DOI:10.5958/j.0976-4038.5.1.008

Effect of Water Regime and Nitrogen on Growth, Productivity and Economics of Summer Rice Varieties

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Article History

Manuscript No. 374
Received in 4th November, 2012
Received in revised form 14th February, 2013
Accepted in final form 5th March, 2014

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Keywords

Summer rice, water regimes, nitrogen, productivity, economics

Abstract

The results of field experiment conducted during summer season of 2004 and 2005 showed that continuous field saturation increased plant height, tillers production, LAI, DMA, CGR, panicle and grain production, and test weight that ultimately produced high grain (6025 kg ha^{-1}) and straw yield (6296 kg ha^{-1}) with high harvest index, gross return and net return. IR-36 recorded higher number of tillers m^{-2}, LAI, DMA, CGR, greater number of panicles m^{-2} and test weight and finally produced higher grain (5671 kg ha^{-1}) and straw (6001 kg ha^{-1}) yields and paid greater gross and net return than those of Annapurna. The crop receiving 120 kg N ha^{-1} (RDN) increased plant height, tiller production, LAI, DMA, CGR, recorded higher number of panicles m^{-2} and grains $panicle^{-1}$ and produced higher grain and straw yield with higher return. The crop at continuous saturation with RDN recorded greater tiller production, LAI and CGR during reproductive period over most of the other treatment combinations. It increased panicle and grain production and produced the highest grain (6299 kg ha^{-1}) yield and paid very high net return (₹ 16818 ha^{-1}) from summer rice. IR 36 receiving RDN produced greater number of tillers m^{-2}, LAI and CGR during reproductive period, recorded the higher number of panicles m^{-2} and grains $panicle^{-1}$ and produced the highest grain yield (5882 kg ha^{-1}) of summer rice over most of the other treatments. IR 36 at continuous saturation with RDN improved growth attributes, increased yield components, produced high grain yield and paid high net return under the study.

1. Introduction

Rice (*Oryza sativa* L.) is the most important and staple food crop for more than 67% of the population of India. The slogan 'Rice is Life' is appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural households. The acreage under rice in India is about 44.6 m ha with a production of about 104.32 million tones (Anonymous, 2010). Thanks to miracle semi-dwarf, photo insensitive, fertilizer responsive, non-lodging varieties, that heralded a new era of green revolution. During the period 1950-51 to 2001-02, the area increased by one and half times (31.0 to 44.6 mha), productivity by three times (668 to 2086 kg ha^{-1}) and production by four and half times (20.58 to 90 mt). At the current rate of population growth, rice production has to be enhanced to about 125 mt by 2020. It is a major challenge as the increase has to come with shrinking land and water, scarce and costly labour and other inputs and deteriorating environment. Therefore, rice farming has to be re-oriented to face the future challenges and our farmers too have to change their mindset to turn rice into a lucrative economic product rather than a simple food commodity (Mishra, 2005).

West Bengal is the major rice producing state in India. Further expansion of cultivable rice area is not possible in West Bengal. Thus, increase in rice productivity should come from vertical growth. The productivity of summer (*boro*) rice is higher per unit area as compared to *kharif* rice due to clear weather, efficient water, nutrient and other inputs management (Bhowmick and Nayak, 2000). The productivity of summer rice can further be increased by efficient nitrogen and water management. With the decline in water availability for rice cultivation, aerobic rice may come into the intensive cropping high productive areas. Summer rice requires large quantity of readily available nutrients. Soil is unable to supply nutrients in accordance with the crop demand. Again, different varieties responded differently to nitrogen levels. Appropriate variety with favourable environment and production inputs may help in improving the productivity of summer rice (Chandrasekhar et al., 2001). Keeping this idea in view and realizing the importance of the problem, an investigation was undertaken to study the growth, productivity and economics of summer rice varieties at varying nitrogen and water regimes in lateritic belt of West Bengal.

