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Effect of alternate wetting and drying (AWD) irrigation method on yield and economic potential of different rice (*Oryza sativa* L.) varieties in puddled soil

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Abstract
A field experiment was conducted to study the yield and economic potential of rice varieties as influenced by different irrigation regimes on sandy clay soil at Agricultural College farm, PJTSAU, Rajendranagar, Hyderabad during *kharif,* 2016. The experiment was laid out in a split plot design with three irrigation regimes (irrigation of 5 cm when water level falls below 5 cm from soil surface in field water tube, irrigation of 5 cm, at one day after disappearance of water on the surface of the soil and recommended submergence of 2-5 cm water level as per crop stage) as main treatments and four rice varieties (Telangana sona, Kunnaram sannalu, Bathukamma and Sheethal) as sub plots treatments has replicated thrice. The data recorded indicated that recommended submergence of 2-5 cm water level recorded significantly higher grain yield (6289 kg ha^{-1}), straw yield (8703 kg ha^{-1}), gross returns (1,04,106 ₹ ha^{-1}), net returns (63,691 ₹ ha^{-1}) and B: C ratio (2.59) over AWDI of 5 cm when water falls below 5 cm from soil surface in field water tube and was on par with AWDI of 5 cm at one DADSW. Bathukamma produced higher grain yield (6468 kg ha^{-1}), straw yield (7755 kg ha^{-1}) and Telangana Sona produced higher gross returns (₹ 1,10,576 ha^{-1}), net returns (₹ 70,121 ha^{-1}) and B: C (2.73) ratio compared to Kunaram Sannalu and Sheethal. Based on the results it can be concluded that Bathukamma recorded higher grain yield, straw yield and Telangana Sona recorded higher gross returns, net returns and B: C ratio under recommended submergence of 2-5 cm water level as per crop stage.

Keywords: AWD- alternate wetting and drying, rice varieties, yield, economic potential

1. Introduction

Rice (*Oryza sativa* L.) is staple food of more than 60% of the world's population. Flood-irrigated rice utilizes two or three times more water than other cereal crops such as maize and wheat. Rice is a heavy water consumer but water for rice production is becoming scarce and expensive due to the increased demand for water from the ever growing population and industries (Choudhury *et al*., 2014) [3]. On an average, more than 5000 liters of water are used to produce one kilogram of rice. Rice production in Asia is increasingly constrained by water limitation [Arora, 2006] [1] and increasing pressure to reduce water use in irrigated production as a consequence of global water crisis [Tuong and Bouman, 2002] [14]. It is predicted that by 2025, 15 out of 75 million hectare of Asia's flood-irrigated rice crop will experience water shortage. Yet more rice needs to be produced with less and less water to feed the ever-growing population, which needs judicious water management practices and suitable water saving technologies in rice cultivation [Tuong and Bouman, 2003] [15]. A number of water-saving irrigation (WSI) technologies to reduce water use, to increase water use efficiency, and to maintain or increase production for rice-based systems have been developed [Tuong and Bhuiyan, 1999; Li. 2006] [13, 9]. In irrigated wet seeded rice cultivation, water use efficiency on the farm can be increased by applying the amount of water, which is needed to the crop. Among the different methods of water-saving irrigation, the most widely adopted is alternate wetting and drying AWD irrigation method [Li and Barker, 2004] [8]. The new varieties developed through systematic breeding procedures have inherent genetic potential for enhanced yield and economic potential as well as other desirable characters. Therefore, present field experiment was conducted to study the yield and economic potential of newly released rice varieties as influenced by different water regimes in sandy clay loam soil.

2. Materials and Method

2.1 Location

The field experiment was conducted during 2016 *kharif* season at the College Farm, College of Agriculture, Rajendranagar, Hyderabad. The farm is geographically situated in the southern part of Telangana at 17°32' N latitude and 78°40' E longitude at an altitude of 542.6 m above mean sea level.

2.2 Treatments and design

The experiment was laid out in a split plot design with three irrigation regimes as main plots and four different rice varieties as sub plots and replicated thrice. The treatments combination include three irrigation regimes (I_1-irrigation of 5 cm when water level falls below 5 cm from soil surface in field water tube, I_2- irrigation of 5 cm, at one day after disappearance of water on the surface of the soil and I_3- recommended submergence of 2-5 cm water level as per crop stage) as main treatments and four popular rice varieties in the Telangana region (V_1- Telangana sona, V_2- Kunnaram sannalu, V_3- Bathukamma and V_4- Sheethal) as sub plots treatments respectively. The experimental plot size was 6 m×4.2 m. The seedlings of different rice varieties at 21days old were transplanted by adopting a spacing of 15 cm × 15 cm. The experimental field was provided with proper irrigation channels, buffer channels and the individual plots were demarcated by bunds.

