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FULL PAPER

Agromorphological Characteristics and Tungro Response of Selected Philippine Traditional Rice Varieties

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Traditional rice varieties (TRVs) are affected by rice tungro disease, which is one of the constraints of rice production. Planting of TRVs must consider varieties that possess both tungro resistance and good agromorphological traits. This study aimed to identify tungro resistant Philippine TRVs with good agromorphological traits. Data on agromorphological traits and tungro response of 61 TRVs were obtained with permission from the PhilRice Genebank. Varieties with tungro resistance and good agromorphological characteristics including qualitative and quantitative traits were determined. Among the 61 TRVs presented in this study, six have intermediate resistance while 55 are susceptible. Tungro intermediate resistant varieties with good agromorphological traits are: Dinurado (Ilocos Norte) with intermediate culm lodging resistance (CLR), semi-compact panicle branching attitude (PBA) and low panicle shatterring (PS); Denorado 1 (Maguindanao) with semi-compact PBA; Azucena 4 (Negros Occidental) with strong CLR, slightly drooping panicle main axis attitude (PMA) and low PS; Azucena 1 (North Cotabato) with semi-compact PBA and moderate PS; Maliket (Ilocos Norte) with intermediate CLR, strong upright PMA, semi-compact PBA and very low PS; and Milagrosa Pula (Palawan) with strong CLR, and semi-compact PBA. Spearman's rank correlation analysis using 12 agromorphological traits of 61 TRVs showed that none of the four qualitative and eight quantitative traits has significant correlation with tungro response. Screenhouse evaluation showed that all 15 Maguindanao TRVs tested in this study were tungro susceptible with disease index (DI = 9) comparable to the susceptible control variety, TN1. Varieties with susceptible response have high disease incidence, high symptom severity rating and high area under disease progress curve (AUDPC). Most of the Maguindanao TRVs have intermediate CLR, semi-upright PMA and semi-compact PBA. Some of the Maguindanao TRVs possessing good agromorphological traits are Dinorado 2 with desirable plant height, strong CLR, semi-upright PMA, semi-compact PBA and moderate PS. Kua-Kua has desirable panicle length (PL) (30.6 cm) with intermediate CLR, semi-upright PMA and semi-compact PBA. Inabaka has desirable panicle length (PL) (35.4 cm), semi upright PMA and semi compact PBA.

Keywords: agromorphological traits, Philippine traditional rice varieties, tungro resistance

INTRODUCTION

Traditional rice varieties (TRVs) are varieties that have been selected and cultivated by local farmers over generations, and are usually well adapted to local environmental conditions. They are classified as pigmented or non-pigmented, aromatic or non-aromatic, and glutinous or non-glutinous (IRRI, 2018). TRVs are mostly tall with strong culms, vigorous seeds and can withstand waterlogging and drought conditions (Rathnabharathi 2009). In both tropical and subtropical countries, TRVs generally mature in 140-170 days which are suitable for growing one crop a year during the wet season but not for multiple cropping systems (Khush and Virmani, 1985). Several farmers prefer to plant TRVs due to their good eating quality and adaptability to a particular area (Swiderska et al. 2011), high nutritional value, and resistance to biotic and abiotic stresses (IRRI, 2018). TRVs are also rich in genetic diversity and have potential novel genes that serve as the foundation of any rice genetic improvement program (Perez 2015).

In the Philippines, a collection of 7716 TRVs obtained from different regions have been stored at the Philippine Rice Research Institute (PhilRice) Genebank located in Munoz, Nueva Ecija (Ferrer et al. 2020), 976 TRVs at UPLB-PhilRice storage facility, and 2,752 at the International Rice Research Institute (IRRI) Genebank in Los Banos, Laguna (IRRI, 2021/ https://gringlobal.irri.org/gringlobal/search). TRVs are grown in all regions of the country while the major growing areas are located in the Cordillera Autonomous Region (CAR), Cagayan Valley, Ilocos region, Bicol region in Luzon island; Iloilo in the Visayas; Cotabato (Arakan Valley and Lake Sebu) and SOCCSKSARGEN (Sarangani and Sultan Kudarat provinces) and Maguindanao in Mindanao (www.fao.org/3/Y4347E/y4347e1g.htm). Planting of TRVs ensures household food security and survival of the tribal families (Bangi 2019).

The Philippine TRVs are continuously being characterized for their agromorphological traits. Agromorphological characterization is important to determine the TRVs genetic identity and to identify varieties with desirable traits for direct utilization or as potential donors for rice genetic improvement (Rabara et al. 2014; Ferrer et al. 2020). Agromorphological characterization of 307 TRVs from the collections at the PhilRice Genebank has identified 11 accessions with desirable traits that could be potential donor parents in rice breeding (Rabara et al. 2014). These TRVs meet the desirable plant height (90–100 cm) and maturity (110–120

days) and growth duration of 120 days. Recently, an additional 199 TRVs have been evaluated for 58 agromorpological traits, and identified some of them with desirable traits such as longest panicle size (>32 cm) and heaviest grain weight (>35g) (Ferrer et al. 2020).

The TRVs are also evaluated for resistance to tungro disease. Tungro is the most devastating virus disease of rice in South and Southeast Asia causing significant yield reduction (Hibino et al. 2018). The disease is caused by *Rice tungro bacilliform virus* (RTBV) and *Rice tungro spherical virus* (RTSV) (Hibino et al. 1978; Hibino et al. 2018). RTBV has a genome of circular double-stranded DNA of 8-kb encapsidated in bacilliform particle (Hibino et al. 1991; Jones et al. 1991; Hibino et al. 1996), whereas RTSV has a single-stranded RNA genome of about 12 kb, which is encapsidated within isometric particles (Hibino et al. 1991; Jones et al. 1991; Shen, 1993; Hibino et al. 1996). Both viruses are transmitted in a semi-persistent manner by the green leafhopper (GLH) with *Nephotettix virescens* as the most efficient vector. RTBV is transmitted after the vector acquired RTSV simultaneously or previously while RTSV is transmitted independently (Hibino et al. 1978; Hibino, 1983). Plants infected with both RTBV and RTSV have the typical tungro symptoms of distinct yellow orange discoloration and stunting. Plants infected with RTBV alone have milder symptoms of yellow or orange discoloration` and stunting (Hibino et al. 1978; Hibino, 1983). However, RTSV alone infected plants do not show distinct yellow orange discoloration but with very mild stunting. (Hibino 1989; Hibino et al. 1996).

Tungro resistance would be the most effective means to manage the disease. However, TRVs must possess both tungro resistance and good agromorphological traits. Information on the tungro response and agromorphological traits of Philippine TRVs are available from PhilRice Genebank. However, TRVs possessing both good agromorphological traits and tungro resistance have not been fully determined. Furthermore, TRVs that have been evaluated for agromorphological and tungro resistance are still limited. It is important to identify more varieties that can be recommended for planting especially on a particular location where TRVs are mainly grown. Evaluation of tungro response involves forced-tube inoculation in the screenhouse and natural infection in the field (Hibino et al. 1990; Azzam et al. 2000; RTWG-NSIC 1997).

