

# Yield Response of Direct Seeded *Aus* Rice Varieties under Rainfed Condition

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## Abstract

Rainfed *Aus* rice is a popular conventional rice cultivation technique that through appropriate variety selection can accelerate the benefits of the farmer. On this context, an experiment was carried out at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706 from April to August in 2014 to evaluate yield performance of some *Aus* rice varieties under rainfed condition. The experiment was laid out in a split plot design with three replications. The experiment consisted of two sets of treatments: water regime as irrigated (irrigation when necessary) and rainfed (dependent on rainfall) in the main plot and 15 varieties into sub-plots. It was revealed that yield and yield contributing characters were significantly influenced by water regime, variety and their interaction. The traits like number of effective tillers and non-effective tillers-hill<sup>-1</sup>, number of filled grains and unfilled grains panicle<sup>-1</sup>, panicle length, test weight, grain yield and harvest index were higher in irrigated crops compared to rainfed. Considering the performance of yield, the highest grain yield recorded in BRRI dhan27 (irrigated-2.47 t·ha<sup>-1</sup> and rainfed-2.26 t·ha<sup>-1</sup>) followed by BRRI dhan55 (irrigated-1.95 t·ha<sup>-1</sup> and rainfed-1.88 t·ha<sup>-1</sup>), BRRI dhan48 and BRRI dhan43 under both irrigated and rainfed treatment. BRRI dhan27 ranked the top under both irrigated and rainfed conditions, however the relative yield was maximum in BRRI dhan55 (reduction was only 3.59%) followed by Nerica10. Hence, considering the yield stability and absolute yield performance, BRRI dhan27 may be considered favorably cultivable for *Aus* season in Bangladesh followed by BRRI dhan55, BRRI dhan48 and BRRI dhan43.

## Keywords

Irrigation, Rice, Varietal Performance, Nerica, Relative Yield

## 1. Introduction

Rice (*Oryza sativa* L.) is the staple food in Bangladesh and also for more than three billion people globally [1]. To feed this huge number of consumers, it needs to cultivate rice at a large scale of area and at a very higher production rate. However, the population of Bangladesh is up surging by about two million every year and expected to increase by another 30 million over the following 20 years. Thus, Bangladesh will demand about 27.26 million tons of rice by 2020 to feed the increased mass of people. On the contrary, total arable land is supposed to be shrunk down to 10.28 million hectares from 11.25 million ha due to settlement and other causes [2]. However, in spite of lots of efforts to escalate productivity, crop loss is stirring at large scale due to several earthly and man-made reasons. Estimates indicate that, more than two hundred million tons of rice is lost every year due to environmental stresses, diseases and pest incidents [3]. Among the environmental stresses, water stress is a major yield restraining factor of rainfed rice, which occupies almost half of the land used for rice production in Asia and in some countries including Bangladesh, Thailand, Laos; it is the dominant rice ecosystem. However, in global aspect, rainfed rice growing areas comprise 45% of the total cultivated rice growing area where drought in mild, moderate or severe forms occurs in most years [4]. Regrettably, highest loss in this practice also befalls due to drought, for its high requirement of water, thus causing damage to 2.32 million hectares crop per annum [5]. These water stress vulnerability scenarios are likely to be worsen in the future with predicted climate change scenarios, which will also lead to more complex interactions of water stress with other abiotic and biotic stresses. The frequency of water stress varies in timing and severity among locations and years. Among the rice cultivating seasons in Bangladesh viz. *Aus*, *Aman* and *Boro*, *Aus* rice is mostly cultivated under rainfed condition during April to August where June to July are most important as the crop passes its reproductive stage during this time yet the rainfall is very erratic in nature. Consequently, water stress upsurge occurs and affects translocation of assimilates and grain development in rice which results in loss of yield, particularly during reproductive stage when plants are highly sensitive to water stress [6]. Water stress reduces the grain filling percentage and grain weight, resulting in a significant decrease of grain yield by 11.6% to approximately 14.7%. *Aus* rice requires less number of days to mature compared to *Aman* and *Boro*. So, it has the capability to escape late season drought [2]. Therefore, prearranged the large area under rainfed rice cultivation system and the increasing prevalence of drought stress in a wide range of cultivation systems because of declining water table depths, improving the *Aus* rice varieties has a large potential for helping to achieve sustainable rice production. Hence, increasing *Aus* rice productivity may become substitute the gap in progress due to water scarcity as well as reduce pressure upon groundwater. Henceforth, it is necessary to find out *Aus* rice genotypes which exhibit the desired characters like short duration, high yield potential and tolerant towards water stress, so that they can be taken for mass scale production

under rainfed condition. Use of yield as an index for adaptation to water stress in rice [7] may be considered as a reasonable approach, as grain yield is a major attribute of interest in most plant breeding programs. Therefore, selection of rice varieties and breeding lines with high levels of stress tolerance is one of the main challenges for rice research in recent times [8]. With that background problem and opportunity, this research was initiated to assess yield and yield contributing characters and recommend the ones which give higher yield in spite of rainfed condition.