2.3 Soil properties and Fertilizer application

The experimental soil was sandy clay in texture, moderately alkaline in reaction, non-saline, low in organic carbon content, low in available nitrogen (N- 244.8 kg ha^{-1}), medium in available phosphorous (P_2O_5- 56.3 kg ha^{-1}) and potassium (K_2O- 230.7 kg ha^{-1}). A uniform dose of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied. The N, P and K were applied in the form basally in the form of urea, single super phosphate and muriate of potash respectively. The entire P fertilizer was applied as basal in the form of single super phosphate (16% P_2O_5). The K fertilizer was applied in the form of muriate of potash (60% K_2O ha^{-1}) in two equal splits as basal and at panicle initiation stage. The fertilizer N was applied in the form of prilled urea (46% N) in three equal splits at basal, active tillering stage and at panicle initiation stage.

2.4 AWDI Practice and Water measurements

AWDI practice is to measure the depth of standing water and water tables in the field, either above the surface or below the surface. Three different irrigation regimes based on water levels below the surface will be practiced using this tube. Irrigation will be given when water depth goes below the surface to 5 cm. Water level depth in this tube will be measured by simple measuring scale. The subsequent irrigation will be given to re-flood the field to a depth of 5 cm as per respective treatments. Irrigation was with-held 15 days ahead of harvest.

In this experiment, PVC pipes were used to measure the water level below the ground level in the field. The diameter and the length of the PVC pipe were 15 cm and 40 cm, respectively, having perforations 2 cm away from each other. The pipe was installed in the field keeping 20 cm above the soil and the remaining portion (20 cm) below the soil. After application of irrigation, water entered in the pipe through small perforations and the water level inside the pipe was the same as that of outside. After some days when the water level went below the ground level then water level was measured by scale. Thus, irrigation water was applied when the water level inside the pipe reached a predetermined position as per treatment.

2.5 Imposition of treatments

In conventional method of irrigation (I_3) the field was kept flooded up to 3cm depth from 15 DAT to panicle initiation and up to 5 cm depth of irrigation from panicle initiation to physiological maturity. The irrigation treatments I_1 and I_2 were imposed from 10 days after transplanting to grain filling stage of crop wherein, 5 cm irrigation to a depth of 5 cm submergence was given based on disappearance of ponded water on soil surface (I_1) and irrigation of 5 cm submergence was given at one day after disappearance of water on the surface of the soil (I_2). The irrigation water was applied through plastic pipe from the source and a water meter was used for measuring irrigation water.

Field water tubes were placed in each main plot to measure the depth of standing water and water tables in the field, either above the surface or below the surface. Using this tube irrigation was given when water depth goes below the surface to 5 cm. Water levels in the tube were measured by simple ruler. In all the irrigation regimes irrigation was with-held 15 days ahead of harvest.

2.6 Calculations and statistical analysis

The data collected from the experiment were analyzed statistically by analysis of variance (ANOVA) method for split plot design with irrigation regimes and rice varieties as main and subfactor, respectively. Whenever the treatment differences were found significant (F test), critical differences were worked out at five per cent probability level. Treatment differences that were non-significant were denoted by NS. The yield and economics data recorded and tabulated after statistical test.

3. Result and Discussion

Grain yield, straw yield and harvest index of rice was significantly influenced by different rice varieties and irrigation regimes (Table 1 and Fig 1). However, there was no significant effect of interaction between different rice varieties and irrigation regimes.

3.1 Grain yield (kg ha^{-1})

Among the different irrigation regimes, recommended submergence of 2-5 cm water level as per crop stage (I_3) recorded significantly higher grain yield of 6289 kg ha^{-1} than AWDI of 5 cm irrigation when water level falls below 5 cm in the field water tube (I_1) and was at par with AWDI of 5 cm at one day after disappearance of ponded water (I_2). Significantly lower yield (5928 kg ha^{-1}) was obtained with AWDI of 5 cm irrigation when water level falls below 5 cm in the field water tube (I_1) and was on par with the AWDI of 5 cm, one day after disappearance (I_2) of ponded water (6049 kg ha^{-1}).