This study aimed to identify the Philippine TRVs with both tungro resistance and good agromorphological traits using the information from the PhilRice Genebank, and determine the relationship between tungro response and agromorphological traits; identify additional tungro resistant TRVs with good agromorphological traits using the Maguindanao varieties. Effective utilization of TRVs can be enhanced if these materials are properly identified for their potential in direct use or in the breeding program.

MATERIALS AND METHODS

Gathering Information from the PhilRice Genebank on the Agromorphological Traits and Tungro Response of Selected Philippine TRVs

Data on agromorphological traits and tungro response of 61 TRVs were obtained with permission from the PhilRice Genebank. Varieties with tungro resistance and good agromorphological characteristics including qualitative and quantitative traits were determined. At PhilRice, evaluation of tungro response was conducted by forced-tube inoculation method under screenhouse condition (Hibino et al. 1990) and natural infection in the field. Field evaluation followed the NCT guidelines for the evaluation of tungro resistance (NCT, 1997). Tungro response was determined based on disease incidence wherein varieties with 0-20% were considered as Resistant (R), 21-40%, Intermediate (I) and 41-100%, Susceptible (S). Presence of the disease was determined by visual assessment of tungro symptoms such as yellow orange discoloration and stunting. Majority of the varieties were evaluated by field screening at the PhilRice Central Experiment Station at their place of collection for other varieties.

Characterization of Quantitative and Qualitative Agromorphological Traits

The qualitative and quantitative agromorphological traits of 61 TRVs were characterized following the standard descriptor list for cultivated rice (*Oryza* spp.) published by Bioversity International, IRRI and WARDA (2007). Qualitative traits are culm lodging resistance (CLR), panicle main axis attitude (PMA), panicle branching attitude (PBA) and panicle shattering (PS). Quantitative traits included culm length (CL), panicle length (PL), plant height (PH), panicle number (PN), filled grains (FG), unfilled grains (UG), 100g weight of seeds (WS) and percent heading date (%HD). Cluster analysis was performed to determine the similarities between TRVs across qualitative and quantitative morphological traits, and determine the qualitative and quantitative traits of Philippine TRVs including the Maguindanao TRVs.

Correlation Analysis of Tungro Response and Agromorphological Characteristics

Correlation analysis between agromorphological traits of 61 TRVs and their tungro response was performed by simple matching using Spearman's rank correlation analysis of Statistical Tool for Agriculture and Research (STAR), v.2.0 (IRRI).

Agromorphological Characterization of Maguindanao TRVs

Seed samples of 15 TRVs from Maguindanao were obtained from the UPLB-PhilRice storage facility at UPLB. Seeds were oven-dried for three days at 50°C to break the dormancy and sown following the wet bed method. Seedlings were transplanted 21 days after sowing and the field was maintained at its saturated water level. The experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications. The harvested panicles (at 80% maturity) were placed in individual clean net bags with tags, threshed manually, and air-dried for two to three weeks. Characterization of agromorphological traits consisting of four qualitative and eight quantitative

traits of rice varieties was conducted following the standard descriptor as described in the previous section.

Evaluation of Maguindanao TRVs for their Response to Tungro

The tungro response of 15 Maguindanao TRVs was evaluated in the Screenhouse at IWEP-UPLB. The GLH were allowed to acquire the virus for 72 hr from the susceptible TN1 variety infected with both RTBV and RTSV (Hibino et al.1990; Azzam et al. 2000). Virus inoculation was conducted following a forced-tube inoculation method wherein one ten-day old seedling was placed in a test tube and three viruliferous GLH were allowed to feed for 24 hr. Inoculated plants were then transplanted into potted soil. The experiment was laid out in a Completely Randomized Design (CRD) with three replications for five seedlings for each TRV.

Assessment of disease incidence was conducted every week, starting from one-week post inoculation (wpi) to 6 wpi, while symptom severity at 2 wpi and 4 wpi. The presence of tungro disease was determined by visual observation of typical symptoms of yellow orange discoloration and stunting compared with the susceptible control TN1 variety. Disease incidence was computed as the percentage of the total number of symptomatic plants over the total number of inoculated plants. Symptom severity was determined following the symptom severity rating scale: 1=no symptoms; 3=1-10% height reduction, no distinct yellow to yellow-orange leaf discoloration; 5=11-30% height reduction, no distinct yellow to yellow-orange leaf discoloration; 7=31-50% height reduction with distinct yellow to yellow-orange leaf discoloration; and 9= more than 50% height reduction, with distinct yellow to yellow-orange leaf discoloration (INGER, 1996). The symptoms severity score was used in the computation of disease index as described below. The area under disease progress curve (AUDPC) which determines the progress of percent disease incidence over time was computed following the formula:

$$AUDPC = \sum_{i=1}^{n}[(Y_i + Y_{i+1})/2]\ (t_{i+1} - t_i)$$

where *Yi* is assessment of disease incidence at the *ith* observation, *ti* is time (in weeks) at the *ith* observation, and *n* is the total number of observations (Shaner and Finney, 1977). Analysis of variance (ANOVA) was carried out to determine the significance differences among treatments using the Statistical Tool for Agricultural Research (STAR) of IRRI. Treatment mean comparison was done using Tukey's Honest Significant Difference (HSD) test.

The response to tungro disease was determined based on Disease Index (DI) computed following the Standard Evaluation System (SES) for Rice (INGER, 1996). Disease index (DI) for each TRV was calculated using the formula DI = 3(n)+5(n)+7(n)+9(n)/tn), where: n= number of plants with severity score for each rating scale of 3, 5, 7, 9 and tn = total number of plants inoculated. Based on the computed DI, the response was classified as resistant or tolerant with DI = 0-3; moderate = 4-6; and susceptible = 7-9.

RESULTS

Agromorphological Traits of Selected Philippine TRVs

Simple matching using cluster analysis of 61 TRVs has produced three clusters with 72.4% similarity for qualitative traits and 54.6% for quantitative traits. For qualitative traits, Cluster I consisted of 30 TRVs, 24 for Cluster II and two for Cluster III (Figure 1, Table 1). Cluster I TRVs have intermediate CLR, slightly drooping PMA, compact PBA, and moderate PS (Table 3). Some varieties belonging to cluster 1 are Azucena 1, Denorado 1 and Denorado 2, Dinorado 2, Dinorado Puti, Dinorado 5, Dinorado Haba, Dinurado, Hinumay 1 and 2, Hinumay 3 and 4, Milagrosa Pula, Palawan 3, Remolitis 1 and 2, Sinampablo 1 and 2 (Table 1) and others. Cluster II TRVs have weak CLR, semi-upright PMA, semi-compact PBA and moderate PS. Some TRVs belonging to Cluster II are Awot 1, Awot 2, Dinorado 1, Dinorado 3, Dinorado 4, Maliket, Palawan 1, Palawan 2. Cluster III has Azucena 2 and Speaker, which is characterized by strong CLR, slightly drooping PMA, horizontal PBA and high PS (Table 1, Table 3).