## 2. Materials and Methods

### 2.1. Description of Experimental Site

The experiment was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur 1706 during April to August 2014 to evaluate some *Aus* rice varieties for their yield performance under rainfed condition. The site was high land and located in Madhupur Tract under Agro Ecological Zone-28. The soil of the experimental site belongs to Salna series representing shallow Red-Brown Tarace soil type which falls under the order of Inceptisols of soil taxonomy [9]. The meteorological data during the study period were recorded from the meteorological station of BSMRAU and was given in **Table 1**.

### 2.2. Experimental Details

Cultivated fifteen popular *Aus* rice varieties viz. BR3, BR14, BR16, BR21, BR24, BR26, BRR1 dhan27, BRR1 dhan42, BRR1 dhan43, BRR1 dhan48, BRR1 dhan55, BRR1 dhan57, Nerica1, Nerica10 and NericaABSS (mutant) were used as planting materials. The experiment was laid out in a split plot design with three replications. The number of main plots and sub-plots was 6 and 90 respectively and the size of unit sub-plot was 3 m × 1 m. The experimental treatments viz. water regime as irrigated (irrigation when necessary) and rainfed (dependent on rainfall) were applied in main plots and the varieties were placed into the sub plots. Water regime treatment started at 20 days after sowing (DAS).

**Table 1.** Month wise meteorological data.

Month of 2014	AT (°C)			ST in depth (°C)		H (%)	R (mm)	E (mm)	AP (Hg)	GWT (m)
	Max.	Min.	Avg.	10 cm	20 cm					
April	35.48	23.71	29.6	29.61	28.41	74.63	112.64	187.02	29.91	23.22
May	34.74	26.06	30.40	31.74	30.47	81.80	138.62	139.94	29.87	23.00
June	32.75	26.63	29.69	31.61	30.06	84.33	322.33	97.19	29.82	23.00
July	33.06	27.22	30.14	32.11	30.62	85.19	229.69	103.91	14.38	22.84
August	31.75	26.90	29.33	29.77	28.98	83.96	420.05	84.57	00.00	-

Here, AT = Air Temperature; ST = Soil Temperature; H = Humidity; R = Rainfall; E = Evaporation; AP = Atmospheric Pressure and GWT = Ground Water Table.

### 2.3. Operations

The land preparation was done by repeated ploughing and cross-ploughing with a tractor drawn disc plough and then harrowed. Each ploughing was done followed by laddering for breaking the clods, leveling the lands and collecting the stubbles and removing the weeds. Rainfed plots were protected by polythene sheet to control entry of irrigation water. Healthy and vigorous seeds were collected from Bangladesh Rice Research Institute (BRRI). The selected seeds were soaked in water for 24 hours and then these were kept in gunny bags. The seed started sprouting after 48 hours and almost all seeds were sprouted after 72 hours. Three rice seeds·hill<sup>-1</sup> was sown maintaining 20 cm × 15 cm spacing in line by hand on 9 April 2014. After sowing of seeds, light irrigation was provided to ensure uniform establishment of plants. A basal dose of P K and S at the rate of 80, 110 and 100 kg·ha<sup>-1</sup> was applied respectively. Nitrogen fertilizer was applied at the rate of 175 kg·ha<sup>-1</sup> in three splits. First split as basal dose and rest at 35 DAS and 55 DAS. Gap filling was done 15 DAS for maintaining the optimum plant population. Hand weeding was done at 15, 35, 55 and 75 DAS to keep the field weed free. Rice bug (*Leptocorisa acuta*) was controlled instantly by using insecticide Diazinon 60EC@3 ml/L at 65 DAS by successive two sprays at seven days intervals.

### 2.4. Data Collection

The crop varieties were harvested from 100 to 130 DAS when the grains attained full maturity. Ten hills were randomly sampled from each sub-plot (outside the area selected for final harvest) for recording necessary data. At maturity (when 90% of the grains became golden yellow in color), one square meter area from each sub-plot was randomly selected from the central portion and cut manually from the ground level to measure grain and straw yields. The harvested crops of each plot were separately bundled, properly tagged and then brought to the threshing floor. The harvested crops were threshed manually. The grains were cleaned and dried to around 14% moisture content. Final grain yields plot<sup>-1</sup> were recorded and converted to t·ha<sup>-1</sup>. Data were collected for number of effective and non-effective tillers·hill<sup>-1</sup>, number of filled and unfilled grains panicle<sup>-1</sup>, panicle length (cm), test weight (g), grain yield (t·ha<sup>-1</sup>) and harvest index (%).

The formula used for different parameters:

Grain yield at 4% moisture

$$= \frac{(100 - \text{Sample moisture content (\%)} \times \text{fresh weight of grain (t/ha)})}{(100 - 14)}$$

Biological yield = Grain yield + Straw yield,

$$\text{Harvest index (\%)} = \frac{\text{Grain yield} \times 100}{(\text{Grain yield} + \text{Straw yield})}$$

$$\% \text{ Reduction} = \frac{\text{Irrigated data} - \text{rainfed data}}{\text{irrigated data}} \times 100.$$

## 2.5. Data Analysis

The data were analyzed statistically and the differences among treatment means were adjudged by least significant difference (LSD) test at 5% level of significance [10]. Analysis was done with the help of statistical analysis package program Statistix 10.

