International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

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Effect of water stress on growth, yield and yield components of rice (*Oryza sativa L.*) genotypes

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International Journal of Science and Research Archive, 2022, 05(01), 028–038

Publication history: Received on 20 December 2021; revised on 27 January 2022; accepted on 29 January 2022

Article DOI: https://doi.org/10.30574/ijsra.2022.5.1.0030

Abstract

This study aimed to examinate effects of drought stress on rice agronomical traits and identify rice genotypes and elite lines that are tolerant to drought. Twenty genotypes consisting of seventeen inbred lines, two parental lines (IR64 and B6144F-MR) and drought tolerant variety APO were evaluated in a split plot design with four replications in experiment with and without water stress. Analysis of variance results indicated that the effects of genotype and drought stress were highly significant for day to 50% flowering, panicle leaf length, panicle leaf width, plant height, panicles number per m^2, 1000 grains yield and grains yield. Genotype, drought stress, and Genotype × drought interaction was highly significant for day to 50% flowering, plant height and grains yield. Number of tillers m^2, panicle leaf length, plant height, 1000 grains weight, biomass and grains yield were decreased with increasing water stress level; however, day to 50% flowering and panicles number per m^2 were increased. Responses of the rice genotypes in water stress varied significantly. There had been different degree of reduction to the yield contributing characters for the stress. From the findings of this study genotypes APO, IRB-MR-412 and B6144F-M showed best drought tolerant level, as these genotypes gave significantly higher yield than the other genotypes under study.

Keywords: Rice; Genotype; Water stress; Growth stages; Yield; Yield components; Drought

1. Introduction

Drought is one of the inherent abiotic constraints that affect agricultural productivity worldwide. It is estimated that water stress can potentially reduce crop yields by nearly 20% [4]. Water is needed at every phase of rice plant growth from seed germination to plant maturation. Thus, insufficient water supply during critical phases of development such as vegetative, flowering or fruit set stages causes substantial yield loss any crops [17]. Rice is known to be the important primary and staple food for more than two-third of the world's population bur it is susceptible to drought as compared to other crop species [20, 23]. This sensitivity normally severe at reproductive stage and it can lead to various degrees of sterility.

Drought stress is of high importance for drought-sensitive plants, particularly in rice. According to [24] and [26], rice varieties have differential responses to water stresses because of the complexity of interactions between stress factors and various molecular, biochemical, and physiological processes that affect plant growth and development. It is a common constraint in upland cultivation systems of plants and more than 20 million hectares of rain-fed lowland rice

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worldwide suffer water deficit at different growth stages [2, 16 and 25]. Several studies reported that drought stress can reduces the rice growth and severely affects different traits, such as seedling biomass, stomatal conductance, photosynthesis, starch metabolism, plant–water relations, grain yield [2, 6 and 16].

Increasing crop tolerance to water shortage would be the most economical approach to improve productivity and to minimize agricultural use of fresh water resources. To meet this objective, a deeper understanding of the possible mechanisms underlying water stress environment is a must. Since water availability will be a major constraint for rice productivity in the near future, we studied the response of some inbred lines of rice along with its parental lines to water deficit aiming to evaluate effect of water stress on growth, yield and yield components of rice genotypes in a field experiment.

2. Material and methods

2.1. Experimental site

Field experiment was carried out at INERA (Environmental and Agricultural research Institute of Burkina Faso) research station based at Banfora in Burkina Faso western region. The experimental site was located between 6°25.415N and 2°19.684E at an altitude of 21 m above sea level.

2.2. Plant materials

To conduct this study, twenty (20) genotypes consisting of seventeen (17) inbred lines from the Indica's cross included their two parents (IR64 and B6144F-MR) and the indica variety APO were used. The inbred lines were obtained from crossing IR64 X B6144F-M. B6144F-M, is a drought resistant landrace and IR64, a variety which possesses many agronomical superior traits. APO is a popular variety known for its adaptation in drought, was used as a check.

2.3. Experimentation and drought induction

Field experiment was conducted in research station of INERA located at Banfora during dry season in 2015 from February to June. Experiment was laid out in a split plot design with four (4) replications. The twenty (20) genotypes were sown in two blocks of irrigation corresponding the two levels of water stress (control: full irrigation and drought stress: water stress at reproductive stages). Twenty-one days old seedlings were transplanted at 20 x 20 cm spacing. The spaces between blocks and between replications were respectively of 0.5 m and 1 m. A well-irrigated block received standard irrigation practices served as the control treatment; and a water-limited block simulated drought stress using a rain-out shelter with minimum irrigation. Experiment was managed following high input system with 300 kg of fertilizers (NPK + urea) and optimum weed and pest management.