For quantitative traits, Cluster I consisted of 22 TRVs, 15 for Cluster II and one for Cluster III (Figure 2 and Table 2). Cluster 1 TRVs have mean CL (132.01 cm), PL (27.24 cm), PH (159.25 cm), PN (11.89), FG (182.72), UFG (49.99), 100 GW (2.29) and 50% HD (98 days) (Table 3). Some TRVs belonging to Cluster I are Azucena 2, Awot 2, Black Rice, Denorado 1 and Denorado 2, Dinorado 3, Dinorado 4, Dinorado Puti, Dinorado 5, Gabay, Hinumay 1, Hinumay 2, Maliket, Remolites 1 and Remolites 2 (Table 2). Cluster II TRVs have mena CL (111.43 cm), PL (25.13 cm), PH (136.56 cm), PN (12.33), FG (124.02), UFG (24.92), 100%GW (2.40) and 50% HD (94.47 days) (Table 2). Some TRVs belonging to Cluster II are Azucena 1, Binernal White, Dinorado Haba, Galo 1, Ininkantong Puti, Kalingkit, Kanukot, Kasagpi 1 and Kasagpi 2. Cluster III TRVs have CL (129.20 cm), PL (27.88 cm), PH (157.08 cm), PN (23), FG (128), UFG (20.40), 100%GW (2.55) and 50% HD (80). Awot 1 belongs to Cluster III.

Response of Selected Philippine TRVs to Tungro Disease

Among the 61 TRVs from the PhilRice Genebank that were presented in this study, six have intermediate (I) resistance while 55 are susceptible (S) (Table 4). Varieties with intermediate resistance are Azucena 1 (North Cotabato), Azucena 4 (Negros Occidental) Denorado 1 (Maguindanao), Dinurado (Ilocos Norte), Maliket (Ilocos Norte) and Milagrosa Pula (Palawan). However, varieties with similar names collected from other provinces or from the same province are susceptible. Eight of the 10 Dinorado TRVs from other provinces (Agusan del Sur, Antique, Leyte, Negros Oriental, Zamboanga del Norte), Dinorado Haba (Oriental Mindoro), and from the same province (Denorado 2 and Dinorado Puti from Maguindanao) are susceptible. Similarly, the other Azucena (Azucena 2) from another province (Ilocos Norte) has a susceptible tungro response. Most of the TRVs (55/61) presented in this study have consistent susceptible response. These are TRVs with names such as Galo, Kasagpi, Mismis, Palawan, Remolites,

Table 1. Selected traditional rice varieties belonging to different clusters based on 'simple matching' analysis of morphological qualitative traits.

Cluster 1		Cluster 2		Cluster 3
Azucena 1	Kasagpi 1	Awot 1	Makarato	Azucena 2
Binernal White	Kasagpi 2	Awot 2	Maliket	Speaker
Denorado 1	Malido	Binerhen	Manumbalay	
Denorado 2	Milagrosa (Pula)	Black Rice	Palawan 1	
Dinorado 2	Mimis 1	Dinorado 1	Palawan 2	
Dinorado (Puti)	Mimis 2	Dinorado 3	Perla	
Dinorado 5	Palawan 3	Dinorado 4	Pindinga (B)	
Dinorado Haba	Pinalawan	Gabay	Sintanganod	
Dinurado 1	Remolites1	Hasik Palawan	Tangtang	
Galo 1	Remolites 2	Iningkantong Puti		
Hinumay 1	Sinampablo 1	Kanukot		
Hinumay2	Sinampablo 2	Kawilan		
Hinumay3	Talutap	Lubag / Galo (Red)		
Hinumay4	Tipak	Lubang Matalom		
Karabkab (Maliket)	White Palawan	Magsanaya		

Sinampablo. Other varieties such as Azucena 2, Azucena 3, Binerhen, Binernal White, Black Rice, Duriat, Gabay, Hasik Palawan, Ininkantong Puti, Kalingkit black, Kanukot, Karabkab, Kawilan, Lubag, Lubang Matalom, Magsanaya, Makarato, Malido, Manumbalay, Perla, Pinalawan, Pindinga, Sintanganod, Speaker, Talutap, Tangtang, Tipak, White Palawan are all susceptible.

Agromorphological Characteristics of TRVs with Intermediate Resistance

The agromorphological characteristics of TRVs with intermediate resistance are presented in Table 5. Dinurado (Ilocos Norte) has intermediate CLR, strong drooping PMA, semi-compact PBA and low PS. Denorado 1 (Maguindanao) has weak CLR, strong drooping PMA, semi-compact PBA and high PS. Azucena 4 (Negros Occidental) has strong CLR, slightly drooping PMA, drooping PBA, and low PS. Azucena 1 (North Cotabato) has weak CLR, strong drooping PMA, semi-compact PBA and moderate PS. Maliket (Ilocos Norte) has intermediate CLR, strong upright PMA, semi-compact PBA and very low PS. Milagrosa Pula (Palawan) has strong CLR, strong drooping PMA, and semi-compact PBA. The six TRVs with intermediate resistance as well as varieties with the same name have varying agromorphological characteristics. For instance, Denorado 1 (Maguindanao) and Dinurado (Ilocos Norte) have the same PMA of strongly drooping, and semi compact PBA but differed in CLR and PS. Likewise, Azucena 4 (Negros Occidental) Azucena 1 (North Cotabato) differ in qualitative traits. Azucena 4 has a strong CLR, slightly drooping PMA, drooping PBA and low PS, while Azucena 1 has weak CLR, strong drooping PMA, semi-compact PBA and moderate PS. Similarly, the six TRVs with intermediate tungro response have varying quantitative traits such as culm length, panicle length, plant height, panicle number, filled grains, unfilled grains, grain weight and 50% heading date.

Table 2. Selected traditional rice varieties belonging to different clusters based on 'simple matching' analysis of morphological quantitative traits.