## 3. Results

### 3.1. Contribution of Yield Components

Tillering is an important agronomic trait for rice production (Badshah *et al.*, 2014) and the number of productive tillers depends on planting density, genotypes and its environment. An effective tiller means the tillers that produce panicle. Effective and non-effective tillers of tested varieties were significantly influenced by irrigated and rainfed treatment (**Table 2**). Among the tested varieties, the maximum number of effective tillers-hill<sup>-1</sup> (25.32 and 22.33) was found in BRRI dhan27 which was statistically different from others and the minimum was (9.14 and 6.54) noticed in Nerica1 which was statistically akin to Nerica10 under both irrigated and rainfed treatment respectively. However, the highest relative number of effective tillers-hill<sup>-1</sup> was found in BRRI dhan55 (reduction was only 7.22%).

**Table 2.** Effect of irrigated and rainfed condition on effective and non-effective tillers-hill<sup>-1</sup> of *Aus* rice varieties

Varieties	Effective tillers-hill <sup>-1</sup>			Non-effective tillers-hill <sup>-1</sup>		
	irrigated	rainfed	% reduction	irrigated	rainfed	% reduction
BR3	20.24c	18.32c	9.48	2.84b	3.74b	-31.69
BR14	16.80e	14.88d	11.42	1.91d	0.97fg	49.21
BR16	17.56d	14.26d	18.79	1.08d	2.84c	-162.96
BR21	14.71e	13.54de	7.95	0.78f	2.14d	-174.35
BR24	20.35c	17.86c	12.23	1.68d	2.30d	-36.90
BR26	20.20c	14.87d	26.38	1.67d	1.33f	20.36
BRRI dhan27	25.32a	22.33a	11.81	4.03a	2.87c	28.78
BRRI dhan42	18.24d	15.17d	16.83	1.58d	2.09d	-32.27
BRRI dhan43	20.41c	18.24c	10.63	2.19c	2.40d	-9.59
BRRI dhan48	21.54b	19.79bc	8.12	0.43g	2.70c	-527.91
BRRI dhan55	22.98b	21.32b	7.22	1.97d	1.95e	1.02
BRRI dhan57	19.7cd	15.27d	22.48	1.29e	1.26f	2.33
Nerica1	9.14g	6.54g	28.45	0.82f	4.83a	-489.02
Nerica10	11.54fg	8.25fg	28.51	0.71f	2.67c	-276.05
NericaABSS	15.41e	13.48de	12.52	1.83d	2.73c	-49.18
CV (%)		7.58, 9.84			4.65, 7.45	

Mean values having the similar letter (s) differ insignificantly whereas mean values having dissimilar letter (s) differ significantly as per DMRT at the 0.05 probability level.

Again, data presented in **Table 3** revealed that the highest number of non-effective tillers-hill<sup>-1</sup> (4.03) was found in BRR1 dhan27 which was statistically different from others and the lowest (0.43) was noticed in BRR1 dhan48 under irrigated condition. In contrast, under rainfed, the highest number of non-effective tillers-hill<sup>-1</sup> (4.83) was found in Nerica1 which was statistically different from other varieties and the lowest (0.97) was observed in BR14. The highest relative number of non-effective tillers-hill<sup>-1</sup> was found in BRR1 dhan55 (reduction was only 1.02% from irrigated condition).

Irrigated and rainfed treatment had considerable effect on number of filled and unfilled grains panicle<sup>-1</sup> of the studied varieties (**Table 3**). Among the fifteen varieties of *Aus* rice, the highest (141.90 and 136.21) and the lowest (69.33 and 55.8) number of filled grains panicle<sup>-1</sup> was recorded in BRR1 dhan27 and in Nerica1 under both irrigated and rainfed conditions respectively. Yet, the highest relative number of filled grains panicle<sup>-1</sup> was found in BRR1 dhan55 (reduction was only 3.71%) followed by BRR1 dhan27.

The highest number of unfilled grains panicle<sup>-1</sup> (39.46) was observed in Nerica1 which was statistically different from other varieties and the lowest (16.53) was observed in BR21 under irrigated condition (**Table 3**). On the other hand,

**Table 3.** Effect of irrigated and rainfed condition on filled and unfilled grains panicle<sup>-1</sup> of *Aus* rice varieties.