2.4. Measurement of agronomical yield and yield components

Several agronomical were evaluated at appropriate times, including day to 50% flowering (D50F), number of tillers per m^2 (Tiller/m^2), panicle length (PL), panicle leaf length (PLL), panicle leaf width (PLW), plant height (PH), panicles number per m^2 (PAN), Biomass (Biomas), 1000 grains weight (1000GW) and grains yield (Gyield).

2.5. Statistical analysis

Analysis of variance (ANOVA) based on two factors (water treatments and genotype) combination model, followed a split plot design, was carried out. The subsequent multiple comparisons among the means of treatments, genotypes and treatments by genotype interactions were examined based on least significant differences (LSD) multiple range tests. All statistical analyses were performed using Statistix 10.

3. Results

3.1. Analysis of variance

The results of analysis of variance related to agro-morphological and yield component traits attributes of rice genotypes under drought stress at and control condition have been presented in Table 1. Analysis showed that water treatment effect was significant for all traits studies except for panicle length (PL) and panicle leaf width (PLW).

Table 1 Analysis of variance of agro-morphological and yield component traits

Source	df	D50F	Tiller/m²	PL	PLL	PLW	PH	PAN	1000GW	Biomas	Gyield
Rep	3	6.8	55241	374.92	123.075	0.04556	319.7	812	4.667	38160000	797259
Genotype (G)	19	29.1**	4699ns	337.74ns	41.488*	0.10717**	200.8**	457.4**	8.119**	61730000ns	5020053**
Water traitement (Wt)	1	17284.8**	1389053**	1000ns	378.225**	0.01056ns	11828.4**	26342.6**	417.025**	2028000000**	1132000000**
Wt X G	19	62.2**	4368ns	362.11ns	28.488ns	0.02306ns	226.8**	252.9ns	2.353ns	30040000ns	3868005**
Error		5.7	4505	344.53	24.579	0.02428	51.9	177.8	2.184	41310000	229804
CV (%)		2.29	19.19	74.39	19.76	11.87	6.39	18.83	6.46	95.92	10.02

D50F: day to 50% flowering, Tiller/m²: number of tillers per m², PL: panicle length, PLL: panicle leaf length, PLW: panicle leaf width, PH: plant height, PAN: panicles number per m², Biomas: Biomass, 1000GW: 1000 grains weight, Gyield: grains yield, *: significant at level $p<0.05$; **: significant at level $p<0.001$; ns: no significant

Genotype effect also were significant for all traits except for number of tillers, panicle length and biomass. The interactions between water treatment and genotypes (Wt x W) showed significantly effects only for day to 50% flowering (D50F), plant height (PH) and grains yield (Gyield). Remaining traits, i.e. panicle length (PL), number of tillers, panicle leaf length (PLL), panicle leaf width (PLW), number of panicles (PAN), 1000 grains weight (1000GW) and biomass don't showed any difference for interaction effect between the two factors studies.

3.2. Drought effect on day to 50% flowering

Days to 50% flowering (D50F) significantly affected in rice genotypes due to drought stress. Water stress decreased day to 50% flowering compared to control condition. Genotype mean of day to 50% flowering ranged from 89 days (IRB-MR-103, IRB-MR-208, IRB-MR-250, IRB-MR-255, IRB-MR-420 and IRB-MR-68) to 102 days (B6144F-M) under non stress (control) irrigated condition and from 105 days (IRB-MR-108) to 119 days (IRB-MR-349) under stress condition.

3.3. Drought effect on Number of tillers / m^2

Water stress and genotypes interacted significantly on number of tillers per m^2. the highest number of tillers per m^2 were obtained with genotype B6144F-M in control condition and with genotype IRB-MR-349 in drought stress condition respectively of 502 and 303 tillers per m^2. The results showed that drought stress decreased the number of tillers per m^2 compared to irrigation condition.