2. Materials and Methods

2.1. Study area

A field experiment was conducted during *boro* (Summer) season of 2004 and 2005 to study the effect of water regime, variety and nitrogen on growth, productivity and economics of summer rice at the Farm of the Institute of Agriculture (Palli Siksha Bhavana), Visva-Bharati, Sriniketan, West Bengal. The place is situated at $23^0 39'$ N latitude, $87^0 42'$ E longitude and an elevation of 58.9 m above mean sea level. Occasional breaks in rain are common in this area during summer season due to nor-western cyclone. However, the crop received less rainfall (206.3 mm) in 2004 and (214.5 mm) in 2005 as compared to normal rainfall (234.4 mm) during the crop season of this area. The soil was sandy loan in texture (60.4% sand, 23.9% silt and 15.7% clay), neutral in reaction (pH 6.2) low in organic carbon (0.30%), available nitrogen (163.4 kg N ha^{-1}), available phosphorous (10.6 kg P ha^{-1}) and available potassium (140 kg K ha^{-1}) status.

2.2. Experimental details

The experiment was laid out in split plot design with two water regimes (alternate drying & wetting and continuous saturation) and two varieties (IR 36 and Annapurna) in the main plots and three levels of nitrogen (60, 90 and 120 kg N ha^{-1}) in the sub-plots replicated thrice. All plots received 26.7 kg P ha^{-1} and 50.0 kg K ha^{-1} and 1/3rd N at basal and remaining N fertilizer in two equal splits-at mid-tillering and after panicle initiation as per treatments. The crop was transplanted on February 20, 2004 and February 21, 2005 taking two seedlings per hill at 20×15 cm^2 spacing. Crop under alternate drying and wetting received four irrigations during both the years and at saturation received nine irrigations in 2004 and seven irrigations in 2005. Insects were controlled by chemicals to avoid biomass and yield loss. The weeds were removed manually at 20 and 40 days after transplanting (DAT). The crop was harvested on May 30, 2004 and May 31, 2005.

2.3. Observations recorded

The observation on plant height was recorded from 10 hills in each plot at different stages. Tiller number was counted from 10 hills in each plot at 45 DAT. Samples for biomass has been collected from 5 hills of ear-marked area in each plot at different stages. The fresh weights of the plant samples were recorded. The samples then separated into stem (leaf sheath+stem), green leaves (lamina) and panicles and kept in separate paper packets in an oven for drying at 65-70^{0}C till constant weights were obtained. The dry weights of leaves, stems and panicles were noted for recording dry matter accumulation (DMA). The leaf dry weight was used for determining leaf area index (LAI) as suggested by Watson (1952). DMA was used for determining crop growth rate (CGR). Observation on number of panicles m^{-2}, number of filled grains panicle^{-1}, test weight, grain yield, straw yield and harvest index were recorded at maturity. The economics of summer rice was worked out considering the prevailing market price of the inputs and outputs. The data were statistically analyzed applying the techniques of analysis of variance and the significance of different sources of variations were tested by error mean square of Fisher Snedecor's 'F' test at probability level 0.05 (Cochran and Cox, 1977).

3. Results and Discussion

3.1. Growth attributes

Plant height, tillering, LAI, DMA and CGR increased markedly in crop grown at continuous saturation over those of alternate drying and wetting condition. Crop at alternate drying and wetting suffered from moisture deficit during hot dry sunny days in summer season. Thus it reduced most of the growth attributes at most of the stages during both the years (Tables 1 and 2). The results clearly indicate that rice crop favour continuous saturation rather than alternate drying and wetting condition for its better growth in summer season. Application of irrigation at saturation might create favourable condition for improving growth parameters of summer rice over those obtained at alternate drying and wetting (Bhatnagar, 2002). Neelima and Kumar, 2011 reported that among different aerobic systems of rice production is feasible in scarce rainfall zone of AP and MTU 4870, RDR 1010, RDR 977 and RDR 996 resulted in significant higher grain yield over all other tested varieties.

