IJABR, VOL.8 (2) 2018: 244-249 ISSN 2250 – 3579

INTERNATIONAL JOURNAL OF ADVANCED BIOLOGICAL RESEARCH

www.scienceandnature.org

STUDIES ON YIELD, ECONOMICS AND ENERGETICS OF RICE (*Oryza sativa* L.) IN RELATION TO ESTABLISHMENT SYSTEMS AND SITE SPECIFIC NITROGEN MANAGEMENT APPROACHES

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ABSTRACT
A field experiments were conducted during *kharif* 2014 and 2015 at College of Agriculture, Navile, Shivamogga to evaluate three rice establishment systems *viz*. aerobic, system of rice intensification (SRI) and conventional system under four site specific nitrogen management approaches *viz*. soil test and crop response (STCR), Soil test laboratory (STL), Leaf colour chart (LCC) and Recommended fertilizers (RDF). Among different systems of establishment, SRI system registered significantly higher grain and straw yield (7767 and 8879 kg ha^{-1}), gross returns (113752 Rs. ha^{-1}), net returns (78288 Rs. ha^{-1}), B:C ratio (2.2), output energy (225626 MJ ha^{-1}), energy ratio (7.86), energy productivity (581.14 g MJ^{-1}) as compared to aerobic and conventional systems. Among different site nitrogen management approaches, STCR approach recorded significantly higher grain and straw yield (7183 and 8314 kg ha^{-1}), gross returns (105300 Rs. ha^{-1}), net returns (69314 Rs. ha^{-1}), B:C ratio (1.9), output energy (209197 MJ ha^{-1}) and specific energy (15.82 kg MJ^{-1}). A treatment combination of SRI system with STCR approach of nitrogen management recorded higher grain and straw yield (8348 and 9479 kg ha^{-1}), gross returns (122201 Rs. ha^{-1}), net returns (86421 Rs ha^{-1}), B: C ratio (2.4) and output energy (240789 MJ ha^{-1}) and found feasible.

KEY WORDS: Economics, Energetics, Establishment, Management, Nitrogen, Rice.

INTRODUCTION
Rice (*Oryza sativa* L.) is one important cereal crop which plays a key role in food security. More than 90% of total rice production in the world is consumed in Asian countries, where it is a staple food for a majority of the population (Mohanty, 2014). India has recorded production of rice to the tune of 106.54 million tonnes (Anon., 2014); but considering the present growth rate of population as well as per capita income, the demand for rice has been projected as 156 million tonnes by 2030 (ICAR, 2010). System establishment influences the performance of rice through its effect on growth and development. Although, conventional system has been reported to be the best establishment system (Jana *et al*., 1981 and Singh *et al*., 1997) but due to high water and labour requirement alternatives like aerobic and SRI are being explored. It is estimated that about 3000-5000 litres of water is required to produce 1 kg of rice by conventional transplanting method of rice cultivation (Rao *et al*., 2013). Hence, in recent years, systems of rice cultivation have been developed to use water more efficiently. Two prominent systems among them are system of rice intensification (SRI) and aerobic method. These two methods are considered as systems rather technology as they involve holistic management of resources to provide ideal growing condition for rice plant. In SRI method of rice cultivation, field is kept moist rather than continuously saturated, minimizing anaerobic conditions as this improves root growth and supports the growth of the plant. Whereas aerobic condition is growing the crop like other arable crop with frequency of irrigation is 4 to 5 days interval to keep the soil moist which saves water by eliminating continuously seepage and percolation, reducing evaporation and eliminating wetland preparation. System of rice intensification and aerobic methods are emerged as water saving technologies which can help the farmers to overcome the present water scarcity (Bharati *et al.*, 1999). Effective management of fertilizer, particularly nitrogen is a major challenge for researchers and producers. Hence, decisions regarding improvement in fertilizer nitrogen use efficiency begin at the field scale. A new concept, called site specific nutrient management (SSNM) approach which provides timely application of fertilizer at optimal rates to fill the deficit between the nutrient needs of crop and nutrient supplying capacity of soil.