Varieties	Filled grains panicle <sup>-1</sup>			Unfilled grains panicle <sup>-1</sup>		
	irrigated	rainfed	% reduction	irrigated	rainfed	% reduction
BR3	133.14b	118.21c	11.21	21.93f	29.86fg	-36.16
BR14	110.28e	106.48d	3.45	25.43de	34.23de	-34.60
BR16	117.54d	100.14d	14.80	24.00e	35.40cd	-47.50
BR21	100.34f	88.54e	11.76	16.53h	27.50hi	-66.36
BR24	113.41de	103.18d	9.02	27.03d	36.63bc	-35.52
BR26	107.63e	97.57d	9.34	24.83de	33.56de	-35.16
BRR1 dhan27	141.90a	136.21a	4.01	21.80f	27.23fg	-24.91
BRR1 dhan42	108.16e	94.9de	12.25	31.20b	40.97bc	-31.31
BRR1 dhan43	127.16c	114.59c	9.89	24.56e	42.10b	-71.42
BRR1 dhan48	130.21b	114.24c	12.26	26.60de	35.80cd	-34.59
BRR1 dhan55	128.93c	124.15b	3.71	27.80d	39.83bc	-43.27
BRR1 dhan57	130.54b	118.1c	9.53	18.83gh	29.36fg	-55.92
Nerica1	69.33g	55.8g	19.51	39.46a	56.20a	-42.42
Nerica10	102.3f	79.27f	22.51	29.13c	43.73b	-50.12
NericaABSS	105.97e	94.33de	10.98	30.70bc	33.17ef	-8.05
CV (%)		6.73, 9.46			3.48, 7.25	

Mean values having the similar letter (s) differ insignificantly whereas mean values having dissimilar letter (s) differ significantly as per DMRT at the 0.05 probability level.

Nerica1 produced the highest number of unfilled grains panicle<sup>-1</sup> (56.20) which didn't show statistical harmony with other varieties and the lowest number of unfilled grains panicle<sup>-1</sup> (27.33) was observed in BRR1 dhan27 under rainfed. However, the maximum relative number of unfilled grains panicle<sup>-1</sup> was observed in NericaABSS (reduction was only by 8.05%) followed by BRR1 dhan27.

Panicle length and test weight contributed much to increase of grain yield. Data presented in **Table 4** exerted meaningful effect on panicle length and test weight by irrigated and rainfed condition. The highest panicle length (28.77 cm and 26.93 cm) was measured in BRR1 dhan27 which was statistically different from others and the lowest was (21.10 cm and 20.23 cm) obtained from Nerica1 under both irrigated and rainfed respectively. However, the highest relative panicle length was found in NericaABSS (reduction was only 1.70%) followed by Nerica10.

Among the varieties, the highest test weight (29.97 g) was found in BRR1 dhan27 which was statistically similar with BR3 and the lowest 1000-grain weight (19.23 g) was observed in BR26 which showed statistical harmony with BR21 under irrigated (**Table 4**). In contrast, under rainfed the highest test weight (29.23 g) was also found in BRR1 dhan27 and the lowest (19.34 g) was found in

**Table 4.** Effect of irrigated and rainfed condition on panicle length and test weight of *Aus* rice varieties.

Varieties	Panicle length			Test weight		
	irrigated	rainfed	% reduction	irrigated	rainfed	% reduction
BR3	25.17b	24.09b	4.29	28.25ab	27.67b	2.05
BR14	24.29c	23.57c	2.96	27.84b	26.21b	5.85
BR16	25.13b	24.18b	3.78	25.35c	24.41c	3.71
BR21	24.11c	22.53d	6.55	20.67ef	19.84f	4.02
BR24	24.79bc	23.19c	6.45	22.84e	21.47e	5.99
BR26	23.72d	22.19d	6.45	19.23f	19.34f	-0.57
BRR1 dhan27	28.77a	26.93a	6.39	29.97a	29.23a	2.46
BRR1 dhan42	22.73e	21.11e	7.12	22.35e	21.29e	4.74
BRR1 dhan43	23.99d	21.85e	8.92	23.39d	21.58e	7.7
BRR1 dhan48	24.69c	22.97d	6.97	23.75d	21.50e	9.47
BRR1 dhan55	25.76b	24.19b	6.09	24.76cd	24.21c	2.22
BRR1 dhan57	24.87c	23.14c	6.96	23.79d	22.83d	4.04
Nerica1	21.10f	20.23f	4.12	26.62bc	25.16bc	5.48
Nerica10	23.15d	22.62d	2.29	23.45d	22.19d	5.37
NericaABSS	24.08c	23.67c	1.70	23.91d	22.64d	5.31
CV (%)		4.55, 5.02			2.81, 3.36	

Mean values having the similar letter (s) differ insignificantly whereas mean values having dissimilar letter (s) differ significantly as per DMRT at the 0.05 probability level.

BR26 which was statistically identical to BR21. And yet, the highest relative 1000-grain weight was found in BR3 (reduction was only 2.05%) followed by BRRI dhan55.

The major factor of increasing harvest index (HI) is to increase economic yield. In the present study **Table 5** showed that the highest HI (45.66%) was found in BRRI dhan27 which was statistically similar with BRRI dhan55 and the lowest HI (34.60%) was observed in Nerica1 which was statistically different from others under irrigated treatment.