IR 36 recorded higher number of tillers m^{-2}, greater LAI, DMA and CGR of the crop over those of Annapurna; but Annapurna produced taller plants than that of IR 36 (Tables 1 and 2). The might be due to the intrinsic characters of the variety governed by the genetic makeup (Chandrasekhar et al., 2001). Nitrogen exerted significant effect on improving the growth variables of summer rice. Plant height, number of tillers m^{-2}, LAI, DMA and CGR of the crop increased markedly due to the application of 120 kg N ha^{-1} (RDN) over its low level (60 kg N ha^{-1}) that recorded the lowest value of all of the above growth attributes (Tables 1 and 2). Use of 90 kg N ha^{-1} produced crop with intermediate values of growth attributes between recommended and low N levels. The results are in conformity with the findings of Ali et al. (2001) and Ghosh et al. (2004).

3.2. Yield components and crop productivity

The crop at continuous saturation produced greater number of panicles m^{-2}, grains panicle^{-1} and test weight and ultimately recorded significantly higher grain (6025 kg ha^{-1}) and straw yield (6296 kg ha^{-1}) when compared to those of the crop grown under alternate drying and wetting condition (Table 3). Continuous saturation increased grain yield by 21.3% and straw yield by 17.1% over alternate drying and wetting condition. The harvest index did not vary much between the above water regimes. Decrease in tillering, LAI, DMA and CGR of the crop at alternate drying and wetting led to reduce panicle production, grain formation and grain development and ultimately recorded poor crop yield under hot dry sunny days in summer season as compared to those of continuous saturation. The results corroborate the findings of Das et al. (2000) and Sarkar (2001).

Greater number of panicles m^{-2}, higher test weight (1000-grain weight) and lower number of grains per panicle were noticed in IR 36 when compared with Annapurna (Table 4). IR 36 ultimately produced higher grain (5671 kg ha^{-1}) and straw (6001 kg ha^{-1}) yield over those of Annapurna (5322 kg grain and 5669 kg straw ha^{-1}). The difference in productivity of rice variety might be due to differential production potentiality of the varieties. Similar varietal differences in rice productivity were also obtained by Thakur et al. (2002).

Number of panicles m^{-2} and number of grains panicle^{-1} increased steadily as the level of N application increased. The crop at RDN (120 kg N ha^{-1}) produced the highest number of panicles m^{-2} and greatest number of grains panicle^{-1} and was significantly superior to those of the crop receiving lower N levels (Table 3). The lowest number of panicles m^{-2} and grains panicle^{-1} were obtained from the crop at the lowest N level (60 kg N ha^{-1}) and was markedly lower than that of the crop even at medium N level (90 kg N ha^{-1}). Accordingly, higher grain (5778 kg ha^{-1}) and straw yield (6179 kg ha^{-1}) were obtained due to the application of 120 kg N ha^{-1} (RDN) over that of the crop at medium (90 kg N ha^{-1}) and low (60 kg N ha^{-1}) N levels. The crop at medium N level also produced markedly higher grain (5503 kg ha^{-1}) and straw yield (5847 kg ha^{-1}) than that of low N level. Application of 120 kg N ha^{-1} increased grain yield by 10.9% over those of low N level. The results showed very high response of summer rice to applied nitrogen. The results are in conformity with the findings of Reddy et al. (2003). Singh et al., 2010 reported that increasing N levels increase the leaf pigments which will ultimately increase the yield of rice plant because the leaf pigments directly influence the light harvest and biogenesis of electron transport system for photosynthesis.

