Munimannanri, Panikuthi shyamlal, PhoolPakri, Tarapakri, Tulaipanji, Tulsibhog	29	More than 80% of plants are lodged	Highly lodging susceptible

Table 3: Lodging score at drought stress created by spraying KI.

Bora, Dubari Komal, Sadamala, Satia and Tulsimukul exhibited 41-60% lodging. Eleven local genotypes, namely, Badshabhog, Jashyopa, Kalodhyapa, Kauka, Sial Bhomra, Garu Chakua, Gobindabhog, Kataribhog, Konkoni Joha, Laldhyapa and Malshira showed 61-80% lodging. Thus, total of 16 local genotypes were moderately lodging tolerant under drought condition created by spraying KI. Twenty nine FVs showed more than 80% lodging under drought condition created by spraying of KI (Table 3) and these genotypes were considered highly susceptible towards lodging.

Lodging score at normal terminal drought

Twenty three local genotypes of rice, namely Baigon Machua, Boichi, Dhyapa, Garu Chakua, Ghee Bora, Gobindabhog, Hatidat Komal, Kagey, Kalojeera, Kalo Joha, Kaltury, Kataribhog, Kharadhan, Khasa, Konkoni Joha, Laldhyapa, Mohanbhog, Panikuthi Shyamlal, Sadamala, Seshphal, Sial Bhomra, Thuri and Tulsimukul were identified as highly lodging tolerant under normal terminal drought condition (Table 4). No lodging was recorded in the population of these local genotypes under normal terminal drought condition. The genotypes who showed less than 20% lodging were Badshabhog, Bonnidhan, Jhagrikartik, Kalodhyapa, Kalokhasa, Kalshipa, Kauka, Malshira, Phoolpakri, Satia and Tulsibhog (Table 4). Two genotypes, such as, Kashiya Binni and Sitalkuchi had 20-40% lodging plants. These 13 local genotypes together classified as moderately lodging tolerant.

Baigon Machua, Boichi, Dhyapa, Garu Chakua, Ghee Bora, Gobindabhog, Hatidat Komal, Kagey, Kalojeera, Kalojoha, Kaltury, Kataribhog, Kharadhan, Khasa, Konkonijoha, Laldhyapa, Mohanbhog, Panikuthi shyamlal, Sadamala, Seshphal, Sial Bhomra, Thuri, Tulsimukul	23	No plants are lodged	Highly lodging tolerant
Badshabhog, Bonnidhan, Jhagrikartik, Kalodhyapa, Kalokhasa, Kalshipa, Kauka, Malshira, PhoolPakri, Satia, Tulsibhog	11	Less than 20% plants are lodged	Moderately lodging tolerant
Kashiya binni, Sitalkuchi	02	20-40% of plants are lodged	
Bora, Dubari Komal, Ladu	03	41-60% of plants are lodged	Moderately lodging susceptible
Binni, Dudhekalam, Jashyopa, Kalonunia, Silathia Bora	05	61-80% of plants are lodged	
Beto, Bitti, Dudheswar MotaJaswa, Dudheswar, Fudugey, Jhapaka, Kabra, Kalakali, Lagidhan, Munimannanri, Radhatilak, Radunipagal, Rampha, Tarapakri, Tulaipanji	15	More than 80% of plants are lodged	Highly lodging susceptible

Table 4: Lodging score at normal terminal drought stress.

Three genotypes, such as Bora, Dubari Komal and Ladu showed 41-60% lodging plants in their respective population. Binni, Dudhekalam, Jashyopa, Kalonunia and Silathia Bora exhibited 61-80% lodging plants. These five local genotypes were categorized as moderately lodging susceptible (Table 4). Fifteen genotypes, that is, Beto, Bitti, Dudheswar Mota Jaswa, Dudheswar, Fudugey, Jhapaka, Kabra, Kalakali, Lagidhan, Munimannanri, Radhatilak, Radunipagal, Rampha, Tarapakri and Tulaipanji showed more than 80% logged plants in their respective plant population and they were found to be highly lodging susceptible under normal terminal drought condition.