There was saving of water by 10.8 (1118.1mm) and 11.2 (1113.1mm) per cent total water and 28.5 and 34.6 per cent applied irrigation water over recommended submergence (1253.8 mm), though there was 4 and 6 per cent increase in yield under recommended submergence over AWDI of 5 cm at one DADSW and AWDI of 5 cm at 5 cm water level fall in field water tube from surface. The effective rainfall was 64.6 and 71.9 percentage of total rainfall in AWDI of 5 cm at one day after disappearance of ponded water (I_2) and AWDI of 5 cm irrigation when water level falls below 5 cm in the field water tube (I_1) against 58.5 per cent under normal irrigation.

The saving in water was 8.5 per cent (37.2 mm) in AWDI of 5 cm at 5 cm water level fall in field water tube from surface over AWDI of 5 cm at one day after disappearance of surface water (I_2), though there was reduction in yield was 2.0 per cent (121 kg ha^{-1}).

Among varieties, Bathukamma recorded significantly higher grain yield (6468 kg ha^{-1}) than Telangana Sona (5820 kg ha^{-1}) and Sheethal (5748 kg ha^{-1}) and was at par with Kunaram Sannalu (6318 kg ha^{-1}). Significantly lower yield was recorded with Sheethal than Kunaram Sannalu and Bathukamma and was on par with Telangana Sona. The grain yield with Bathukamma was 2.4, 11.1 and 12.5 per cent higher than Kunaram Sannalu, Telangana Sona and Sheethal respectively. The yield with Telangana Sona was 10.0 lower than the yield of Bathukamma and was 1.25 per cent higher than Sheethal. Similarly Sheethal recorded lower by 1.2, 9.0 and 11.1 per cent of Telangana Sona, Kunaram Sannalu and Bathukamma respectively. The lower yield of Telangana Sona might be due to lower test weight and panicle length as compared to Bathukamma.

The increased yields under recommended submergence might be due to favorable growing and nutrition supply environment resulted in higher dry matter and increased uptake of nutrients which lead the plants with superior growth. The favorable growth traits enhanced the yield attributing characters with higher source to sink conversion, which in turn resulted in higher grain yields. On the other hand, AWDI irrigation practice at 5cm when water level falls 5 cm below in the field water tube and at one day after disappearance of ponded water (DADPW) also attained same level of yield. These results are in line with findings of Thiyagarajan *et al*. (2002) [12] and Geethalakshmi *et al.* (2009) [5]. On the other hand, AWDI irrigation practice at 5cm drop of water level in the field water tube and one day after disappearance of ponded water (DADPW) also attained on par yield. Similar results were found by Ashouri (2014) [2].

3.2 Straw yield (kg ha^{-1})

Mean straw yield of 8703 kg ha^{-1} registered under recommended submergence of 2-5 cm water level as per crop stage (I_3) was significantly higher than AWDI of 5 cm at one day after disappearance of surface water (I_2) with 7408 kg ha^{-1} and AWDI of 5 cm irrigation when water level falls 5 cm below in the field water tube (I_1). Significantly lower straw yield was obtained with AWDI of 5 cm submergence when water level falls 5 cm below in the field water tube (I_1) with 5839 kg ha^{-1} than rest of the treatments. Highest straw yield of rice under the conventional method of irrigation practice might be due to adequate moisture availability which contributed to increased dry matter accumulation. Similar results were reported by Sariam and Anuar (2010) [10], Kumar *et al*. (2014) [7] and Ashouri (2014) [2].

Among the varieties, Bathukamma recorded significantly higher mean straw yield (7755 kg ha^{-1}) than Kunaram Sannalu (7158 kg ha^{-1}) and Telangana Sona (6858 kg ha^{-1}) and was on par with Sheethal (7496 kg ha^{-1}). Significantly lower straw yield was recorded with Telangana Sona than rest of the varieties except Kunaram Sannalu which was at par with Telangana Sona. Similarly Kunaram Sannalu and Sheethal also at par in straw yield. The lower straw yield of Telangana Sona might be due to lower plant height and low dry matter as compared to Bathukamma.