3.3. Economics of summer rice

The crop at continuous saturation paid greater gross (₹ 39567 ha^{-1}) and net return (₹ 16600 ha^{-1}) as compared to those under alternate drying and wetting condition (Table 4). But it did not pay higher return per rupee invested over that of alternate

Table 1: Effect of water regime, variety and nitrogen on plant height (cm), tillering and LAI of summer rice (pooled data)

Treatments	Plant height (cm) at different DAP			Tillers m^{-2}	LAI at different DAP		
Water regime	30	60	90		30	60	90
Drying & wetting	38.4	64.0	75.4	332	3.24	5.34	0.77
Saturation	45.4	71.2	79.4	382	3.76	5.73	1.03
SEm±	0.6	0.8	0.8	6.4	0.07	0.10	0.02
CD (p=0.05)	1.7	2.1	2.1	18	0.20	0.27	0.06
Variety							
IR-36	39.6	64.1	73.9	373	3.64	5.70	0.98
Annapurna	44.3	71.2	80.9	341	3.37	5.37	0.82
SEm±	0.6	0.8	0.8	6.4	0.07	0.10	0.02
CD (p=0.05)	1.7	2.1	2.1	18	0.20	0.27	0.06
N levels (kg ha^{-1})							
60 (50% RDN)	40.6	65.6	75.9	338	3.27	5.23	0.75
90 (75% RDN)	41.9	67.6	77.4	356	3.51	5.54	0.91
120 (100% RDN)	43.2	69.7	78.9	377	3.73	5.83	1.04
SEm±	0.8	0.9	0.9	7.9	0.09	0.12	0.03
CD (p=0.05)	1.9	2.4	2.3	19	0.22	0.30	0.07

DAP: Days after planting; LAI: Leaf area index

Table 2: Effect of water regime, variety and nitrogen on DMA and CGR of summer rice (pooled data)

Treatments	DMA (g m^{-2}) at different DAP			CGR (g m^{-2} day^{-1}) at different DAP	
Water regime	30	60	90	30-60	60-90
Drying & wetting	436	624	1056	10.37	9.43
Saturation	508	667	1220	12.95	11.66
SEm±	10.1	13.6	19.1	0.30	0.29
CD (p=0.05)	28	37	52	0.83	0.81
Variety					
IR-36	479	656	1181	12.43	11.50
Annapurna	465	634	1096	10.91	9.59
SEm±	10.1	13.6	19.1	0.30	0.29
CD (p=0.05)	28	37	52	0.83	0.81
N levels (kg ha^{-1})					
60 (50% RDN)	446	609	1056	10.82	9.13
90 (75% RDN)	475	633	1145	11.66	10.68
120 (100% RDN)	495	680	1213	12.46	11.82
SEm±	12.3	16.6	23.3	0.37	0.36
CD (p=0.05)	31	41	58	0.92	0.89

DAP: Days after planting

drying and wetting condition. Better growth and higher yield of the crop grown at continuous saturation were mainly responsible for paying greater return from summer rice when compared to that alternate drying and wetting condition. IR 36 paid greater gross (₹ 37145 ha^{-1}) and net return (₹ 16282 ha^{-1}) over that of

Annapurna (₹ 34659 and ₹ 14063 ha^{-1} respectively). IR 36 showed greater yield potentiality and thus paid higher return than that of Annapurna (Table 6). The crop receiving 120 kg N ha^{-1} (RDN) paid the highest gross (₹ 37517 ha^{-1}) and net (₹ 16171 ha^{-1}) returns and was comparable to that of medium (90 kg N ha^{-1}) N level; but, significantly superior to that of low (60 kg N ha^{-1}) N level. However, the return per rupee invested did not vary much due to different levels of N application.

3.4. Interaction effect

Significant interaction effect of water regime and nitrogen (W×N) was recorded on various growth and yield attributes of summer rice (Table 5). The crop at continuous saturation receiving 120 kg N ha^{-1} (RDN) produced greater number tillers m^{-2}, LAI at maximum tillering to flowering (30-60 DAT) and CGR during grain filling period (60-90 DAT) over most of the other treatments. It recorded the highest number of panicles m^{-2} and grains $panicle^{-1}$ and finally produced the highest grain (6299 kg ha^{-1}) yield (Figure 2a) and paid very high net return (₹ 16818 ha^{-1}) from summer rice as compared to most of the other treatments. The crop at alternate drying and wetting condition with low N level (60 kg N ha^{-1}) recorded poor growth, lowest grain yield (4730 kg ha^{-1}) and paid very low net return (₹ 13678 ha^{-1}). Continuous saturation with RDN created most favourable condition for summer rice that helped in increasing tillering and developing high LAI functioning over grain filling period resulting in greater CGR and finally higher grain yield over other situations (Singh et al., 2001).