3.4. Drought effect on number of panicles per m^2

Table 2 Water stress effect on day to 50% flowering, number of tillers per m^2 and panicles number per m^2 of rice genotypes

Genotypes	D50F		tiller/m^2		PAN	
	control	stress	control	stress	control	stress
Apo	97.5b	114.75def	471.25ab	242.5cdefgh	61abc	74.25cde
B6144F-M	102.75a	112.75fg	502.5a	223.5h	45.667d	58.75e
IR64	95bcde	112.75fg	478.75ab	260.75bcdefg	67.667a	92abcd
IRB-MR-103	89g	114defg	462.5ab	259.75bcdefgh	61.667abc	112.75a
IRB-MR-108	97bc	105.25h	466.25ab	272.75abcd	60abcd	81.5bcde
IRB-MR-130	92.5efg	118.75a	376.25bc	230.75fgh	59abcd	79bcde
IRB-MR-167	96.5bcde	112.5g	412.5abc	275.5abc	59.667abcd	75.75cde
IRB-MR-177	92.75defg	114.75def	458.75ab	251.75bcdefgh	57.333abcd	73.5de
IRB-MR-208	89.75g	114.5defg	396.25abc	248.75cdefgh	66.667a	99.75ab
IRB-MR-232	96.75bcd	117.5ab	475ab	288ab	61.333abc	73.5de
IRB-MR-250	89g	114.75def	466.25ab	235.75efgh	50cd	81.5bcde
IRB-MR-251	94.5bcdef	112.75fg	471.25ab	260bcdefgh	57abcd	82.25bcde
IRB-MR-255	89.5g	115.75bcd	443.75abc	273.75abcd	65.333ab	95.5abcd
IRB-MR-269	97.75b	113.75defg	416.25abc	263.5bcdef	60abcd	80.25bcde
IRB-MR-278	93cdefg	117.25abc	333.75c	271.5abcde	61abc	97.5abc
IRB-MR-349	90.75fg	119.25a	468.75ab	251.5bcdefgh	62.667abc	74.75cde
IRB-MR-412	92.5efg	113fg	488.75ab	303.5a	60.333abc	89bcd
IRB-MR-420	89.5g	114.75def	391.25abc	255bcdefgh	51.667bcd	93.75abcd
IRB-MR-463	96bcde	113.5efg	433.75abc	226.75gh	60abcd	80.5bcde
IRB-MR-68	89.75g	115.25cde	446.25abc	237.75defgh	59.667abcd	76.75bcde

D50F: day to 50% flowering, Tiller/m^2: number of tillers per m^2, PAN: panicles number per m^2

Number of panicles per m^2 significantly affected in rice genotypes due to drought stress. It ranged from 45 (B6144F-M) to 67 panicles (IR64) under irrigation condition and from 58 (B6144F-M) to 99 panicles (IRB-MR-208) under water stress condition. The result showed that the number of panicles per m^2 under stress condition was the highest than under control condition.

3.5. Drought effect on panicle length, panicle leaf length and panicle leaf width

Table 1 shows that there were no significant differences between treatments, significantly different among the genotypes and significant interaction between treatments and genotypes for panicle length. The means of evaluated for panicle length in non-stress and stress are shown in Table 3. The means of panicle length for almost genotypes and checks were not significantly different between non-stress and water stress. Hence, it shows water stress had no effect on panicle length for these check varieties and genotypes tested.

The result showed also that panicle leaf length were significant differences between treatment and genotypes and not significant for interaction between treatment and genotype. However, panicle leaf width showed significant differences only for genotype effects. The means of panicle leaf length and panicle leaf width for almost genotypes were respectively significantly different and not significantly different between non-stress and water stress. Hence, it shows water stress had effect on panicle leaf length and no effect on panicle leaf width.

Table 3 Drought effect on panicle length, panicle leaf length and panicle leaf width of rice genotypes