Boichi and Seshaphal were found to be highly lodging tolerant in all the three environments. These two genotypes showed 'strong' culm strength in all the three environments. Seshaphal had the shortest plant (110.47 cm) among the studied materials and Seshaphal may be classified under very short (<91 cm excluding panicle) group [18]. Short-statured plants have lower 'center of gravity' than normal plants, which improves their resistance against bending pressure. The proportionality between the physical strength of lower internodes and the weight of the upper parts determines a plant's susceptibility to lodging [19]. In cereals, the reduction of plant height has been the main target for improving lodging resistance. Plant breeders have reduced lodging risks by introducing semi-dwarf traits to produce shorter genotypes, known as the Green Revolution [20]. Dwarf and semi-dwarf plants have increased lodging resistance in the culm and their breaking resistance is significantly reduced. In order to reduce the occurrence of lodging in rice production, breeders have utilized the semi-dwarfing genes to produce shorter varieties [21].

Increase in the plant height is usually attributed to lodging most of the times [22]. However, this is not always applicable. Boichi was also found to be lodging tolerant (Table 2). However, it was interesting to note that Boichi had tall plants (152.28 cm) at the same time it is resistant to lodging at all the three environments. Similar result was also observed in wheat [22]. Rajkumara [22] reported that the wheat variety Baviacora, a tolerant variety despite having 103 cm plant height recorded low lodging (6%) due to low number of tillers/m^2 (413) with greater diameter of first (3.915 mm), second (4.216 mm) and third basal internodes. On the contrary Pastor with similar height (101 cm) is prone to lodging (55%) due to higher number of tillers/m^2 (482) and lesser diameter of internodes. Thus, the genotype Boichi had really strong culm to resist the lodging. Plant height was not necessarily the most important factor in determining lodging resistance [23], but long culm length and large leaf area index rice varieties may cause an increase in bending moment [24], resulting in high lodging index [25]. Since *smos1* (a stiff culm trait of rice mutant) possesses high breaking-type lodging resistance which is different from semi-dwarf plants with high bending type lodging resistance, an alternative approach of using thick culm lines for the creation of rice with increased lodging resistance is hereby proposed [26].

The numbers of highly susceptible FVs towards lodging were 55, 29 and 15 at irrigated, drought created by spraying KI under irrigated condition and normal terminal drought environments, respectively (Tables 2, 3 and 4). Rice genotypes were found to be more susceptible to lodging under irrigated condition as compared to normal terminal drought condition and drought condition created by spraying KI under irrigated condition at reproductive stage (Figure 1). Similar observation was also evident from the findings of Price et al. [27]. Local genotypes of rice grew excessively tall when fertilizer was abundant and became susceptible to lodging, resulting in significant yield loss. In contrast, varieties with short stature are resistant to lodging even when fertilized excessively and thus are capable of supporting their own body even if high grain yielding trait is introduced. In cereal crop production, lodging resulting from low mechanical strength severely damages the vascular bundles [8], thereby affecting the transport of water, nutrients and reserves contained in vegetative organs to the developing grain and decreasing grain yield and quality.

Figure 1: Lodging status at different situations. A) Lodging status at normal terminal drought condition; B) Lodging status at terminal drought crated condition by spraying KI; C) Lodging status at irrigated condition.

It is widely known that as major components, cellulose and lignin are mainly deposited in the walls of certain specialized cells, such as the tracheary elements, sclerenchyma and phloem fibers. Considering that cellulose and lignin impart rigidity and structural support to the wall and strongly assist in the transport of water and nutrients within xylem tissue by decreasing the permeability of the cell wall [28].

Comparison of grain yield and lodging

Lodging is one of the factors causing grain yield reduction in rice, and could reduce grain yield by up to 50%, especially for rice in high-yielding environments [3]. Occurrence of lodging is more common after strong wind accompanied by heavy rains during the grain filling period. Recently, over-luxuriant growth due to excessive nitrogen application, high planting density, normal irrigation also have led to increase lodging susceptibility [4].

In this present study, it was found that lodging was more frequent in irrigated condition than the normal terminal drought condition or drought situation created by spraying of KI along with normal irrigation (Table 5). The mean reduction in yield was more in the drought situation created by spraying of KI along with normal irrigation (20.62%) than the normal terminal drought (18.66%). The average lodging susceptibility also reduced in normal terminal drought condition (3.58) as compared to the drought situation created by spraying of KI along with normal irrigation (6.32) (Table 5). In most of the cases lodging caused remarkable yield loss. The findings of Zhang et al. [29] corroborated this result.