Crop variety and nitrogen (V×N) also exerted significant

Table 4: Effect of water regime, variety and nitrogen on the economics of summer rice (pooled data)

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Return $rupee^{-1}$ invested
Water regime				
Drying & wetting	18492	32238	13746	1.74
Saturation	22968	39567	16600	1.73
SEm±		763	327	0.03
CD (p=0.05)		2098	899	NS
Variety				
IR-36	20863	37145	16282	1.78
Annapurna	20597	34660	14063	1.69
SEm±		763	327	0.03
CD (p=0.05)		2098	899	0.08
Nitrogen level (kg ha^{-1})				
60 (50% RDN)	20149	34257	14108	1.70
90 (75% RDN)	20694	35934	15240	1.74
120 (100% RDN)	21347	37517	16171	1.76
SEm±		934	401	0.03
CD (p=0.05)		2317	994	NS

Table 3: Effect of water regime, variety and nitrogen on yield components and yield of summer rice (pooled data)

Treatments	Panicles m^{-2}	Grains $panicles^{-1}$	Test weight (g)	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest Index (%)
Water regime				2004	2005	Pooled	2004	2005	Pooled	Pooled
Drying & wetting	286	85	19.4	4988	4947	4968	5325	5423	5374	48.0
Saturation	338	91	19.8	6091	5959	6025	6233	6358	6296	49.0
SEm±	4.9	1.5	0.11	92.7	87.4	88.5	103.5	88.9	96.2	0.5
CD (p=0.05)	14	4	0.3	254.9	240.3	243	284.7	244.4	265	NS
Variety										
IR-36	332	86	20.6	5717	5625	5671	6003	5999	6001	48.6
Annapurna	291	90	18.7	5362	5281	5322	5556	5782	5669	48.4
SEm±	4.9	1.5	0.11	92.7	87.4	88.5	103.5	88.9	96.2	0.5
CD (p=0.05)	14	4	0.3	254.9	240.3	243	284.7	244.4	265	NS
Nitrogen level (kg ha^{-1})										
60 (50% RDN)	288	83	19.5	5253	5163	5208	5408	5549	5479	48.7
90 (75% RDN)	313	87	19.6	5540	5466	5503	5780	5915	5848	48.5
120 (100% RDN)	334	93	19.7	5825	5730	5778	6150	6208	6179	48.3
SEm±	6.0	1.8	0.14	113.5	107.0	111.4	126.8	108.8	118.5	0.6
CD (p=0.05)	15	4	0.3	282	265	277	314	270	294	NS

Table 5: Interaction effect of water regime and nitrogen on growth and yield attributes of summer rice (pooled data)

Interaction	Tillers m^{-2}		LAI (30 DAT)		LAI (60) DAT		CGR (60-90 DAT)		Panicles m^{-2}		Grains $panicle^{-1}$	
W×N*	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
N_1	310	366	3.05	3.49	5.06	5.42	12.30	14.00	261	315	80.6	84.6
N_2	329	382	3.20	3.81	5.40	5.69	14.32	17.20	287	340	84.4	90.4
N_3	355	400	3.46	3.99	5.56	6.07	16.62	19.98	309	358	89.2	96.8
CD (p=0.05)		17.2		0.25		0.30		2.65		16.5		5.6

*W_1: Alternate Drying & wetting; W_2: Continuous saturation; N_1: 60 kg N ha^{-1}; N_2: 90 kg N ha^{-1} and N_3: 120 kg N ha^{-1}