3.3 Harvest index

The harvest index ranged from 43.7 to 47.3 per cent among different varieties. Among the different irrigation regimes, it ranged from 41.9 to 50.4 per cent and recommended submergence of 2-5 cm water level as per crop stage (I_3) recorded significantly lower harvest index (41.9%) than AWDI of 5 cm irrigation when water level falls 5 cm below in the field water tube (I_1) with 50.4 per cent and was on par with AWDI of 5 cm at one day after disappearance of ponded water (I_2) with 45.2 per cent. Significantly higher harvest index was obtained with AWDI of 5 cm submergence when water level falls below in the field water tube (I_1) with 50.4 per cent than other treatments. Significantly higher harvest index in I_1 might be due to lower grain yield and straw yield and also lower dry matter production at harvest (Table 1).

Among the varieties, Kunaram Sannalu recorded significantly higher harvest index (47.3%) than Sheethal (43.7%) and was on par with Telangana Sona (46.5%), Bathukamma (45.8%). Significantly lower harvest index was recorded with Sheethal than Kunaram Sannalu and Telangana Sona and was on par with Bathukamma. However rice varieties of Kunaram Sannalu, Telangana Sona and Bathukamma were at par in harvest index. The lower harvest index of Sheethal might be due to lower grain yield and higher straw yield and also higher dry matter production at harvest compared to other varieties.

3.4 Economic Analysis

Economic analysis was carried by calculation of cost of cultivation for different operations for growing crop. Gross returns were calculated in different treatments based on grain yield of rice and multiplied with respective value of grain yield then net returns were worked with by deducting cost of cultivation from gross returns.

3.5 Cost of cultivation

Cost of cultivation of rice varied from ₹ 39,604 ha^{-1} to ₹ 40,455 ha^{-1} in different treatments (Table 2). Main variation in cost of cultivation was due to higher number of irrigation given to recommended submergence of 2-5 cm water level as per crop stage treatment (31 irrigations) as compared to irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (17 irrigations). These results are in accordance with findings of Dass and Chandra (2012) [4].

3.6 Gross and Net returns (₹ ha^{-1})

Interaction effect between different rice varieties and irrigation regimes on gross returns and net returns was not significant (Table 2). Among the different irrigation regimes, recommended submergence of 2-5 cm water level as per crop stage (I_3) recorded significantly higher gross and net returns (₹ 1,04,106 ha^{-1} and ₹ 63,691 ha^{-1}) than AWDI of 5 cm irrigation when water level falls 5 cm below in the field water tube (I_1) and was on par with AWDI of 5 cm at one day after disappearance (I_2) of surface water. However lower gross and net returns were obtained with AWDI of 5 cm submergence when water level falls 5 cm below (I_1) in the field water tube (₹ 98,318 ha^{-1} and ₹ 58,109 ha^{-1} respectively) and was on par with the AWDI of 5 cm at one day after disappearance (I_2) of ponded water (₹ 1,00,281 ha^{-1} and ₹ 60,677 ha^{-1} respectively). This was due to higher grain yield under recommended submergence of 2-5 cm water level as per crop stage than other irrigation treatments. These results are in accordance with findings of Dass and Chandra (2012) [4], Sathish. (2015) [11] and Kishore. (2016) [6]. Significantly lower gross and net returns were recorded with 5 cm submergence compared to rest of the treatments because of lower grain yield compared to other treatments.

Among the varieties, Telangana Sona recorded significantly higher gross and net returns (₹ 1,10,576 ha^{-1} and ₹ 70,121 ha^{-1}) than Bathukamma (₹ 1,00,249 ha^{-1} and ₹ 60,419 ha^{-1}), Kunaram Sannalu (₹ 97936 ha^{-1} and ₹ 58,106 ha^{-1}) and Sheethal (₹ 94,845 ha^{-1} and ₹ 55,015 ha^{-1}). Significantly lower gross and net returns was recorded with Sheethal and was on par with Kunaram Sannalu. Higher gross returns with Telangana Sona though significant higher yield was recorded with Bathukamma and Kunaram Sannalu was due to more price for kg grain compared to rest of the varieties as its cooking quality is superior than rest of the varieties. Though higher yield recorded by later varieties, the price per kg grain was not lower than Telangana Sona because of bold grain.

3.7 Benefit: Cost ratio (B: C ratio)

The basic agronomic criteria to decide economic returns is B: C ratio and was calculated based on gross returns divided by cost of cultivation of respective treatment combination. B: C ratio calculated for present investigation was significantly influenced by different rice varieties and irrigation regimes and interaction effect was not significant (Table 2). Significantly higher B:C ratio (2.59) was obtained, among different irrigation water regimes, under recommended submergence of 2-5 cm water level as per crop stage over irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (2.44) and was on par with Irrigation of 5 cm, one day after disappearance of surface water (2.53). The higher benefit cost ratio in this irrigation regime was attributed to higher gross and net returns with reduced cost of cultivation compared to other irrigation regimes. These results are in accordance with findings of Dass and Chandra (2012) [4], Kumar *et al.* (2013) and Kishore. (2016) [6].