Sl. No.	Genotypes / Characters	Grain yield per plant (g)					Lodging score		
		C	S1	S2	R1	R2	C	S1	S2
1.	Beto	34.22	36.36	40.49	-6.24	-15.49	9	9	9
2.	Binni	33.97	18.16	36.59	46.54	-7.17	9	9	7
3.	Bitti	16.06	11.85	10.97	26.19	46.40	9	9	9
4.	Boichi	30.11	18.62	30.98	38.16	-2.82	0	0	0
5.	Bonnidhan	25.48	19.97	55.09	21.60	-53.75	9	9	1
6.	Dhyapa	34.88	29.46	45.97	15.55	-24.12	9	9	0
7.	Dudhekalam	43.01	35.87	30.66	16.59	40.26	9	9	7
8.	Dudheswar MotaJaswa	32.39	26.69	39.06	17.59	-17.08	9	9	9
9.	Jashyopa	39.57	20.82	36.80	47.38	7.53	7	7	7
10.	Jhagrikartik	58.77	62.99	40.36	-7.18	45.61	9	1	1
11.	Kalakali	23.55	14.87	17.34	36.83	35.79	9	9	9
12.	Kalodhyapa	33.92	24.01	42.09	29.21	-19.40	9	7	1
13.	Kalshipa	32.62	26.88	38.15	17.58	-14.52	9	9	1
14.	Kashiya binni	27.89	19.64	35.22	29.58	-20.82	9	9	3
15.	Kauka	30.17	14.32	33.51	52.54	-9.97	9	7	1
16.	Kharadhan	39.54	36.35	18.07	8.06	118.86	9	3	0
17.	Ladu	40.02	40.50	38.90	-1.20	2.87	9	9	5
18.	Laldhyapa	40.49	28.66	44.42	29.20	-8.84	9	7	0
19.	Malshira	39.98	40.66	26.74	-1.70	49.54	9	7	1
20.	Panikuthi shyamlal	52.67	54.02	34.65	-2.56	51.99	9	9	0
21.	PhoolPakri	31.85	21.12	35.93	33.68	-11.35	9	9	1
22.	Sadamala	33.39	34.03	36.03	-1.94	-7.33	9	5	0
23.	Satia	25.31	25.48	25.43	-0.68	-0.48	9	5	1
24.	Seshphal	19.26	20.57	18.38	-6.79	4.82	0	0	0
25.	Sial Bhomra	48.32	26.62	31.17	44.92	55.04	9	7	0
26.	Sitalkuchi	39.20	42.88	32.30	-9.40	21.37	9	0	3

27.	Tarapakri	43.71	24.45	14.50	44.06	201.45	9	9	9
28.	Thuri	28.87	20.50	19.03	28.97	51.67	9	0	0
29.	Tulsimukul	44.85	47.45	15.39	-5.80	191.39	9	5	0
30.	Badshabhog	30.20	20.44	26.66	32.33	13.30	9	7	1
31.	Baigon Machua	38.76	43.95	35.29	-13.38	9.85	9	9	0
32.	Bora	31.41	19.97	40.12	36.40	-21.73	9	5	5
33.	Dubari Komal	40.37	36.21	56.01	10.31	-27.93	9	5	5
34.	Dudheswar	33.94	13.39	23.84	60.54	42.40	9	9	9
35.	Fudugey	30.37	18.72	23.06	38.36	31.70	9	9	9
36.	Garu Chakua	49.56	28.41	51.82	42.67	-4.38	9	7	0
37.	Ghee Bora	56.15	38.55	39.78	31.34	41.16	9	9	0
38.	Gobindabhog	31.09	16.98	28.03	45.37	10.90	9	7	0
39.	Hatidat Komal	54.15	26.35	59.73	51.33	-9.34	9	0	0
40.	Jhapaka	25.25	25.40	23.79	-0.63	6.11	9	9	9
41.	Kabra	24.88	22.71	41.67	8.73	-40.29	9	9	9
42.	Kagey	33.57	9.17	44.39	72.69	-24.38	1	0	9
43.	Kalojeera	17.66	19.64	17.66	-11.22	-0.01	9	9	0
44.	Kalojoha	31.62	20.05	21.93	36.59	44.22	9	9	0
45.	Kalokhasa	25.32	25.69	9.60	-1.48	163.65	9	9	1
46.	Kalonunia	20.04	23.01	21.72	-14.81	-7.74	9	9	7
47.	Kaltury	17.71	19.49	27.27	-10.00	-35.03	9	9	0
48.	Kataribhog	35.93	47.24	33.95	-31.48	5.82	9	7	0
49.	Khasa	34.89	28.54	35.60	18.21	-2.01	9	1	0
50.	Konkonijoha	30.15	21.67	25.56	28.11	17.94	9	7	0
51.	Lagidhan	35.06	36.92	24.40	-5.32	43.71	9	9	9
52.	Mohanbhog	37.38	16.74	23.55	55.20	58.68	9	0	0
53.	Munimannanri	24.77	11.12	32.63	55.09	-24.10	9	9	9
54.	Radhatilak	33.88	15.39	28.26	54.59	19.90	9	0	9
55.	Radunipagal	20.14	17.97	26.70	10.75	-24.58	9	1	9
56.	Rampha	20.08	15.98	23.04	20.42	-12.85	9	1	9
57.	Silathia Bora	45.83	28.75	50.73	37.26	-9.66	9	9	7
58.	Tulaipanji	35.69	29.81	17.48	16.48	104.15	9	3	9
59.	Tulsibhog	30.13	29.69	25.14	1.44	19.84	9	9	1
	Mean	33.90	26.64	31.59	20.62	18.66	8.53	6.32	3.58
	CV (%)	22.11							
		V	E	V × E					