Table 6: Interaction effect of water regime and nitrogen on growth and yield attributes of summer rice (pooled data)

Interaction	Tillers m^{-2}		LAI (30 DAT)		LAI (60) DAT		CGR (60-90 DAT)		Panicles m^{-2}		Grains $panicle^{-1}$	
V×N*	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
N_1	351	324	3.39	3.15	5.32	5.17	14.68	11.61	306	270	81.2	84.0
N_2	374	339	3.65	3.35	5.67	5.42	16.87	14.65	333	293	85.1	89.7
N_3	393	361	3.87	3.58	5.96	5.67	19.97	16.62	356	312	90.2	95.7
CD (p=0.05)		17.2		0.25		0.30		2.65		16.5		5.6

*V_1=IR-36, V_2=Annapurna, N_1=60 kg N ha^{-1}, N_2=90 kg N ha^{-1} and N_3=120 kg N ha^{-1}

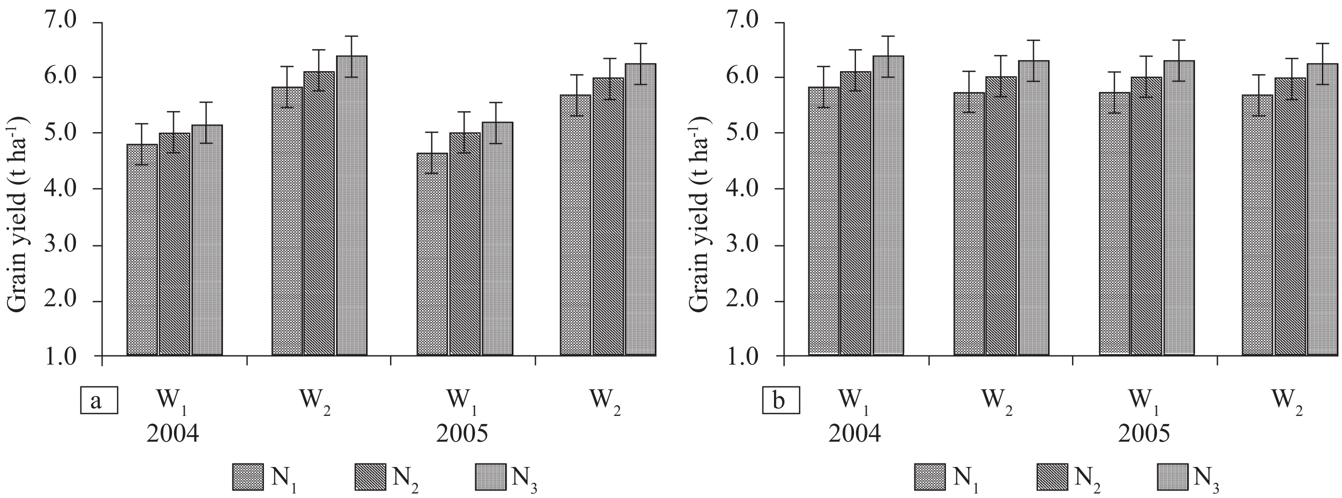

Figure 1: Interaction effect of (a) water regime×nitrogen and (b) nitrogen×variety on grain yield of summer rice

interaction effect on growth and yield attributes of summer rice. IR 36 receiving 120 kg N ha^{-1} (RDN) produced greater number of tillers m^{-2}, leaf area index and crop growth rate during grain filling period over most of the other treatments. It also recorded the higher number of panicles m^{-2} and grains $panicle^{-1}$ (Table 6) that helped in producing the highest grain yield (5882 kg ha^{-1}) of summer rice (Figure 2b).

4. Conclusion

It may be concluded from the above results that IR 36 at continuous saturation with 120 kg N ha^{-1} (RDN) be adapted for improving growth and productivity of summer rice that led to high net return in lateritic belt of West Bengal.

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