In contrast, the maximum HI (44.64%) was noticed in BRRI dhan27 which was statistically identical to BRRI dhan48, BRRI dhan55 and the minimum HI (33.33%) was recorded in Nerica1 which was statistically diverse from other varieties under rainfed. However, the highest relative HI was found in BRRI dhan42 (reduction was only 0.26%) followed by BRRI dhan57.

### 3.2. Ranking of Tested Varieties Based on Grain Yield

Final yield is the product of cumulative seasonal absorption of radiation, radiation use efficiency and the portion of total biomass that goes to grain (harvest index). Yield is a complex phenomenon and influenced by several factors. Yield

**Table 5.** Effect of irrigated and rainfed condition on grain yield and harvest index of *Aus* rice varieties.

Varieties	Harvest index (%)		
	irrigated	rainfed	% reduction
BR3	43.10c	42.55c	1.28
BR14	42.55d	41.15d	3.29
BR16	42.02d	41.15d	2.07
BR21	42.66d	40.65e	4.71
BR24	41.32e	40.48e	2.03
BR26	41.67e	40.32e	3.24
BRRI dhan27	45.66a	44.64a	2.23
BRRI dhan42	42.13d	42.02c	0.26
BRRI dhan43	43.67bc	42.92c	1.72
BRRI dhan48	44.44b	44.05a	0.87
BRRI dhan55	45.05a	44.64a	0.91
BRRI dhan57	43.49c	43.10b	0.89
Nerica1	34.60g	33.33g	3.67
Nerica10	36.76f	35.59f	3.18
NericaABSS	41.32e	40.82e	1.21
CV (%)	2.43, 3.76		

Mean values having the similar letter (s) differ insignificantly whereas mean values having dissimilar letter (s) differ significantly as per DMRT at the 0.05 probability level.



of cereals entirely depends on maximum effective tiller formation, filled grains per panicle, panicle length etc. which rely on availability of water in the field. The ranking of rice genotypes based on their grain yield production under irrigated and rainfed conditions is given in **Table 6**.

It is obvious from the result that most of the genotypes exhibited yield stability under changing growth environment by maintaining almost equal ranking under both irrigated and rainfed conditions, except a few, e.g. BR16. However, the ranking of relative grain yield (% yield under rainfed condition in relation to irrigated condition) was not following that of absolute yield under both the growing conditions.

For instance, BRR1 dhan27 ranked the top under both irrigated and rainfed conditions, but the relative yield was the maximum in case of BRR1 dhan55 (reduction was only 3.59%) followed by Nerica10. Though the relative yield is important consideration for physiologist to understand the yield loss mechanisms due to water shortage, absolute productivity is the main consideration for the cultivators and from the agronomic point of view. Therefore, considering the yield stability and absolute yield performance BRR1 dhan27 may be considered especially for *Aus* rice cultivation followed by BRR1 dhan55, BRR1 dhan48 and BRR1 dhan43.

**Table 6.** Ranking of varieties based on grain yield under irrigated and rainfed conditions.

Varieties	Grain yield (t-ha <sup>-1</sup> )				% reduction
	irrigated	rank	rainfed	rank	
BRR1 dhan27	2.47a	1	2.26a	1	8.50
BRR1 dhan55	1.95b	2	1.88b	2	3.59
BRR1 dhan48	1.90bc	3	1.79c	3	5.79
BRR1 dhan43	1.88c	4	1.71cd	4	9.04
BR3	1.88c	4	1.67d	6	11.17
BRR1 dhan57	1.86c	5	1.69d	5	9.14
BR16	1.70d	6	1.41e	10	17.06
BR14	1.68d	7	1.44e	7	14.29
BR24	1.61e	8	1.42e	9	11.80
BR21	1.58e	9	1.37f	11	13.30
BR26	1.57e	10	1.43e	8	8.92
BRR1 dhan42	1.53e	11	1.32g	13	13.73
NericaABSS	1.52e	12	1.37f	12	9.87
Nerica10	1.31f	13	1.26g	14	3.82
Nerica1	1.22g	14	1.13h	15	7.38
CV (%)			4.19, 6.34		