Rice cultivation requires many energy consuming operations such as tillage, transplanting, irrigation, application of fertilizers, agro-chemicals for plant protection, harvesting, transportation etc. In order to sustain agricultural production, effective energy use is required, since it provides ultimate financial saving, preservation of fossil resources and reduction of environment distortion (Demircan *et al*., 2006). In the present era of energy crisis, for formulating any policy on energy use and conservation, it is imperative to examine the pattern of energy consumption for agricultural production especially rice. Keeping this in view, a field experiments were conducted at the College of Agriculture, Navile, Shivamogga to evaluate the yield, economics and energetics of different rice establishment systems under different Site specific nitrogen nutrient management approaches.

MATERIALS & METHODS

A field experiment was conducted during the *kharif* 2014 and 2015 at College of Agriculture, Navile, UAHS, Shivamogga comes under Southern Transition Zone (Zone-7) of Karnataka. The geographical reference point of experimental site was 13^0 58' to 14^0 1' North latitude and 75^0 34' to 75^0 42' East longitude with an altitude of 650 m above the mean sea level. The field experiments were laid out in adjacent plots of the same block in 2014 and 2015, respectively. The experiment was laid out in spilt plot design with three rice systems of establishment as a main plots (aerobic, SRI and conventional) and nitrogen management approaches as subplots (STCR, STL, LCC and RDF) with three replication and 12 treatment combinations. The main plots were prepared according to desired environment/ecosystem and the subplots were maintained under each main plot. The variety used in the experiment was KRH-4. Twelve days old seedlings were carefully planted (single seedling hill^{-1}) at a spacing of 25 x 25 cm in SRI system, two seeds were dibbled per spot at a spacing of 25 x 25 cm and depth of not more than two cm accounting seed rate of five kg ha^{-1}. After ten days of sowing, only one seedling was maintained by removing the excess seedling and necessary gaps were filled during the time in case of aerobic system. Twenty one days old seedlings were planted (one seedling hill^{-1}) at a spacing of 20 cm x 15 cm in conventional system.

A common dose of FYM @ 10 tonnes ha^{-1} was incorporated uniformly into the soil two weeks before planting for all systems of establishment. For all the treatment plots, a common dose of 20 kg $ZnSo_4$ ha^{-1} was applied at the time of sowing/transplanting. The quantity of different major fertilizer used under different approaches are mentioned below, for STCR approach under all the system of establishment the quantity of major plant nutrients were calculated with a target yield of 80 q ha^{-1} by using target yield equations for Bhadra command area (Anon., 2008).

FN = 2.981 T – 0.30 SN ($KMnO_4$ - N)
FP_2O_5 = 1.232 T – 0.786 SP_2O_5 (Bray's P_2O_5)
FK_2O = 1.173 T – 0.155 SK_2O (NH_4OAC – K_2O)
Where,
T = Targeted yield (80 q ha^{-1}) i.e. 80 q ha^{-1}
FN = Nitrogen supplied through Fertilizer (kg ha^{-1})
SN = Initial available Nitrogen in soil (kg ha^{-1})
FP_2O_5 = Phosphorous supplied through Fertilizer (kg ha^{-1})
SP_2O_5 = Initial available P_2O_5 in soil (kg ha^{-1})
FK_2O = Potassium supplied through Fertilizer (kg ha^{-1})
SK_2O = Initial available K_2O in soil (kg ha^{-1})