Genotypes	PL		PLL		PLW	
	control	stress	control	stress	control	stress
Apo	22b	21.5abcde	24bcd	24abc	1.6a	1.5a
B6144F-M	24.75b	24.5a	32.5a	24.75abc	1.45abc	1.5a
IR64	23.5b	23.25abc	24bcd	26.75ab	1.15d	1.3bcde
IRB-MR-103	22.25b	20.75cde	17.75d	20c	1.275cd	1.2e
IRB-MR-108	23.75b	22.25abcde	28ab	25.5abc	1.25cd	1.4abcd
IRB-MR-130	25.25b	22.25abcde	25.5abc	22.75bc	1.4abc	1.4abcd
IRB-MR-167	25.25b	24ab	26.25abc	25abc	1.3cd	1.425abc
IRB-MR-177	25b	22.75abcd	20.75cd	21.75bc	1.175d	1.25cde
IRB-MR-208	25b	19.25e	32.5a	23.25abc	1.15d	1.3bcde
IRB-MR-232	26.25b	24.25ab	26.25abc	29.5a	1.6a	1.45ab
IRB-MR-250	24.75b	24ab	26abc	26abc	1.275cd	1.225de
IRB-MR-251	23.75b	24ab	26.75abc	21.75bc	1.325bcd	1.3bcde
IRB-MR-255	24.25b	21.5abcde	29ab	21.25bc	1.25cd	1.15e
IRB-MR-269	27.75b	22.75abcd	27.75abc	21.5bc	1.325bcd	1.2e
IRB-MR-278	24.5b	21.75abcde	26abc	23.25abc	1.525ab	1.4abcd
IRB-MR-349	23b	22.75abcd	27.75abc	24.5abc	1.325bcd	1.325abcde
IRB-MR-412	83a	21.25bcde	30ab	23abc	1.4abc	1.2e
IRB-MR-420	23.5b	20de	25.25bc	21.5bc	1.15d	1.15e
IRB-MR-463	25b	23.5abc	26.25abc	21.75bc	1.325bcd	1.225de
IRB-MR-68	26.5b	22.75abcd	30.25ab	23.25abc	1.175d	1.2e

PL: panicle length, PLL: panicle leaf length, PLW: panicle leaf width,

3.6. Drought effect on plant height

The means of plant height for the genotypes were in the range of 88.93 cm (IR64) to 135.60 cm (IRB-MR-250) under no-stress and 97.40 cm (IRB-MR-463) to 107 cm (Apo) under water stress condition are shown in table 4. Water stress had no effect on plant height for IR64 as the mean between control condition and stress condition was not significantly different, with the means of 88.93 cm and 106.45 cm respectively. IRB-MR-177 showed similar result with no significant difference in plant height mean between control condition (99.67 cm) and drought stress condition (105.92 cm). High reduction in plant height was recorded in IRB-MR-463 (33.33 cm) while low reduction in IRB-MR-420 (10.43 cm), Apo (13.18 cm) and IRB-MR-269 (13.48 cm).

Table 4 Drought effect on plant height of rice genotypes

Genotypes	Plant height	
	control	stress
Apo	120.33bcde	107ab
B6144F-M	115.73de	102.55fghi
IR64	88.93f	106.45abc
IRB-MR-103	126.33abcde	102.05ghi
IRB-MR-108	127.67abcd	104.9bcde
IRB-MR-130	119.53bcde	104.3cdefg
IRB-MR-167	125.47abcde	103.5efgh
IRB-MR-177	99.67f	105.92abcd
IRB-MR-208	117.67de	101ij
IRB-MR-232	131.67ab	104.1defg
IRB-MR-250	135.6a	108a
IRB-MR-251	119.8bcde	99.55jk
IRB-MR-255	121.87bcde	106.45abc
IRB-MR-269	118.13de	104.7cdef
IRB-MR-278	114.73e	101.55hij
IRB-MR-349	124.87abcde	105.9abcd
IRB-MR-412	118.73cde	105.2bcde
IRB-MR-420	118.53cde	108.1a
IRB-MR-463	130.73abc	97.4k
IRB-MR-68	130.87abc	103.9defg

3.7. Drought effect on yield and yield components

3.7.1. Grains yields

Rice genotypes grown under water stress condition produced significantly lower grain yields than irrigation condition (Table 5). Grains yields were ranged from 6292 kg/ ha (IR64) to 8923.3 kg/ ha (IRB-MR-232) under irrigation condition and from 1049 kg/ha (IRB-MR-251) to 5471.8 kg/ha (Apo) under stress condition. Yield decline was observed in all rice genotypes grown under drought stress condition. High reduction in grains yields between water treatments was recorded by IRB-MR-251 (2686,4 kg/ha) while low reduction by Apo (2613,5 kg/ha) and IRB-MR-412 (2686,4 kg/ha).

3.7.2. 1000 Kernel Weight

The results showed that 1000 kernel weight was significantly different between treatments. Table 5 shows the mean value of this trait for each of the evaluated genotypes under irrigation and water stress conditions. The means of the 1000 Kernel weight for all of almost genotypes were significantly different between non-stress and water stress treatments. However, the check variety Apo and the genotype IRB-MR-255 showed that the water stress had no effect on 1000 kernel weight.