	S. Ed.	3.875	0.873	6.711					
	C. D. at P=0.05	7.647	1.724	13.245					
	C.D. at P=0.01	10.092	2.275	17.480					

Table 5: Mean performance of 59 Farmers' Varieties under different drought stress conditions in respect of grain yield and lodging.

The local genotypes, namely, Hatidat Komal, Kagey, Mohanbhog, Radhatilak, Sitalkuchi and Thuri were reported to be highly susceptible under irrigated condition, whereas, they were found highly lodging tolerant under drought condition created by spraying KI at reproductive stage under irrigated condition. The yield of those genotypes also increased under normal terminal drought condition (Table 5). Rajkumara [22] also reported that in intensively cultivated cereals with high inputs like irrigation and fertilizer are more prone to lodging. Irrigation is conducive to lodging, which is particularly detrimental during the period of grain development. Price et al. [27] reported that some genotypes, lodging were less under non-irrigated conditions than under irrigated conditions.

Similarly, the FVs- Baigon Machua, Dhyapa, Garu Chakua, Ghee Bora, Gobindabhog, Hatidat Komal, Kagey, Kalojeera, Kalo Joha, Kaltury, Kataribhog, Kharadhan, Khasa, Konkoni Joha, Laldhyapa, Mohanbhog, Panikuthi Shyamlal, Sadamala, Sial Bhomra and Thuri, Tulsimukul were highly lodging tolerant under normal terminal drought situation. These local genotypes were established to be lodging susceptible under irrigated condition (Table 2). Subsequently, these genotypes showed higher grain yield at normal terminal drought situation than the grain yield at corresponding irrigated and KI sprayed environments. This is inconsistent with the findings of Zhu et al. [17] that increased grain yield in rice varieties tolerant towards lodging.

Beto, Bitti, Dudheswar, Mota Jaswa, Fudugey, Jhapaka, Kabra, Kalakali, Lagidhan, Munimannanri, Radhatilak, Radunipagal, Rampha, Tarapakri and Tulaipanji exhibited susceptibility under all the three environments. This finding confirmed that these 15 FVs are highly susceptible to lodging. In a lodged plant community, the normal canopy structure is destroyed, leading to reduced photosynthetic ability and dry matter production [5]. Severe lodging prevents the transport of water, nutrients, and assimilates through the xylem and phloem, resulting in a reduction in assimilates for grain filling [6]. Furthermore, high moisture levels in a lodged plant community may be favorable for fungal growth and the occurrence of diseases, which have detrimental effects on grain quality [2]. *In situ* germination may occur in lodged plants due to suitable environment especially for genotypes with weak seed dormancy. As a result, lodging could cause great losses in both grain yield and quality. In addition, it also causes difficulties in harvest operations, increases demand for grain drying, and consequently results in increased production cost [30].

Regression analysis as done by Lang et al. [31] suggested that, lodging one day earlier at the grain-filling stage could cause 2.66% to 2.71% of yield loss, 1.8 to 2.6 percentage points decrease of seed-setting rate, 0.26 to 0.32 g reduction of 1000-grain weight, 0.097 to 0.155 percentage point decline of milled rice rate, as well as 0.13 to 0.27 percentage point increase of chalky grain rate, and 0.021 to 0.024 percentage point rise of protein content, and subsequently lower the eating quality.

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