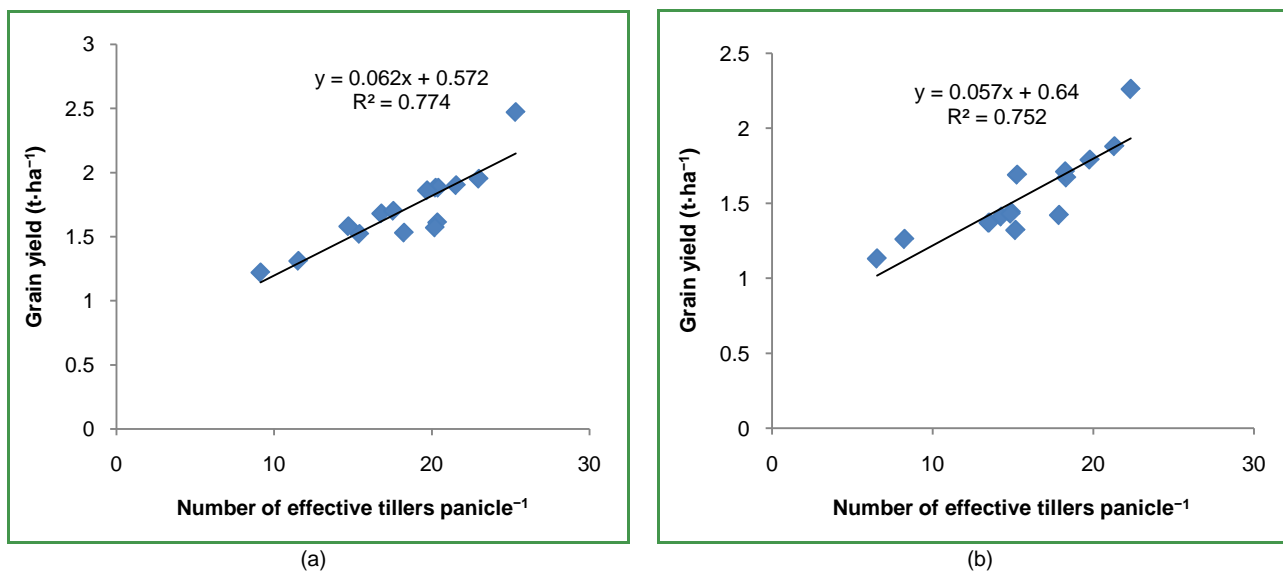
Mean values having the similar letter (s) differ insignificantly whereas mean values having dissimilar letter (s) differ significantly as per DMRT at the 0.05 probability level.

### 3.3. Correlation between Effective Tillers and Yield

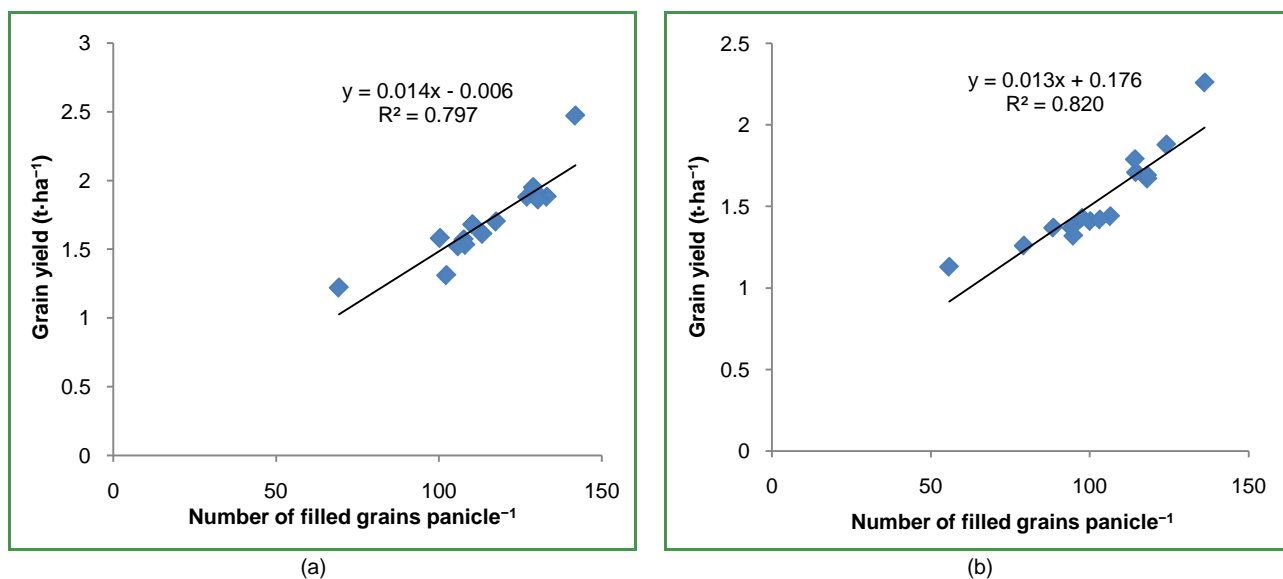
There has been observed significant correlation between numbers of effective tillers and grain yield (Figure 1). Yield was increased due to profuse number of effective tillers.

### 3.4. Correlation between Filled Grains Panicle<sup>-1</sup> and Yield

Results illustrated in Figure 2 indicated that there was significant correlation between numbers of filled grains panicle<sup>-1</sup> and grain yield. Yield was increased due to the production of considerable number of filled grains panicle<sup>-1</sup>.



**Figure 1.** Correlation between number of effective tillers panicle<sup>-1</sup> and grain yield under irrigated and rainfed condition. (a) Irrigated; (b) Rainfed.



**Figure 2.** Correlation between number of filled grains panicle<sup>-1</sup> and grain yield under irrigated and rainfed condition. (a) Irrigated; (b) Rainfed.

### 3.5. Correlation between Days of Panicle Initiation and Yield

There was also seen noteworthy correlation between duration of reproductive period and grain yield (Figure 3). The more the duration of reproductive stage, the more will be the yield.