3.7.3. Biomass

Water stress had an effect on biomass for all genotypes studies as the means between non stress and stress were very significantly different (Table 5). The means of biomass for the genotypes were in the range of 8238 kg/ha to 10776 kg/ha obtained with IRB-MR-232 and IRB-MR-255 under no-stress and 1890.3 kg/ha to 7457.2 kg/ha recorded by IRB-MR-251 and Apo under water stress.

Table 5 Drought effect on grains yield, 1000 grains weight and biomass of rice genotypes

Genotypes	Gyield		1000GW		Biomas	
	control	stress	control	stress	control	stress
Apo	8085.3ab	5471.8a	23.813abc	22.31bc	10148b	7457.2a
B6144F-M	6712.7defg	3484.3b	26.277a	22.213bc	9693b	4486.3c
IR64	6292fg	1497.3fghi	24.853abc	20.59efg	9034b	2968.5defg
IRB-MR-103	6488.7efg	2320.5cd	24.507abc	20.44efg	9608b	3108.3def
IRB-MR-108	6108.3g	1687efg	24.627abc	20.905de	8741b	2817.3efgh
IRB-MR-130	7519.3bcd	1340.8fghi	22.093c	20.48efg	9890b	2948.2defg
IRB-MR-167	7461bcd	1503.3fghi	23.947abc	19.595h	8741b	2296.5hij
IRB-MR-177	6458.3efg	1624.5fgh	26.133a	22.58ab	9532b	2417.5ghij
IRB-MR-208	7053.3cdef	2168.5de	23.6abc	20.34fg	10031b	3376.8de
IRB-MR-232	8923.3a	2531.5cd	24.347abc	21.245d	8238b	3456.8d
IRB-MR-250	6716.7defg	1207.8ghi	25.373ab	23.055a	9357b	2196.8ij
IRB-MR-251	7955.7b	1049i	25.113abc	21.968c	9097b	1890.3j
IRB-MR-255	7986b	1390.8fghi	23.747abc	22.21bc	10776b	2092.5ij
IRB-MR-269	7861.3bc	1245.8fghi	24.04abc	20.62efg	9435b	2248.8hij
IRB-MR-278	7322bcde	1494.3fghi	22.813bc	20.53efg	8031b	2535.3fghi
IRB-MR-349	7613.7bc	2711.3c	23.333abc	20.83def	9706b	3309.3de
IRB-MR-412	8041.7b	5355.3a	26.28a	22.248bc	36314a	6545b
IRB-MR-420	7417bcd	1495.5fghi	26.307a	22.43bc	8547b	2092.5ij
IRB-MR-463	8180.7ab	1724ef	25.8ab	20.405fg	8506b	2499.8ghi
IRB-MR-68	7903.3bc	1181.5hi	25.107abc	20.232g	8452b	2064ij

Gyield: grains yield, 1000GW: 1000 grains weight, Biomas: Biomass.

3.8. Mean's comparisons of different traits as influenced by stress x genotype interaction

Generals means comparison showed that treatment had significant differences for all traits studied traits except for panicle length (PL) and panicle leaf width (PLW) (Table 6). As expected, for all traits studies minimum means were observed in stress condition and maximum performance in normal irrigation excepted for day to 50% flowering and number of panicles. Stress condition compared to normal irrigation significantly decreased number of tillers of 189 tillers, panicle leaf length of 3 cm, plant height of 17 cm, 1000 kernel weight of 3.23 g, biomass of 7121 kg/ha and grains yield of 5319.2 kg/ha. However, water stress increased the day to 50% flowering of 20 days and number of panicles of 25 panicles compared to normal irrigation condition.

Table 6 Mean's comparisons of agro-morphological traits, yield and yields component of rice as influenced by stress x genotype interaction