Telangana Sona, among varieties recorded significantly higher B: C ratio (2.73) than Bathukamma (2.52), Kunaram Sannalu (2.46) and Sheethal (2.38). Significantly lower B: C ratio was recorded with Sheethal though it was on par with Kunaram Sannalu. However Bathukamma and Kunaram Sannalu were recorded at par B: C ratio with each other. The higher B:C ratio with Telangana Sona was due to higher gross returns than rest of the varieties, though cost of cultivation was higher with Telangana Sona than other varieties.

4. Conclusion

It can be concluded that recommended submergence of 2-5 cm water level recorded significantly grain yield, straw yield, gross returns, net returns and B: C ratio over AWDI of 5 cm when water falls below 5 cm from soil surface in field water tube and was on par with AWDI of 5 cm at one DADSW. Bathukamma produced higher grain yield, straw yield and Telangana Sona recorded higher gross returns, net returns and B: C ratio compared to Kunaram Sannalu and Sheethal. Among varieties, Bathukamma recorded higher grain yield, straw yield and Telangana Sona recorded higher gross returns, net returns and B: C ratio under recommended submergence of 2-5 cm water level as per crop stage.

Table 1: Grain yield, Straw yield (kg ha^{-1}) and harvest index (%) of rice varieties as influenced by irrigation regimes

Treatment	Yield (kg ha^{-1})		Harvest index (%)
	Grain	Straw	
Main plot- (Irrigation regimes)			
I_1: AWDI of 5 cm, when water level falls below 5 cm from soil surface in perforated pipe.	5928	5839	50.4
I_2: AWDI of 5 cm, one day after disappearance of ponded water on the surface of the soil.	6049	7408	45.2
I_3: Recommended submergence of 2-5 cm water level as per crop stage.	6289	8703	41.9
SEm±	63	220	0.8
C.D (P=0.05)	249	864	3.3
Sub plot- (Varieties)			
V_1 – RNR 15048 (Telangana Sona)	5820	6858	46.5
V_2– KNM 118 (Kunaram Sannalu)	6319	7158	47.3
V_3– JGL 18047 (Bathukamma)	6468	7755	45.8
V_4– WGL 283 (Sheethal)	5748	7496	43.7
SEm±	85	187	0.8
C.D (P=0.05)	253	555	2.5
Interaction			
Rice varieties at same level of Irrigation regimes			
SEm±	148	323	1.5
C.D (P=0.05)	NS	NS	NS
Irrigation regimes at same or different rice varieties			
SEm±	143	356	1.5
C.D (P=0.05)	NS	NS	NS

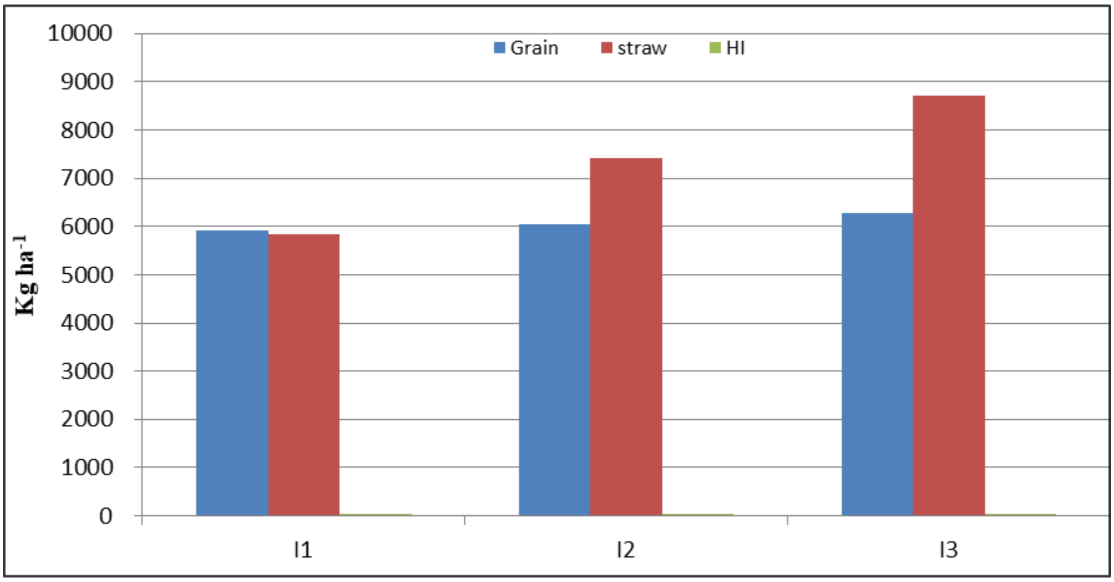
AWDI: Alternate wetting and drying irrigation NS: Non-Significant