Cluster 1		Cluster 2	Cluster 3
Azucena 2	Hinumay 1	Azucena 1	Awot 1
Awot 2	Hinumay 2	Binernal White	
Binerhen	Lubang Matalom	Dinorado Haba	
Black Rice	Makarato	Galo 1	
Denorado1	Maliket	Iningkantong Puti	
Denorado2	Mimis 1	Kalingkit (Black)	
Dinorado 3	Palawan 3	Kanukot	
Dinorado 4	Pindinga (B)	Kasagpi 1	
Dinorado (Puti)	Remolites 1	Kasagpi 2	
Dinorado 5	Remolites 2	Lubag / Galo (Red)	
Gabay		Magsanaya	
Hasik Palawan		Malido	
		Manumbalay	
		Palawan 1	
		White Palawan	

Correlation of Agromorphological Characteristics and Tungro Response

Spearman's rank correlation analysis did not show a significant relationship between tungro response with agromorphological characters for any of the eight quantitative and four qualitative traits (data not shown). Quantitative traits such as culm length, panicle length, plant height, filled grains, unfilled grains, grain weight, 50% heading date, culm lodging resistance and panicle branches attitude have positive correlation coefficients (*r*) with tungro

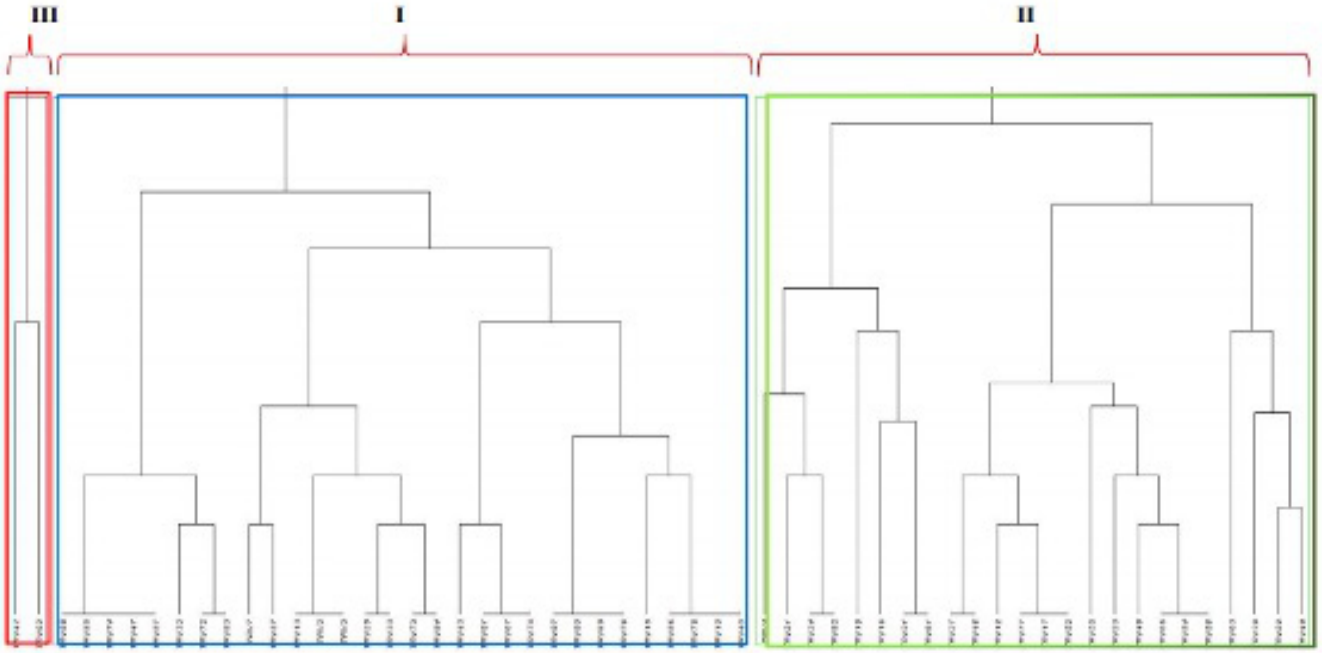

Figure 1. Dendrogram by Agglomerative clustering analysis of 61 traditional rice varieties based on four qualitative morphological traits at 72.4 % similarity

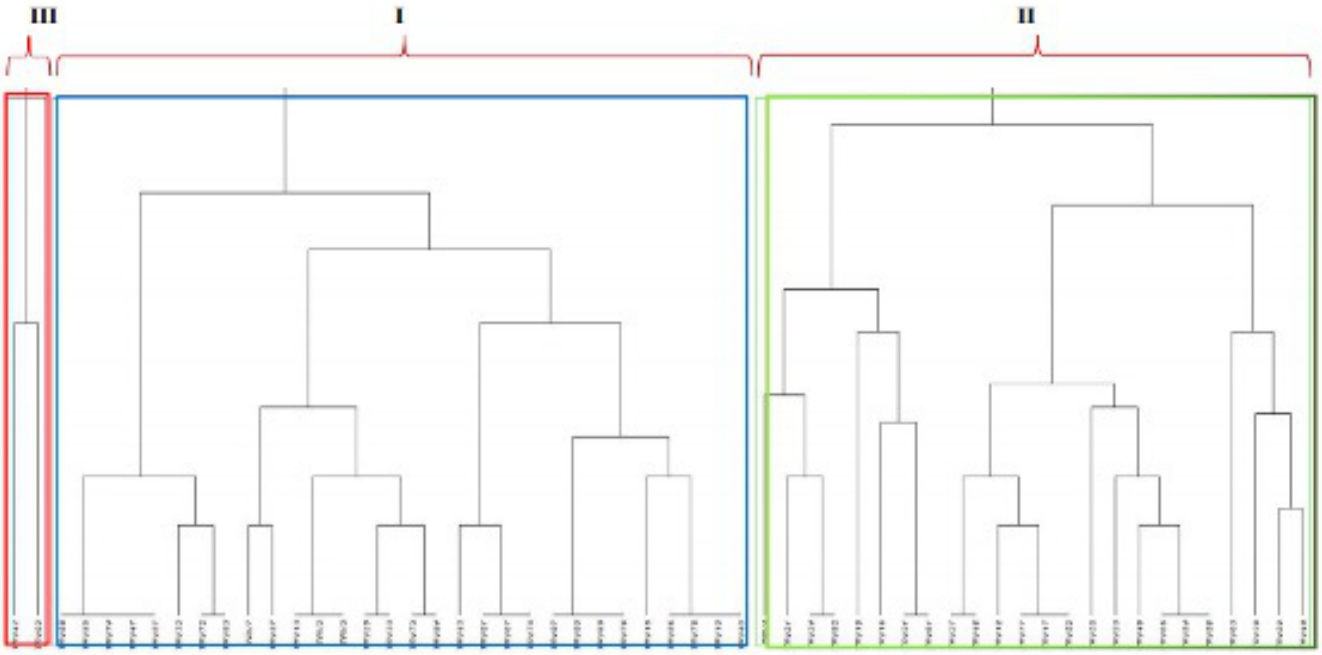

Figure 2. Dendrogram generated by Agglomerative clustering analysis of 61 traditional rice varieties based on eight quantitative morphological traits at 54.6 % similarity.

response. On the other hand, correlation of panicle number, panicle main axis attitude and panicle shattering with tungro response have negative correlation coefficients. However, both correlations for each trait were not significant with *F* values greater than *P* >0.05.