## 4. Discussion

Significant differences for all traits due to irrigated and rainfed treatment amongst the *Aus* rice varieties have been noticed. Those differences were occurred might be due to improper distribution of rainwater and due to prevailing high temperature during the crop cycle particularly early growth stages that caused a relatively higher evapotranspiration rate during the entire crop cycle. In the meantime, air temperature as well as the soil temperature was higher which made the crops difficult to uptake lesser amount of water and minerals required for plants growth and development. The impact of water regime was considerably important for varietal performance. The effect of water stress may vary with genotypes as well as growing environment of the crop. It indicates that there is sufficient scope to select the promising genotypes from the present study for yield and some other economic plant traits.

The number of effective tillers was higher under irrigated condition. Water influences to increase tiller numbers of the varieties by upholding cell turgidity and it is the fundamental input for occurring photosynthesis as well as acts as a major integral of tissue, an element in chemical reaction, a solvent for and mode of translocation for metabolites and minerals within the plant body. Besides these function, it is also essential for cell enlargement through increasing turgor pressure ultimately accelerating growth and development of the number of effective tillers. Another reason might be due to maintaining relatively higher water potential outside the plant which is necessary for absorbing water with minerals by the plant roots as well as due to receiving water from both irrigation and

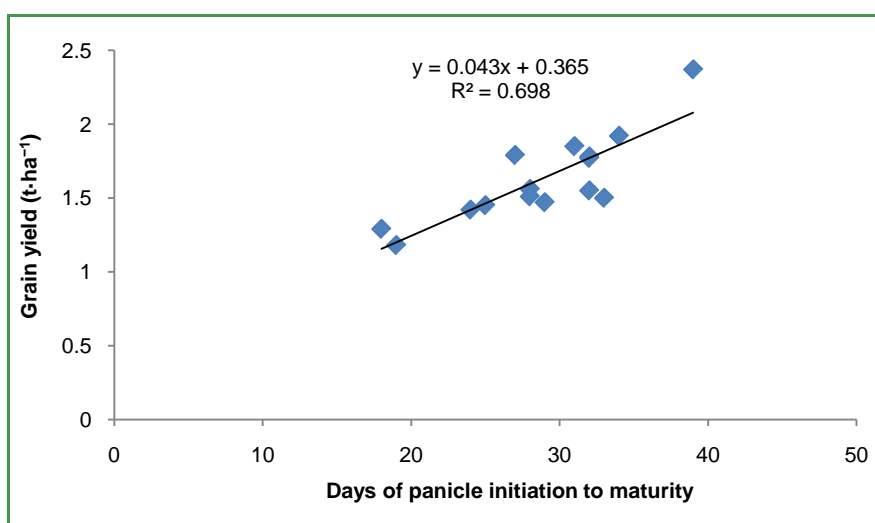


Figure 3. Correlation between days of panicle initiation to maturity and grain yield.

rainfall. In contrast, the lowest number of effective tillers was observed under rainfed condition might be due to lack of available soil moisture and due to have reduced transpiration rate with a view to conserving water for their survival and also for having low relative water content of the cells [11] [12] [13] [14] [15]. Another reason might be due to prevalent high temperature during the period of formation of tillers which eventually increased evapotranspiration rate and lowered the differences of water potential gradient. However, water deficit caused impaired mitosis, cell elongation and expansion resulted in decreased growth of the number of tillers [16] and induced lesser number of effective tillers which affects its yield [17] [18]. Results are agreed with the findings of [19] and stated that plants produced lower number of effective tillers when subjected to water stress (**Table 2**).

From the **Table 2** it is noticed that the highest number of non-effective tillers was observed in rainfed due to the reduction in turgor pressure under stress and finally cell growth of the tillers was severely impaired [20]. Water stress affects both expansion as well as enlargement of growth [21] of the tillers thus producing a large number of non-effective tillers. It interrupts plant net photosynthesis [19] [22], rate of transpiration [23], stomatal conductance [24], water use efficiency [25], intercellular carbon-dioxide, photosystem-II activity [26], relative water content of the cell [25] [27] [28] and ultimately membrane stability index [29]. All of these factors reduce under water shortage in rice plant [30] [31] [32].

The higher number of filled grains panicle<sup>-1</sup> was recorded under irrigated condition might be due to effective translocation of substantial amount of photo-assimilates from source to sinks and due to have produced profuse number of effective tillers (**Table 3**). On the contrary, filled grains were reduced in rainfed condition due to produce less number of effective tillers as well as reduced transpirational water loss for their subsistence. Another reason might be due to having high air and soil temperature, high evaporation during early growth stages of the crops. Similar results were found by several scientists [33] [34] [35].

The number of unfilled grains was followed an increasing trend under rainfed treatment (**Table 3**) might be due to reduced photosynthetic rate of the varieties and due to the production of less number of effective tillers and filled grains as well as due to causing spikelet sterility that ultimately lead to unfilled grains [36]. Increase in spikelet sterility [29] [37] is commonly observed under water stress. Results are in agreement with the findings by some scientists [38] [39].