	D50F	tiller/m²	P_L	PLL	PLW	PH	PAN	1000KW	Biomass	Gyield
WATER TREATMENT										
Control	93.59 b	443 a	22.45a	26.625a	1.3212a	121.32a	57.962 b	24.49a	10261a	7443.4a
stress	114.38 a	256.65 b	27.45a	23.55 b	1.305a	104.13 b	83.625a	21.261 b	3140 b	2124.2 b
GENOTYPES										
APO	106.13abc	356.88abcd	21.75b	24abc	1.55a	113.9bcd	64.75efg	23.21bcdef	8815b	6756.4a
B6144F-M	107.75a	363abcd	24.625b	28.625a	1.475ab	108.73defg	51.75g	23.59bcd	7251b	5067.8cd
IR64	103.87cdefg	369.75abc	23.375b	25.375abc	1.225efg	102.85fg	79.5abcd	23.275bcde	5956b	3906h
IRB-MR-103	101.5hi	361.13abcd	21.5b	18.875d	1.2375efg	115.15abcd	85.75a	22.24defg	6394b	4435.1efg
IRB-MR-108	101.13i	369.5abc	23b	26.75ab	1.325bcdef	116.88ab	70.75bcdef	22.618cdefg	5766b	3963.3gh
IRB-MR-130	105.63abcd	303.5cd	23.75b	24.125abc	1.4abcd	114.58bcd	68.375cdef	21.45g	6417b	4546.4ef
IRB-MR-167	104.5cdef	344abcd	24.625b	25.625abc	1.3625bcde	115.23abcd	66.625cdef	21.407g	5508b	4544.3ef
IRB-MR-177	103.75defgh	355.25abcd	23.875b	21.25cd	1.2125efg	101.99g	66.75cdef	25.13a	6064b	3958.5h
IRB-MR-208	102.13ghi	322.5bcd	22.125b	27.875ab	1.225efg	106.13efg	81.875ab	21.765fg	6734b	4827.1cde
IRB-MR-232	107.13ab	381.5ab	25.25b	27.875ab	1.525a	116abc	66.375def	22.758cdefg	5860b	5663b
IRB-MR-250	101.88ghi	351abcd	24.375b	26abc	1.25defg	122.1a	64.125fg	24.243ab	5701b	3873.6h
IRB-MR-251	103.63defgh	365.63abcd	23.875b	24.25abc	1.3125cdef	109.5cdef	68.625cdef	23.426bcde	5465b	4630.8def
IRB-MR-255	102.62fghi	358.75abcd	22.875b	25.125abc	1.2fg	114.3bcd	79.625abc	23.085bcdef	6386b	4562ef
IRB-MR-269	105.75abcd	339.87abcd	25.25b	24.625abc	1.2625defg	114.25bcd	70.125bcdef	22.42cdefg	5897b	4635.5def
IRB-MR-278	105.13bcd	302.63d	23.125b	24.625abc	1.4625abc	108.65defg	77.5abcde	21.58g	5259b	4348.1fgh
IRB-MR-349	105bcde	360.13abcd	22.875b	26.125abc	1.325bcdef	116.05abc	68.5cdef	22.005efg	6585b	5159.8c
IRB-MR-412	102.75efghi	396.13a	52.125a	26.5ab	1.3defg	112.63bcde	74.625abcdef	23.734abc	17956a	6621.4a
IRB-MR-420	102.13ghi	323.13bcd	21.75b	23.375bcd	1.15g	113.13bcde	72bcdef	24.23ab	5322b	4488.5ef
IRB-MR-463	104.75cdef	330.25abcd	24.25b	24abc	1.275defg	114.8bcd	70.875bcdef	22.708cdefg	5520b	5056.9cd
IRB-MR-68	102.5fghi	342abcd	24.625b	26.75ab	1.1875fg	117.68ab	67.375cdef	22.641cdefg	5159b	4631.6def

D50F: day to 50% flowering, Tiller/m²: number of tillers per m², PL: panicle length, PLL: panicle leaf length, PLW: panicle leaf width, PH: plant height, PAN: panicles number per m², Biomas: Biomass, 1000GW: 1000 grains weight, Gyield: grains yield.

Mean's comparisons for different genotypes revealed that the twenty (20) studied genotypes showed different performance for all traits measured. Day to 50% flowering ranged from 101 (IRB-MR-103, IRB-MR-108 and IRB-MR-250) to 107 (IRB-MR-232 and the check B6144F-M) days after sowing. Genotype IRB-MR-412 had higher performance for number of tillers /m^2 (396 tillers), panicle length (52.125 cm) and along with check variety Apo for grains yield respectively of 6621.4 and 6756.4 kg/ha, while genotype IRB-MR-250 recorded higher performance for plant height (122.1 cm) and 1000 kernel weight (24.243 g). In addition, susceptible check IR64 had shortest plant height (102.85 cm) and along with genotype IRB-MR-250 lowest grains yield respectively of 3906 and 3873.6 kg/ha.