Agromorphological Characteristics of Maguindanao TRVs

Thirteen out of 15 TRVs had CL above 100 cm (102.4-133.6) (Table 6). TRVs with short CL were Denorado 2 (68.4 cm) and Inemay 2 (97.8 cm). Panicle length in most varieties ranged from 22-27.8 cm while Kua-Kua (30.6 cm) and Inabaka 2 (35.4 cm) have longer PL. Most varieties (14/15) were tall with PH of 120.8 to 169 cm while Dinorado 2 was shorter (PH 93.6 cm). Most varieties have GW of more than 2 g. Pulot A Pikit had the highest GW of 3.2 g while Manisi Red, Inemay 1, Manisi, Pulot A Papakan and Inabaka had lower GW (1.4-1.90 g). Eleven TRVs has 50% HD between 70-79 days while longer (82-84) in four varieties. The filled and unfilled grains varied among the TRVs. Most TRVs (11/15) including Pulot A Pikit (White), Inemay 1, Manisi, Kua-Kua, Dinorado 2,

Table 3. Agromorphological characteristics of selected Philippine traditional rice varieties belonging to different clusters obtained by simple matching analysis.

Qualitative traits	Traits per Cluster		
	Cluster 1	Cluster 2	Cluster 3
Culm Lodging Resistance	Intermediate	Weak	Strong
Panicle Main Axis Attitute	Slightly drooping	Semi-Upright	Slightly Drooping
Panicle Branches Attitude	Compact	Semi-Compact	Horizontal
Panicle Shattering	Moderate	Moderate	High
Quantitative traits	**Cluster 1**	**Cluster 2**	**Cluster 3**
Culm length	132.01	111.43	129.20
Panicle length	27.24	25.13	27.88
Plant height	159.25	136.56	157.08
Panicle number	11.89	12.33	23.00
Filled Grains	182.72	124.02	128.00
Unfilled. Grains	49.99	24.92	20.40
100 grain weight	2.29	2.40	2.55
50% Heading Date	98.00	94.47	80.00

Percent Similarity of Qualitative traits = 72.4%; Percent Similarity of Quantitative traits= 54.6%

Table 4. Response of Philippine traditional rice varieties to tungro disease.

Province	Variety	[1]TR	Province	Variety	[1]TR	Province	Variety	[1]TR
North Cotabato	Awot 1	S	Aurora	Hasik Palawan	S	Capiz	Palawan 2	S
Sultan Kudarat	Awot 2	S	North Cotabato	Hinumay 1	S	Nueva Vizcaya	Palawan 3	S
North Cotabato	Azucena 1	I	North Cotabato	Hinumay 2	S	Misamis Occidental	Perla	S
Ilocos Norte	Azucena 2	S	Surigao Del Sur	Hinumay 3	S	Quezon	Pinalawan	S
Negros Occidental	Azucena 3	S	Surigao Del Sur	Hinumay 4	S	Palawan	Pindinga (B)	S
Negros Occidental	Azucena 4	I	Rizal	Iningkantong Puti	S	Surigao Del Sur	Remolites 1	S
Cavite	Binerhen	S	Zamboanga Del Sur	Kalingkit (Black)	S	Surigao Del Sur	Remolites 2	S
Bulacan	Binernal White	S	Davao Oriental	Kanukot	S	Surigao Del Sur	Sinampablo 1	S
Bataan	B-Rice (Black Rice)	S	Ilocos Norte	Karabkab (Maliket)	S	Surigao Del Sur	Sinampablo 2	S
Maguindanao	Denorado 1	I	Sultan Kudarat	Kasagpi 1	S	Laguna	Sintanganod	S
Maguindanao	Denorado 2	S	Sultan Kudarat	Kasagpi 2	S	Misamis Oriental	Speaker	S
Maguindanao	Dinorado (Puti)	S	Laguna	Kawilan	S	Laguna	Talutap	S
Agusan Del Sur	Dinorado 1	S	Aurora	Lubag/Galo (Red)	S	Aurora	Tangtang	S
Antique	Dinorado 2	S	Leyte	Lubang Matalom	S	Palawan	Tipak	S
Leyte	Dinorado 3	S	Ilollo	Magsanaya	S	Quirino	White Palawan	S
Negros Oriental	Dinorado 4	S	Samar	Makarato	S			
Zamboanga Del Norte	Dinorado 5	S	Ilollo	Malido	S			
Oriental Mindoro	Dinorado Haba	S	Ilocos Norte	Maliket	I			
Ilocos Norte	Dinurado	I	Ilollo	Manumbalay	S			
Palawan	Duriat	S	Palawan	Milagrosa (Pula)	I			
Laguna	Gabay	S	Agusan Del Sur	Mimis 1	S			
Aurora	Galo 1	S	Agusan Del Sur	Mimis 2	S			
Nueva Vizcaya	Galo 2	S	Bulacan	Palawan 1	S			

[1]Tungro response (TR) based on disease incidence: 21-40% = Intermediate (I); 41-100% Susceptible (S) (Rice Technical Working Group, National Seed Industry Council, Department of Agriculture, Philippines, 1998): *Data Source: PhilRice Genebank, Central Experiment Station (CES), Nueva Ecija

Manek-Manek, Pulot A Narra, Inemay 2, Pulot A Pande have good qualitative traits such as intermediate to strong CLR, semi-upright PMA, semi-compact PBA (Table 6). Among them, Pulot A Pikit (White), Dinorado 2, Pulot A Pande have an additional desirable trait of moderate PS.

Response of Maguindanao TRVs to tungro disease

Disease Progress

The disease development in Maguindanao TRVs is presented as the disease progress curve for disease incidence taken from 1 wpi until 6 wpi (Figure 3). All

Table 5. Agromorphological characteristics of selected Philippine traditional rice varieties with intermediate resistance.

Location	Variety name	Quantitative Characters								Qualitative Characters			
		CL	PL	PH	PN	FG	UFG	GW	HD	CLR	PMA	PBA	PS
Ilocos Norte	Dinurado	115.2	26.5	141.7	11	120	21	2.15	97	Intermediate	Strong Drooping	Semi-compact	Low
Maguindanao	Denorado 1	109	25.22	134.22	10	153	67	2	89	Weak	Strong drooping	Semi-compact	High
Negros Occidental	Azucena 4	111.2	30.1	141.3	16	120	25	2.5	95	Strong	Slightly drooping	Drooping	Low
North Cotabato	Azucena1	107.4	22.14	129.54	11	122	24	2.25	82	Weak	Strong drooping	Semi-compact	Moderate
Ilocos Norte	Maliket	132.2	26.42	158.62	12	103	23	3.3	89	Intermediate	Strong Upright	Semi-compact	Very-Low
Palawan	Milagrosa Pula	120.2	28.52	148.72	11	153	36	2.75	90	Strong	Strong Drooping	Semi-compact	-

Legend: CL-culm length; PL- panicle length; PH- plant height; PN- panicle number; FG- filled grains; UFG- unfilled grains; GW- grain weight; HD- 50% heading date; CLR- culm lodging resistance; PMA- panicle main axis Attitude; PBA- panicle branching attitude; PS-panicle shattering
*Data Source: PhilRice Genebank, Central Experiment Station (CES), Nueva Ecija