Table 2: Cost of cultivation, gross returns, net returns and B:C ratio of rice varieties as influenced by irrigation regimes

Treatment	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Main plot- (Irrigation regimes)				
I_1: AWDI of 5 cm, when water level falls below 5 cm from soil surface in perforated pipe.	40209	98318	58109	2.44
I_2: AWDI of 5 cm, one day after disappearance of ponded water on the surface of the soil.	39604	100281	60677	2.53
I_3: Recommended submergence of 2-5 cm water level as per crop stage.	40145	104106	63961	2.59
SEm±		1035	1035	0.03
C.D (P=0.05)		4065	4065	0.10

Sub plot- (Varieties)				
V_1 – RNR 15048 (Telangana Sona)	40455	110576	70121	2.73
V_2– KNM 118 (Kunaram Sannalu)	39830	97936	58106	2.46
V_3– JGL 18047 (Bathukamma)	39830	100249	60419	2.52
V_4– WGL 283 (Sheethal)	39830	94845	55015	2.38
SEm$\pm$		1384	1384	0.03
C.D (P=0.05)		4112	4112	0.10
Interaction				
Rice varieties at same level of Irrigation regimes				
SEm$\pm$		2397	2397	0.06
C.D (P=0.05)		NS	NS	NS
Irrigation regimes at same or different rice varieties				
SEm$\pm$		2320	2320	0.06
C.D (P=0.05)		NS	NS	NS

AWDI: Alternate wetting and drying irrigation NS: Non Significant



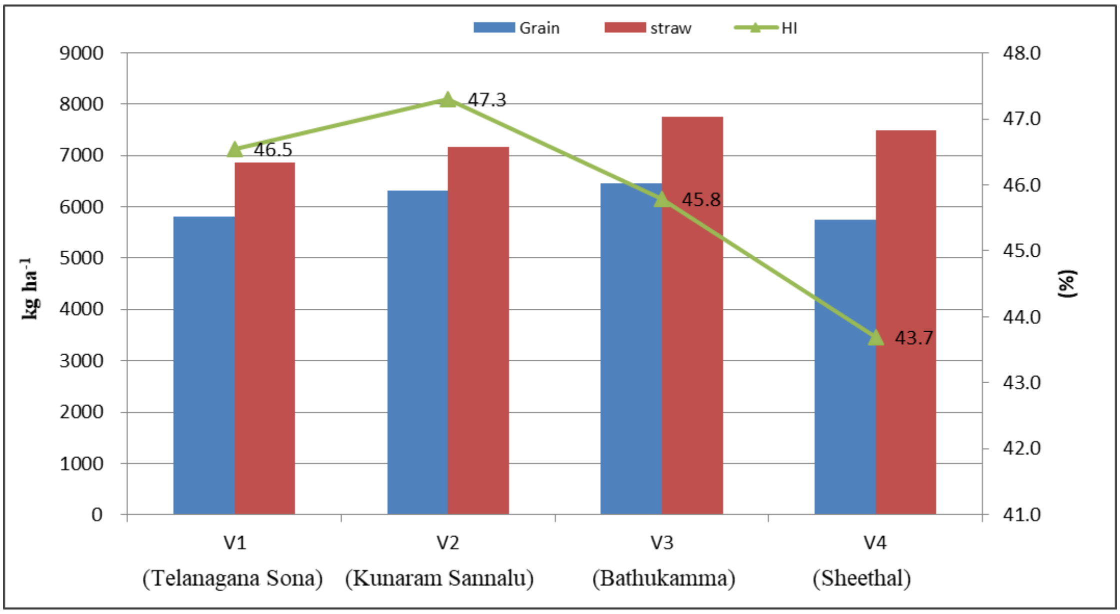


Fig 1: Grain, straw yield (kg ha^{-1}) and harvest index (%) of rice varieties as influenced by different irrigation regimes

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