4. Discussion

In this research, we studied the effect of water stress using elites rice genotypes. Agro-morphological traits, yield and yield component of twenty rice genotypes were tested at two different water stressed conditions. Analysis of variance (ANOVA) showed that water stress significantly affected almost traits measured, including day to 50% flowering, number of tillers per m^2, panicle leaf length, panicle leaf width, plant height, panicles number per m^2, grain yield, 1000 grains weight and biomass, indicating that these traits were highly affected by irrigation regime. Genotype effect was significant for all traits except for number of tillers per m^2, panicle length and biomass. Effect of stress x genotype interaction was significant only for day to 50% flowering, plant height and grains yield, signaling that they all contributed to the different performance of genotype grain yield under both water conditions. This finding is in accordance with previous studies witch reported that significant genotypes and water treatment interactions were observed for most agronomical parameters [3, 10, 15 and 19].

In the present research all the yield parameters were adversely affected at all the stress stages and in almost the rice genotypes. The results showed that drought stress increased the delay of 50% flowering and decreased yield; however, the responses varied among genotypes. According to [10], [13] and [14] Flowering delay due to drought stress is negatively associated with grain yield when stress is imposed between panicle initiation and pollen meiosis. Similar to our study, previous studies also reported delays in plant flowering of drought stress [12, 15 and 21]. The delay in flowering is reduced if drought was induced at later growth stages

The number of tillers per m^2 was decreased with drought stress. Reduced tiller production under drought stress might be the fact that under water stress, plants were not able to produce enough assimilates for inhibited photosynthesis. The results agree with [16, 21, 22 and 27].

The number of panicles per m^2 under water stress was the highest compared to under irrigation condition for all genotypes tested. [18] reported that water stress at at mid-tillering, increased number of panicles. According to [9], It seems that water stress at tillering affects assimilates translocation from the most plant part to the panicles. The reduction in leaf cell expansion would decrease sink strength for vegetative growth and lessen the competition with panicle growth for assimilates.

The results showed that water stress had no effect on panicle length. These results corroborate with those of [5] that suggested the water stress imposed no effect on assimilate translocation from leaf to vegetative growth of panicles.

The interaction effect of water stress levels and rice genotypes on plant height was found significant. Plant height were significantly reduced by severe water stress compared to the well-watered plants. The results indicate that plant height decreased with increasing water stress. It might be due to inhibition of cell division or cell enlargement under water stress. Variation in plant height among the genotypes also indicating that rice genotypes had different water requirement. In some cases, the reduction of plant height was also found previously by [7, 9 and 11].

In breeding for drought tolerance, grain yield under water stress is a primary trait. Drought effect on grains yield is due to the relation with duration of watering from flowering until physiological maturity. The results of this study showed that different water treatment levels and rice genotypes interacted significantly for grains yield. All the genotypes produced the highest grain yield under irrigation (control) condition and the lowest grains yield was obtained under stress condition. So, it was observed that grain grains yield decreased in increasing water stress, indicating high sensitivity of rice genotypes to water stress during the reproductive stage of growth. There were differences in 1000 grains weight due to genotypes and water treatments; however, there were no significant differences for their interaction suggesting, that 1000 grains weight is less affected by water treatments compared to other yield components. In addition, water stress had effect on biomass of all the evaluated genotypes as the means between non-stress and stress were very significantly different. To summarize our findings, it can be said that water treatments affected yield and yield components globally in all evaluated genotypes. These results are in agreement with the earlier finding [1, 2, 7 and 20].

5. Conclusion

Experiment was carried out to investigate water stress responses of rice genotypes and determine the thresholds of rice plant morphological agronomical responses during drying cycles. Water stress on the one hand decreased number of tillers per m^2, Panicle leaf length, panicle leaf width, plant height, 1000 grains weight, biomass and grains yield and on the other hand increase day to 50% flowering and panicles number per m^2. Panicles number per m^2 under water stress was highest compared under irrigation condition, but their yields were lowest compared to them from well-watered plants. From the findings of the study, it may be concluded that genotype Apo following by IRB-MR-412 and B6144F-M can be considered like drought tolerant rice genotypes as these genotypes gave significantly higher yield than the other genotypes under study. So, these genotypes can successful be cultivated in drought prone areas.

Compliance with ethical standards

Acknowledgments

The authors thank warmly the whole team of INERA, Cirad and AfricaRice for their active participation to this study. Financial support from General Challenge Program (GCP) is dully acknowledged.

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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