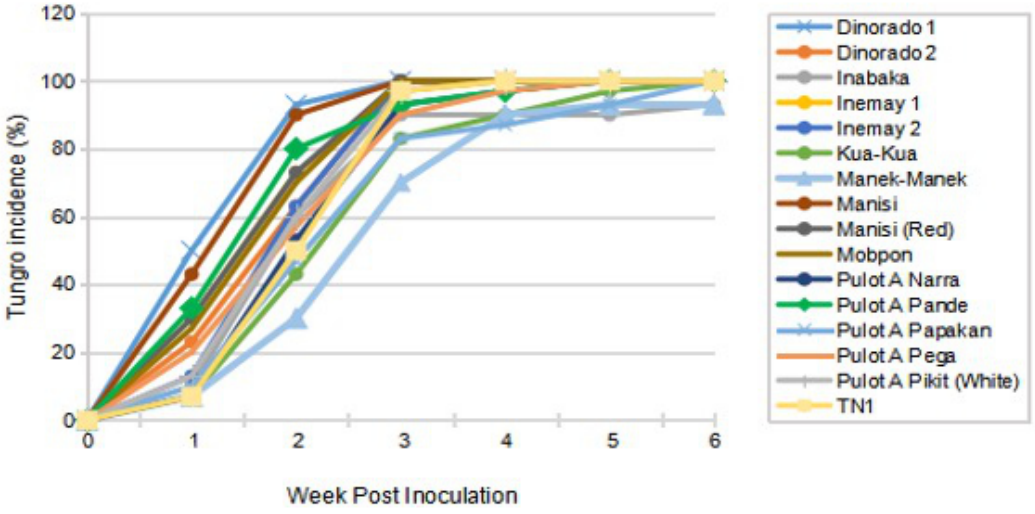

Figure 3. Disease progress curve of percent tungro incidence in traditional rice varieties from Maguindanao.

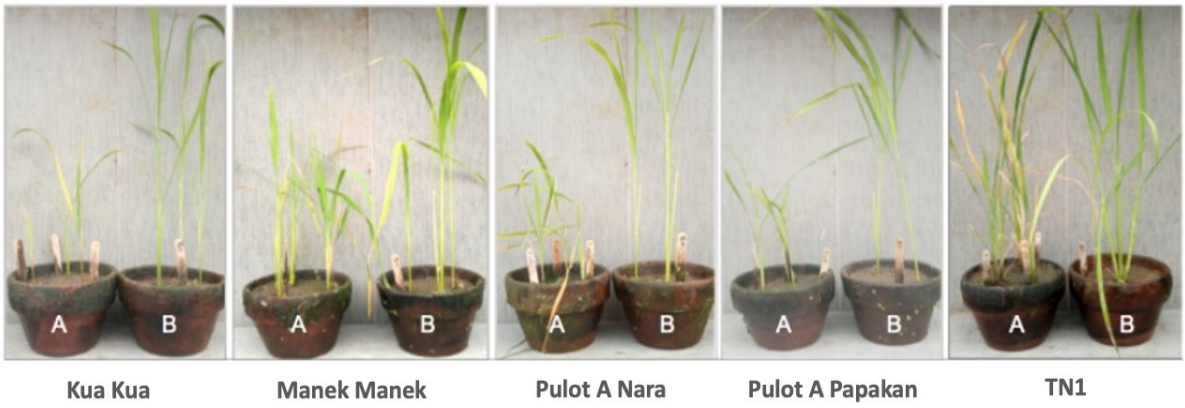

Figure 4. Maguindanao traditional rice varieties with susceptible response to tungro disease showing severe height reduction and yellow orange leaf discoloration. A-Infected; B-Uninoculated control; TN1-susceptible control variety.

the TRVs started to develop the disease at 1 wpi. However, disease incidence during the disease onset at 1 wpi varied among the varieties. Most varieties (8/15) had tungro incidence within the range of 0-20%. These are Inabaka, Inemay, Kua Kua, Manek Manek, Pulot A Narra, Pulot A Papakan, Pulot A Pega, and Pulot A Pikit. TRVs with disease incidence within 21-40% are Dinorado, Inemay, Manisi Red, Mobpon and Pulot A. Pandi while those within the 41-100% incidence are Dinorado and Manisi. The susceptible control variety, TN1 had tungro incidence within the 0-20%. At 2 wpi, all TRVs except Manek Manek (30% incidence) had tungro incidence within the 41-100%. At 3 wpi, all TRVs had incidences of 83-100%. Pulot

Table 6. Agromorphological characteristics of traditional rice varieties from Maguindanao.

Variety Name	Quantitative Traits								Qualitative Traits			
	CL	PL	PH	PN	FG	UFG	GW	HD	CLR	PMA	PBA	PS
Manisi (Red)	109.0	22.0	131.0	12.0	162.0	232.0	1.4	77.0	Strong	Strong Drooping	Spreading	Moderate
Pulot A Pikit (White)	118.4	27.8	146.2	9.6	121.0	53.3	3.2	75.0	Intermediate	Semi-upright	Semi-compact	Moderate
Dinorado 1	109.8	27.0	136.8	10.2	171.0	154.2	2.2	77.0	Weak	Semi-upright	Spreading	Moderate
Mobpon	109.2	25.0	134.2	10.2	154.0	111.0	2.0	82.0	Weak	Semi-upright	Semi-compact	High
Inemay 1	116.8	27.2	144.0	8.0	118.0	191.4	1.8	84.0	Intermediate	Semi-upright	Semi-compact	High
Manisi	119.4	25.0	144.4	7.4	187.0	203.8	1.4	75.0	Intermediate	Semi-upright	Semi-compact	Moderate
Kua-Kua	119.2	30.6	149.8	10.2	74.8	79.4	2.3	75.0	Intermediate	Semi-upright	Semi-compact	High
Dinorado 2	68.4	25.2	93.6	16.4	240.0	121.0	2.0	82.0	Strong	Semi-upright	Semi-compact	Moderate
Manek-Manek	111.2	26.0	137.2	8.4	125.0	46.4	2.7	75.0	Intermediate	Semi-upright	Semi-compact	High
Pulot A Narra	115.8	26.4	142.2	7.6	130.0	117.0	2.3	82.0	Intermediate	Semi-upright	Semi-compact	High
Inemay 2	97.8	23.0	120.8	9.4	150.0	60.0	2.1	70.0	Intermediate	Semi-upright	Semi-compact	High
Pulot A Pega	111.8	26.8	138.6	7.4	138.0	54.8	2.4	79.0	Weak	Semi-upright	Semi-compact	Moderate
Pulot A Pande	110.8	24.0	134.8	10.2	126.0	139.2	2.2	75.0	Intermediate	Semi-upright	Semi-compact	Moderate
Pulot A Papakan	102.4	26.8	129.2	5.4	190.0	75.8	1.9	70.0	Intermediate	Semi-upright	Semi-compact	Moderate
Inabaka	133.6	35.4	169.0	7.8	130.0	167.0	1.9	75.0	Weak	Semi-upright	Semi-compact	High
TN1 (Susceptible Control)	110.0	26.5	136.5	9.5	119.0	126.0	2.0	82.0	Intermediate	Semi-upright	Semi-compact	Moderate

Legend: CL-culm length; PL- panicle length; PH- plant height; PN- panicle number; FG- filled grains; UFG- unfilled grains; GW- grain weight; HD- 50% heading date; CLR- culm lodging resistance; PMA- panicle main axis attitude; PBA- panicle branching attitude; PS-panicle shattering.
*Data Source: PhilRice Genebank, Central Experiment Station (CES), Nueva Ecija.