Accordingly, the quantity of nitrogen was175 and 176 kg ha^{1}, wherein phosphorus and potassium levels stood at 55 and 56 kg ha^{-1} in 2014 and 2015, respectively. In STL approach amount of fertilizer was calculated using soil test rating, where fertilizer recommendations were adjusted empirically by increasing or reducing the general recommendation levels by 30 – 50 per cent for condition of low and high soil fertility status. Since for rice crop recommended dose of nitrogen is 100 kg ha^{-1} and the soil of the experimental area was low in available nitrogen, hence in accordance with table, +12.5 kg ha^{-1} is added along with recommended dose, considering their status, for phosphorus and potassium no change is made in the level of application (50 kg ha^{-1}). Leaf colour chart approach plots received a uniform dose of 14 kg nitrogen ha^{-1} as a basal dose for all the systems of establishment. Further, nitrogen is supplied to the crop based on LCC value off our and below (Balasubramanian *et al*., 1999). Readings started from 14 days in SRI and conventional systems and from 21 days in aerobic system at an interval of three days until first flowering. Nitrogen @ 25 kg ha^{-1} was applied for SRI and conventional systems and 20 kg ha^{-1} was applied in aerobic system at each LCC reading value four and below. The total quantity of nitrogen used in the LCC based approach is 134 in case of aerobic and 164 kg ha^{-1} in SRI and conventional systems in both the year of experiment. Recommended dose of fertilizer 100:50:50 kg N:P_2O_5:K_2O ha^{-1}as per the package of practice of 2010, University of Agricultural Sciences, Bangalore. Other cultural practices were taken as per the recommendation and requirement of the crop.

Grain and straw yield were recorded as per standard procedures. The cost of cultivation, gross return, net return (gross return – cost of cultivation) and benefit cost ratio (gross return/cost of cultivation) were calculated on the basis of prevailing market price of different inputs and outputs. Energy input was estimated in Mega Joule (MJ) ha^{-1} with reference to the standard values prescribed by Mittal *et al*. (1988). The standard energy coefficients for seed and straw were multiplied with their respective yields and summed up to obtain the energy output. Based on the energy equivalents of inputs and output, the energy indices viz., energy ratio (energy output/energy input), specific energy (kg MJ^{-1}) and energy productivity (grain yield (g)/energy input) were calculated as per Rafiee *et al*., 2010.

RESULTS & DISCUSSION

Effect on yield

Systems of establishment and site nitrogen management approaches influenced significantly on grain and straw yield (Table 1). Among different systems of establishment, SRI system recorded significantly higher grain and starw yield (7767 and 8879 kg ha^{-1}) over aerobic (4975 and 5948 kg ha^{-1}) and conventional (7175 and 8105 kg ha^{-1}) systems. Among different nitrogen management approaches, STCR approach recorded significantly higher grain yield (7183 and 8314 kg ha^{-1}) over other nitrogen management approaches, whereas, lesser grain yield was recorded with RDF approach (6196 and 6977 kg ha^{-1}). Interaction between systems of establishment and nitrogen management approaches were not found significant. Whereas, a treatment combination of SRI system with STCR approach of nitrogen management recorded numerically higher grain and straw yield (8348 and 9479 kg ha^{-1}) followed by conventional system with STCR approach (7921 and 8977 kg ha^{-1}) and SRI system with LCC approach of nitrogen management (7914 and 8960 kg ha^{-1}). The better performance under SRI system is mainly due to combination of transplanting early aged (12 days old), single seedlings per hill, shallow depth of planting with wider spacing (25 x 25 cm), least injury to the roots with quick establishment promoting deeper and better distribution of root systems paving way for both improved uptake of nitrogen obtained from STCR approach, from younger seedlings till its peak period of growth and further helping greatly translocation of carbohydrate or photosynthate as a part of partitioning. The results are in conformity with the findings of Suresh Naik (2014).