Panicle length was also greater due to get ample water in addition to have adequate assimilates which was required for increasing length of panicle in irrigated state (**Table 4**). In contrast, Panicle length was reduced in rainfed due to shortage of photo-assimilates production resulting stunted growth and due to have lower water potential around the plants roots compared to plant body. Water stress reduces panicle length [17] [18] [39]. Results are endorsed with the findings of [40].

Under irrigated condition test weight was higher due to uniform grain and

also for having lesser number of shriveled grains as well as varieties were capable to mobilize their assimilates to the economic portion *i.e.* grain (**Table 4**). In contrast, reduction in grain size, weight [6] [14] [41], rate of seed-setting and test weight [42] are commonly noticed under water deficit condition. Results are agreed with the findings of [35]. Thousand-grain weight and grain yield were decreased with increasing water stress levels [40] [43] [44] [45]. Water deficit at vegetative growth particularly booting stage [46], flowering and terminal phases can interrupt commencement of floret, triggering spikelet sterility and slow grain filling, resulted in lower grain weight [36] [42] [47].

The ultimate purpose of growing crops is to fetch greater amount of harvestable yield. Under irrigated situation adequate water allowing high stomatal conductance and transport of CO<sub>2</sub> into leaves, thus produced a large quantity of photosynthates (**Table 6**). In that condition plant produced larger leaf area, more number of effective tillers and filled grains, increased test weight and less number of unfilled grains and irrigation water as well as rainwater necessary for functioning normal metabolic activities of the plants whereas in rainfed condition plant produced smaller leaf area, effective tillers, filled grains and more number of unfilled grains. Nevertheless, chlorophyll content and rate of photosynthesis of the flag leaves declined more quickly in water deficit condition resulting reduction in grain yield [48]. Water stress reduces grain yield probably by shortening the grain filling period [38], troublemaking leaf gas exchange properties, restraining the size of the source and sink tissues, impaired phloem loading and translocation of assimilate [49]. The reduction in yield may also be due to drought stimulated reduction in rates of CO<sub>2</sub> assimilation, reduced conductivity of stomata, photosynthetic pigments, tiny leaf size, disturbed plant water relations, reduction in water use efficiency, reduction in activities of enzymes of sucrose and starch synthesis and reduced photo-assimilate partitioning, leading to a reduction in plant growth and yield [50]. The amount of grain yield loss depends on the duration of shortage of water, the crop growth phase [51] as well as the existing water stress condition [29]. Grain yield of rice severely decreases under water deficit condition [22] [28] [52] [53]. Results are concurred with the findings of numerous researchers [21] [28] [37] [54]-[61].

Under irrigated condition the maintenance of reproductive growth around the time of flowering allowed the maintenance of capability for storing of photo-assimilates later in the crop cycle, thereby increasing trend of harvest index was seen in that condition (**Table 5**). Water stress at flowering and grain filling resulted in lower HI than water stress at tillering and no stress control which are statistically similar with higher HI. Decrease in HI could be largely due to water stress which resulted to decrease in translocation of assimilates to the grains, which lowered grain weight and increased the empty grains. High HI indicate the efficient translocation of assimilates towards sink. Lower HI values under water stress at flowering and grain filling stages indicate that it was more harmful in translocation of assimilates towards the grains. This finding is in accord

with that observed by [62]. Harvest index was higher in irrigation treatment compared to rainfed as application of water encouraged growth of large number of effective tillers, produced more amount of assimilates, less number of non-effective tillers and ultimately substantial grain yield of Aus rice. Henceforth, harvest index exhibited maximum positive direct effect on grain yield [63]. However, harvest index and yield were decreased in water stress condition [34] [35] [64].

### Correlation between Effective Tillers and Filled Grains along with Grain Yield

Yield was increased due to profuse number of effective tillers and due to the production of considerable number of filled grains panicle<sup>-1</sup>. Reference [65] also reported that, higher numbers of effective tillers are positively correlated with higher yield. Reference [66] testified that, the number of effective tillers rather than total number of tillers contributes more to enhance productivity of rice plant.

### 5. Conclusion

All of the yield parameters had exerted decreasing trend under rainfed condition. In the present study the tolerance of rice genotypes subjected to rainfed or water stress varied remarkably. Based on the results it can be concluded that BRRi dhan27, BRRi dhan55, BRRi dhan48 and BRRi dhan43 showed the highest effective tillers, filled grains ultimately grain yield in the both growth environment. In case of yield, BRRi dhan27 ranked the top under both irrigated and rainfed conditions, yet the relative yield was the maximum in BRRi dhan55 followed by Nerika10. Therefore, based on the yield stability and absolute yield performance BRRi dhan27 may be considered satisfactorily for *Aus* rice cultivation, followed by BRRi dhan55, BRRi dhan48 and BRRi dhan43. Farmers could cultivate BRRi dhan27 for the purpose of higher yield under water limiting area.

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