Table 7. Area under the disease progress curve (AUDPC) for percent tungro incidence of Maguindanao traditional rice varieties.

Maguindanao Traditional Rice Varieties	AUDPC Means[1]
Dinorado 1	660.00a
Pulot A Pande	650.00a
Inemay 1	616.67ab
Manisi	613.33 ab
Manisi (Red)	603.33 ab
Mobpon	600.00ab
Dinorado 2	586.67ab
Inemay 2	576.67ab
Pulot A Pikit (White)	563.33ab
Pulot A Narra	556.67ab
Kua-Kua	520.00ab
Pulot A Papakan	520.00ab
Pulot A Pega	496.67ab
Inabaka	496.67ab
Manek-Manek	453.33b
TN1 (Susceptible control)	520.00ab
F-Test	0.0074- significant

[1]Means with the same letter are not significantly different at P<0.05 according to Tukey's Honest Significant Difference (HSD) test.

A Pakpakan and Kua Kua had the lowest incidence of 83% but later increased to 100% at 6 wpi. At 6 wpi, all TRVs except Inabaka and Manek Manek (93%) had 100% incidence similar to TN1.

Area Under Disease Progress Curve (AUDPC)

The AUDPC, which measures the progress of disease incidence over time varied among the Maguindanao TRVs (Table 7). Most varieties (10/15) such as Dinorado 1, Pulot A Pande, Inemay 1, Manisi, Manisi Red, Mobpon, Dinorado 2, Inemay 2, Pulot A Pikit (White), Pulot A Narra had AUDPC values (556.67-660) higher than the value (520) of the susceptible control variety TN1. Kua Kua and Pulot A Papakan had similar AUDPC values (520) with TN1. Only three out of ten TRVs such as Pulot Pega, Inabaka had lower AUDPC values (496.67) and Manek Manek (453.33) than TN1.

Disease Index and Response to Tungro Disease

All the 15 Maguindanao TRVs tested in this study showed a susceptible tungro response based on the computed DI at 2 wpi and 4 wpi (Table 8). Among them, nine had DI values (6.9-8.9), which were higher than the susceptible TN1 variety (6.6) at 2 wpi. These varieties are Dinorado 1 (8.9), Mobpon (8.7), Manisi (Red) (8.5), Manisi (7.8), Inabaka (7.4), Inemay 1 (7.4), Inemay 2 (7.3), Pulot A Pikit (White) (7.1) and Kua-Kua (6.9). Pulot A Pande had DI = 6.6, similar to TN1. Dinorado 2, Manek-manek, Pulot A Narra, Pulot A Pega and Pulot A Papakan had slightly lower DI (6.1) than TN1. At 4 wpi, all TRVs had DI = 9 that corresponds to a susceptible response similar to TN1. Infected TRVs with DI = 9 had more than 50% height reduction, with distinct yellow to yellow-orange leaf discoloration as shown in Figure 4.

Table 8. Disease index (DI) and response of Maguindanao traditional rice varieties to tungro disease.

Maguindanao Traditional Rice Variety	2 weeks post inoculation		4 weeks post inoculation	
	Disease Index[1]	Response[2]	Disease Index[1]	Response[2]
Dinorado 1	8.9	S	9	S
Mobpon	8.7	S	9	S
Manisi (Red)	8.5	S	9	S
Manisi	7.8	S	9	S
Inabaka	7.4	S	9	S
Inemay 1	7.4	S	9	S
Inemay 2	7.3	S	9	S
Pulot A Pikit (White)	7.1	S	9	S
Kua-Kua	6.9	S	9	S
Pulot A Pande	6.6	S	9	S
Dinorado 2	6.1	S	9	S
Manek-Manek	6.1	S	9	S
Pulot A Narra	6.1	S	9	S
Pulot A Pega	6.1	S	9	S
Pulot A Papakan	6.1	S	9	S
TN1 (susceptible control)	6.6	S	9	S

[1]Disease Index: 0-3, resistant or tolerant; 4-6, moderate: 7-9, susceptible; [2] S- susceptible

DISCUSSION

Planting of TRVs must consider varieties that possess both tungro resistance and good agromorphological traits. Simple matching using cluster analysis showed that the 55 out of 61 TRVs clustered into three groups with similarities of 72.4% for qualitative traits and 39/61 with 54.6% for quantitative traits. Percent similarity presents the natural grouping of a set of patterns, points or objects of the variables (www.ipl.org/essay). The analysis showed that TRVs belonging to the same cluster for qualitative traits are not highly similar. Similarities for qualitative traits were lower with 54.6%.

In this study, the Philippine TRVs possessing both good agromorphological traits and tungro resistance have been determined from the information of 61 varieties obtained from the PhilRice Genebank. The 61 TRVs are part of the total 7716 collections stored at the PhilRice Genebank in Munoz, Nueva Ecija. Among the 61 TRVs that have been evaluated by PhilRice, 55 are susceptible and six have intermediate resistance. TRVs with intermediate resistance are characterized by lower disease incidence of 21-40%. These TRVs are Azucena 4 (Negros Occidental), Azucena 1 (North Cotabato), Denorado 1 (Maguindanao), Dinurado (Ilocos Norte), Maliket (Ilocos Norte) and Milagrosa Pula (Palawan). However, TRVs of the same name have different responses to tungro. For instance, the other 8 out of 10 Dinorado tested are susceptible while Dinurado and Denorado 1 mentioned above have intermediate resistance. These TRVs with intermediate tungro resistance possess some good agromorphological traits. Azucena 4 (Negros Occidental) has strong CLR, slightly drooping PMA, and low PS. Azucena 1 (North Cotabato) has semi-compact PMA and moderate PS. Denorado 1 (Maguindanao) has semi-compact PBA, Dinurado (Ilocos Norte) has intermediate CLR, semi-compact PBA and low PS. Maliket (Ilocos Norte) has intermediate CLR, strong upright PMA, semi-compact PBA and very low PS. Milagrosa Pula (Palawan) has strong CLR and semi-compact PBA. Strong lodging resistance is an important trait to keep the plant resistant to strong winds, heavy rains and some of abiotic stresses (Hitaka, 1969). Estimation of heading date greatly helps the breeders to understand the suitability of different varieties in a given location (Desai et al. 2019). Panicle shattering is an important agronomic trait as its rate directly affects relative to yield (Okubo, 2014).