TABLE 1: Grain yield and straw yield of rice as influenced by systems of establishment and nitrogen management approaches

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2014	2015	Pooled	2014	2015	Pooled
Systems of establishment (S)						
S_1 – Aerobic	4933	5018	4975	5948	5949	5948
S_2 – SRI	7726	7807	7767	8882	8875	8879
S_3 – Conventional	7132	7219	7175	8177	8032	8105
S.Em±	78	89	59	296	275	202
C.D. (p=0.05)	307	351	194	1164	1079	659
Nitrogen management approaches (N)						
N_1 – STCR	7144	7222	7183	8362	8266	8314
N_2 – STL	6353	6433	6393	7584	7593	7588
N_3 – LCC	6735	6835	6785	7687	7707	7697
N_4 – RDF	6156	6237	6196	7044	6909	6977
S.Em±	182	192	132	303	313	218
C.D. (p=0.05)	540	570	379	900	929	625
Interaction (SxN)						
S_1N_1	5242	5314	5278	6481	6490	6486
S_1N_2	4794	4872	4833	5894	5903	5899
S_1N_3	5014	5128	5071	5939	5948	5943
S_1N_4	4678	4759	4719	5478	5454	5466
S_2N_1	8308	8389	8348	9474	9483	9479
S_2N_2	7477	7558	7517	8870	8879	8875
S_2N_3	7874	7954	7914	8939	8982	8960
S_2N_4	7248	7329	7288	8246	8155	8201
S_3N_1	7881	7962	7921	9131	8824	8977
S_3N_2	6787	6868	6828	7987	7996	7992
S_3N_3	7317	7421	7369	8183	8192	8188
S_3N_4	6542	6623	6582	7408	7117	7263
S.Em±	315	332	229	525	542	378
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS
CV (%)	8.26	8.61	8.44	11.85	12.32	12.09

NS: Non Significant

Effect on economics

Economics is the ultimate criteria for acceptance or rejection and wider adoption of any technology. Different systems of rice establishment registered significant influence on net returns. SRI system recorded significantly higher gross returns, net returns and B:C ratio (Rs. 113752, 78288 ha^{-1} and 2.2) over aerobic (Rs. 73136, 39910 ha^{-1} 1.2) and conventional (Rs. 104991, 66782 ha^{-1} and 1.7) systems (Table 2). The increased gross returns, net returns and B:C ratio was attributed to higher grain and straw yields obtained in SRI system compared to aerobic and conventional systems, respectively. The results are in conformity with the findings of Jayadeva (2007), Hugar *et al.* (2009) and Suresh Naik (2014).

Among the different site specific nitrogen management approaches, STCR approach recorded significantly higher gross returns, net returns (Rs. 105300, 69314 ha^{-1} and 1.9) over other nitrogen management approaches like RDF (Rs. 90648, 55803 ha^{-1} and 1.6), STL (Rs. 93909, 5887 4ha^{-1} and 1.7) and LCC (Rs. 99314, 62648 ha^{-1} and 1.7) (Table 2). The increased net income and B: C ratio was attributed to higher grain and straw yields obtained in STCR approach of nitrogen management as compared to other approaches. A treatment combination of SRI system with STCR approach of nitrogen management recorded higher net returns and B:C ratio (Rs. 86421 ha^{-1} and 2.4, respectively). It might be attributed due to gross income and reduced cost of cultivation. The results are in conformity with Hugar *et al.* (2009) and Suresh Naik (2014).

TABLE 2: Gross returns, net returns and B: C ratio of rice as influenced by systems of establishment and nitrogen management approaches

Treatments	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C ratio

	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Systems of establishment (S)									
S_1 – Aerobic	70065	76206	73136	36764	43056	39910	1.1	1.3	1.2
S_2 – SRI	109326	118178	113752	73786	82789	78288	2.1	2.3	2.2
S_3 – Conventional	100890	109093	104991	62561	71003	66782	1.6	1.9	1.7
S.Em±	968	1370	839	968	1370	839	0.0	0.0	0.0
C.D. (p=0.05)	3801	5380	2736	3801	5380	2736	0.1	0.1	0.1
Nitrogen management approaches (N)									
N_1 – STCR	101231	109370	105300	65154	73473	69314	1.8	2.0	1.9
N_2 – STL	90168	97650	93909	55043	62705	58874	1.6	1.8	1.7
N_3 – LCC	95238	103391	99314	58482	66815	62648	1.6	1.8	1.7
N_4 – RDF	87071	94226	90648	52136	59471	55803	1.5	1.7	1.6
S.Em±	2297	2752	1793	2297	2752	1793	0.1	0.1	0.0
C.D. (p=0.05)	6826	8177	5141	6826	8177	5141	0.2	0.2	0.1
Interaction (SxN)									
S_1N_1	74631	80890	77761	40901	47311	44106	1.2	1.4	1.3
S_1N_2	68216	74112	71164	35438	41483	38460	1.1	1.3	1.2
S_1N_3	71116	77740	74428	37011	43785	40398	1.1	1.3	1.2
S_1N_4	66295	72083	69189	33707	39645	36676	1.0	1.2	1.1
S_2N_1	117475	126926	122201	81621	91222	86421	2.3	2.6	2.4
S_2N_2	106067	114687	110377	71163	79933	75548	2.0	2.3	2.2
S_2N_3	111295	120345	115820	74609	83809	79209	2.0	2.3	2.2
S_2N_4	102465	110756	106610	67751	76192	71972	2.0	2.2	2.1
S_3N_1	111585	120293	115939	72940	81888	77414	1.9	2.1	2.0
S_3N_2	96221	104151	100186	58527	66698	62612	1.6	1.8	1.7
S_3N_3	103301	112088	107695	63826	72852	68339	1.6	1.9	1.7
S_3N_4	92454	99839	96146	54950	62575	58763	1.5	1.7	1.6
S.Em±	3979	4767	3104	3979	4767	3104	0.1	0.1	0.1
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	7.38	8.16	7.82	11.94	12.58	12.33	11.74	12.51	12.21

NS: Non Significant

TABLE 3: Output energy and energy ratio of rice as influenced by systems of establishment and nitrogen management approaches

Treatments	Output energy (MJ ha^{-1})			Energy ratio		
	2014	2015	Pooled	2014	2015	Pooled
Systems of establishment (S)						
S_1 – Aerobic	147807	148131	147969	5.45	5.46	5.46
S_2 – SRI	225546	225706	225626	7.86	7.86	7.86
S_3 – Conventional	207591	206519	207055	6.78	6.74	6.76
S.Em±	7170	4072	4123	0.23	0.12	0.13
C.D. (p=0.05)	28152	15990	13445	0.90	0.46	0.42
Nitrogen management approaches (N)						
N_1 – STCR	208914	209480	209197	6.08	6.09	6.08
N_2 – STL	188181	189472	188827	7.20	7.25	7.23
N_3 – LCC	195252	196811	196031	6.07	6.12	6.09
N_4 – RDF	182245	178044	180144	7.45	7.28	7.36
S.Em±	4738.0	5170	3506	0.16	0.18	0.12
C.D. (p=0.05)	14078	15361	10057	0.47	0.54	0.35
Interaction (SxN)						
S_1N_1	157657	159247	158452	4.74	4.78	4.76
S_1N_2	144147	145409	144778	5.75	5.80	5.78
S_1N_3	148427	149732	149079	5.31	5.36	5.33
S_1N_4	140998	138136	139567	6.02	5.90	5.96
S_2N_1	239720	241858	240789	7.07	7.13	7.10
S_2N_2	220785	222090	221438	8.59	8.65	8.62
S_2N_3	227480	229202	228341	6.88	6.93	6.90
S_2N_4	214200	209672	211936	8.91	8.72	8.82
S_3N_1	229365	227337	228351	6.42	6.37	6.40
S_3N_2	199612	200917	200264	7.27	7.31	7.29
S_3N_3	209849	211498	210674	6.02	6.07	6.04
S_3N_4	191538	186323	188930	7.42	7.22	7.32

S.Em±	8206	8955	6073	0.28	0.31	0.21
C.D. (*p*=0.05)	NS	NS	NS	NS	NS	0.60
CV (%)	7.34	8.02	7.69	7.13	8.09	7.63

NS: Non Significant

TABLE 4: Specific energy and energy productivity of rice as influenced by systems of establishment and nitrogen management approaches