Spearman's rank correlation analysis using the 61 TRVs did not show any significant correlation between tungro response with both qualitative and quantitative agromorphological characters. However, among the correlations of tungro response and quantitative characters, the highest positive correlation coefficient was found for days to 50% heading followed by culm length, plant height, and panicle length. These quantitative traits can be associated with tungro symptoms such as delayed flowering, stunting or reduced plant height, and small panicles (Ou, 1985). These observations are similar to a study using canonical vector analysis of the divergence of morphological traits between tungro-resistant and susceptible rice varieties which showed that the highest contribution to the divergence was observed for panicle length, plant height and number of unfilled grains per panicle (Latif et al. 2013).

Agromorphological characterization previously conducted by PhilRice had identified other TRVs with desirable agromorphological traits. Eleven out of 37 accessions with short stature (plant height (90–100 cm), short to medium duration or maturity (110–120

days) have been identified (Rabara et al. 2014). In addition, a number of TRVs have been identified with long panicle length (> 32 cm) such as Sto. Nino, Speaker, Sampukoy, Salumanay, Putan-Kapa, Palaweña, Palawan, Malagkit Kapa, Madya, Ilon-ilon, Gobierno, Galo and Canadal, while Tulloy, Salumanay, Pah-nga, Malagkit Kapa, Malagkit Black, Kayasakas, Diko, and Bulgar produced the heaviest grain (> 35 g) (Ferrer et al. 2020). These varieties, except Palawan and Galo, are candidate materials for tungro resistance evaluation. Varieties Palawan and Galo have been evaluated and are among the susceptible TRVs identified by PhilRice.

The TRVs that have been evaluated for agromorphological and tungro resistance are still limited. It is important to identify more varieties that can be recommended for planting especially on a particular location where TRVs are mainly grown. In this study, additional TRVs using 15 Maguindanao varieties were evaluated to identify tungro resistant TRVs with good agromorphological traits. Tungro response evaluated by forced-tube inoculation showed that all of the 15 TRVs were susceptible. Although Dinorado 2, Manek-Manek, Pulot A Narra, Pulot A Pega, Pulot A Papakan had slightly delayed disease development (lower disease index) during the early stage of infection at 2 wpi but their response was comparable to TN1 at 4 wpi. During the evaluation, there was no escape of infection as shown by the susceptible reaction of the control TN1 variety. All the TRVs were found to be susceptible comparable to TN1 with symptoms of severe stunting and yellow-orange discoloration. Some TRVs found to have some good agromorphological traits are Dinorado 2 with PH (93.6 cm), strong CLR, semi-upright PMA, semi-compact PBA and moderate PS. Kua-Kua has desirable PL (30.6 cm), intermediate CLR, semi-upright PMA and semi-compact PBA. Inabaka has a PL of 35.4 cm semi upright PMA, and semi compact PBA.

This study presented the forced-tube inoculation as a preliminary screening method for the evaluation of tungro response following the IRRI standard evaluation system for tungro disease (INGER, 1996; Azzam et al. 2000). In this system, if any promising varieties are identified, then they are subjected to further evaluation under natural infection in the field. Presence of tungro viruses can be tested through detection by enzyme-linked immunosorbent assay (ELISA) or polymerase chain reaction (PCR) especially if the plants do not show distinct tungro symptoms. However, in this study, all the Maguindanao TRVs were all susceptible in the preliminary screening. Further in this study, parameters such as disease progress, computed area under the disease progress curve were used in the assessment of Maguindanao TRVs for their tungro response. Following the IRRI standard evaluation system, response to tungro was based on the computed Disease Index (DI), which is a measure of both disease incidence and symptom severity (INGER, 1996). Using the DI value, the response can be classified as resistant or tolerant with DI = 0-3; moderate = 4-6; and susceptible = 7-9. At PhilRice, tungro resistance evaluation follows the National Cooperative Testing (NCT) Guidelines for field screening under natural infection. Tungro response is based on disease incidence wherein varieties with 0-20% are considered as resistant (R), 21-40%, Intermediate (I) and 41-100%, Susceptible (S).

In the evaluation conducted by PhilRice, varieties with the same name such as Dinorado and Azucena had varying tungro response. For Dinorado, 2 out of 10 (Dinurado from Ilocos Norte, Denorado 1 from Maguindanao) have intermediate resistance while the remaining (8) are susceptible. The susceptible Dinorado TRVs are Denorado 2, Dinorado Puti, Dinorado 1, 2, 3, 4, 5, Dinorado Haba. In this study, the two Dinorado TRVs (Dinorado 1 and Dinorado 2) from Maguindanao were both susceptible. Tungro response may vary depending on the amount of disease pressure during the evaluation in the field. The number of leafhopper vectors and local sources of inoculum vary both within and between seasons, and between locations (Azzam et al. 2000). Likewise, for Azucena, 2 out of 3 (Azucena 4 from Negros Occidental and Azucena 1 from North Cotabato) had intermediate resistance and Azucena 2 (Ilocos Norte) was susceptible. In this study, tungro response was only intermediate in 6 out of the 61 TRVs analyzed, and none was resistant or tolerant. Likewise, none of the 15 Maguindanao TRVs showed resistance or intermediate response.

CONCLUSION

Six Philippine TRVs with good agronomic traits and intermediate tungro resistance were identified from the list of 61 TRVs' obtained from the information in the PhilRice Genebank. These are Azucena 4 (Negros Occidental), Azucena 1 (North Cotabato), Denorado 2 (Maguindanao), Dinurado (Ilocos Norte), Maliket (Ilocos Norte) and Milagrosa Pula (Maguindanao). Azucena 4 (Negros Occidental) has strong CLR, slightly drooping PMA, and low PS. Azucena 1 (North Cotabato) has semi-compact PMA and moderate PS. Dinurado (Ilocos Norte) has intermediate CLR, semi-compact PBA and low PS. Denorado 2 (Maguindanao) has a semi-compact PBA. Maliket (Ilocos Norte) has intermediate CLR, strong upright PMA, semi-compact PBA and very low PS. Milagrosa Pula (Palawan) has strong CLR and semi-compact PBA. None of the agromorphological traits was significantly correlated with tungro response but positive correlation coefficients were found for several quantitative traits. The 15 Maguindanao TRVs evaluated in the study were all susceptible to tungro by forced-tube inoculation. Maguindanao TRVs possessing some of the good agromorphological traits are Dinorado 2 with desirable PH, strong CLR, semi-upright PMA, semi-compact PBA and moderate PS. Kua-Kua has desirable PL, with intermediate CLR, semi-upright PMA and semi-compact PBA. Inabaka has desirable PL, semi upright PMA and semi compact PBA. More TRVs from the Genebank collections need to be screened for tungro resistance. Although limited TRVs have been analyzed in this study, it appeared that TRVs with tungro resistance are limited. Thus, planting of TRVs especially the susceptible ones must be accompanied with proper tungro management.

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