Treatments	Specific energy (kg MJ^{-1})			Energy productivity (g MJ^{-1})		
	2014	2015	Pooled	2014	2015	Pooled
Systems of establishment (S)						
S_1 – Aerobic	16.00	16.02	16.01	404.28	404.22	404.25
S_2 – SRI	15.27	15.28	15.27	581.61	580.67	581.14
S_3 – Conventional	15.54	15.58	15.56	501.69	497.80	499.75
S.Em±	0.09	0.07	0.06	16.96	9.06	9.62
C.D. (*p*=0.05)	0.35	0.29	0.19	66.61	35.59	31.36
Nitrogen management approaches (N)						
N_1 – STCR	15.82	15.82	15.82	449.47	450.51	449.99
N_2 – STL	15.44	15.44	15.44	533.55	536.98	535.27
N_3 – LCC	15.79	15.78	15.79	448.60	452.00	450.30
N_4 – RDF	15.37	15.46	15.41	551.84	537.43	544.63
S.Em±	0.08	0.08	0.05	12.62	13.66	9.30
C.D. (*p*=0.05)	0.23	0.23	0.16	37.50	40.60	26.67
Interaction (SxN)						
S_1N_1	16.37	16.36	16.33	351.11	354.54	352.82
S_1N_2	15.86	15.85	15.81	426.48	429.96	428.22
S_1N_3	16.06	16.05	16.02	392.97	396.19	394.58
S_1N_4	15.73	15.82	15.73	446.58	436.19	441.39
S_2N_1	15.46	15.44	15.40	522.23	526.85	524.54
S_2N_2	15.09	15.09	15.03	636.34	639.85	638.09
S_2N_3	15.51	15.49	15.44	508.21	511.94	510.08
S_2N_4	15.02	15.09	15.00	659.68	644.02	651.85
S_3N_1	15.63	15.67	15.60	475.08	470.14	472.61
S_3N_2	15.38	15.37	15.31	537.84	541.12	539.48
S_3N_3	15.80	15.80	15.74	444.61	447.86	446.23
S_3N_4	15.35	15.45	15.33	549.25	532.09	540.67
S.Em±	0.13	0.13	0.09	21.86	23.67	16.11
C.D. (*p*=0.05)	NS	NS	NS	NS	NS	46.20
CV (%)	1.48	1.50	1.49	7.64	8.29	7.97

NS: Non Significant

Effect on energetics

Energitics significantly influenced by different systems of establishment and site specific nitrogen management approaches (Table 3 and 4.). SRI system recorded significantly higher output energy and energy ratio (225626 MJ ha^{-1} and 7.86) as compared to aerobic (147969 MJ ha^{-1} and 5.46) and conventional (207055 MJ ha^{-1} and 6.76) systems (Table 3). The higher output energy and energy ratio in is due to higher yield and lesser input energy obtained under SRI system as compared to other in test. The energy productivity as proposed by Fluck (1979), measures energy utilization in an agricultural system. It is the quantity of product per unit of input energy conveniently expressed in kg MJ^{-1}. The Highest energy productivity per unit of energy was obtained by SRI system (581.14 g MJ^{-1}) compared to conventional system (499.75 g MJ^{-1})and aerobic (404.25 g MJ^{-1}).Whereas specific energy was higher under aerobic system of establishment (16.01 kg MJ^{-1}) compared to SRI and conventional system (15.27 and 15.56 kg MJ^{-1}). Among different nitrogen management approaches, STCR approach recorded higher output energy (209197 MJ ha^{-1}) and specific energy (15.82 kg MJ^{-1}). Whereas energy ratio (7.36) and energy productivity (544.63 g MJ^{-1}) was higher in case of RDF approach of nitrogen management.

CONCLUSION

In terms of productivity, profitability and energy use, the establishment of rice by the system of rice intensification (SRI) in combination with STCR approach of nitrogen management was found to be superior.

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