Water and fertilizer use efficiency in aerobic rice as influenced by fertigation schedules

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ABSTRACT

Field experiments were conducted during kharif 2016 and summer 2016 in the field of Department of Agronomy, College of Agriculture, Shimoga, Karnataka. The effect of levels and methods of fertilizer application (surface and fertigation) with combination of water soluble fertilizers and normal fertilizers or alone on growth and yield of aerobic rice was studied. Results revealed that among root characteristics studied, fertigated plots recorded higher volume and weight and comparatively length remained high in surface irrigation. Compared to the 100 per cent RDF plots, fertigated plots recorded higher major nutrients to the extent of 25 per cent. Total water used for the kharif and summer in the surface irrigation was 975 and 1,303 mm against 584 and 746 mm for fertigated plots respectively thereby saved the water resulting use efficiency from 43.29 and 34.42 (100% RDF with surface irrigation plots) up to 100+ and 90+ kg/ha respectively for kharif and summer in different fertigated plots. Similarly nutrient use efficiency of nitrogen also increased from 82.09 and 86.18 up to 119.17 and 124.11 kg/ha from surface to fertigated plots respectively. Fertigated plots performed best for achieving yield (60.95-68.92 q/ha grain) with higher water use efficiency (59.29 to 104.81 kg/ha/cm) among the treatments tested.

Keywords: Aerobic rice; drip; fertilizers; fertigation; water soluble fertilizers

INTRODUCTION

India being the second largest producer of rice in the world (116.42 million tonnes) covers an area of 43.79 million ha with the productivity level of 2,659 kg/ha (https://eands.dacnet.nic.in/PDF/At%20a%20Glance%202019%20Eng.pdf). Being cultivated in different ecosystems, its water use efficiency is very low and loss of applied fertilizers in the field is also more thereby creating challenges for rice cultivation. Adoption of aerobic rice system wherever possible is said to be one of the alternatives in the present condition.

Among different inputs applied, it becomes crucial to manage efficiently the soil for nutrients and water for achieving consistent yields in aerobic rice. Because of aerobic situation, location specific factors influence upon optimizing fertilizer requirements of the crop. Maximum yields are obtained when optimum quantities of nutrients are provided for a crop for which interaction of other factors gains importance demanding resource management at its best. Researchers with suitable modifications of the local environment aimed to help the crop to utilize the available resources efficiently to achieve higher production. Nutrient bio-availability is a function of both plant and soil factors that can be altered by water management particularly in relation to the conditions in rhizosphere. Bio-geochemical modelling based on bulk soil conditions emphasizes on dissolved organic ions, pH and redox conditions as major determinants apart from chemical properties of soil and biological processes in rhizosphere. In order to avail relatively mobile elements into the root zone, suitable modifications such as drip system of water distribution, fertigation etc are very helpful under aerobic ecosystem.

Increased total dry matter in rice is well accomplished with higher photosynthesis and NPK uptake which transmit the nutrients to grains and straw. Hence nutrient uptake is a function of biomass and nutrient concentrations in plant. Yield maximization of any crop demands on the process associated with uptake of nutrients, translocation, retention, partitioning, assimilation and mobilization of nutrients at different growth stages. These multitude processes are influenced by genetic potential of varieties, cultural practices, soil manipulation and climatic factors. The enhancement of nutrient content in any given situation rests on availability of nutrients from the soil through added manures and fertilizers. The growth enhancement also depends on nutrients as a part of inorganic constituent in plant system. Growth ie biomass and nutrient uptake is synergistic in bringing the crop for healthy production. Hence production capacity of soil needs to be addressed properly to augment the nutrient uptake by crop plants timely.

Simultaneous use of drip irrigation and fertilizer application (fertigation) opens up new possibilities for controlling water and timely nutrient supply to crops besides maintaining the desired concentration and distribution of nutrients and water into the soil. Fertigation gives advantages such as higher use efficiency of water and fertilizer, minimum losses of N due to leaching, supplying nutrients directly to root zone in available forms, control of nutrient concentration in soil solution and saving in application cost. Thus fertigation becomes prerogative for increasing the yield of most of the crops under drip irrigation. Water soluble fertilizers having high content of nutrients with low salt index can be used for fertigation (Sandhu et al 2012). As water soluble fertilizers are very costly inputs, efforts should be made to reduce the quantity of water soluble fertilizers in conjunction with normal fertilizers (Yanglem and Tumbare 2014). Keeping the above facts in mind, the present study was conducted with the objective to determine the combined fertilizer rates for getting highest growth and yield of aerobic rice production through drip fertigation.

MATERIAL and METHODS

Field study was conducted during summer and kharif rice growing seasons of 2016 in the field of Department of Agronomy, College of Agriculture, UAHS, Shimoga (13°58' North longitude 75°34' East longitude with an altitude of 650 m amsl), located under southern transition zone of Karnataka. The experimental soil had sandy loam texture with a predominance of illite clay mineral which is taxonomically classified under the major group Typic Haplustept. The experiment was laid out in a randomized complete block design (RCBD) comprising 3 replications and 12 treatments viz T_1 (75% RDF through fertigation), T_2 (100% RDF through fertigation), T_3 (125% RDF through fertigation), T_4 (50% RDF- soil application + 25% RDF- fertigation), T_5 (50% RDF- soil application + 50% RDF- fertigation), T_6 (50% RDF- soil application + 75% RDF- fertigation), T_7 (25% RDF- soil application + 50% RDF- fertigation), T_8 (25% RDF- soil application + 75% RDF- fertigation), T_9 (25% RDF- soil application + 100% RDF-fertigation), T_{10} (75% RDF through soil application), T_{11} (100% RDF through soil application) and T_{12} (125% RDF through soil application). Based on 1.0 PE, fertigation was scheduled for 8 equal splits at 10, 20, 30, 40, 50, 60, 70 and 80 DAS. The aerobic rice cultivar used was MAS 946-1 (Sharada).

The land was ploughed once with disc plough followed by two harrowings as per the treatments. The sources of nutrients for water soluble fertilizers used were 19:19:19 and calcium ammonium nitrate (15.5% N and 17% Ca). In standard soil application, the sources of nutrients applied were in the form of urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O). At different fertigation intervals, fertilizer solution was freshly prepared by taking the required quantity of fertilizer and was filled in plastic bucket which was connected with suction device of ventury system. NPK was applied through drip fertigation method by using ventury system to each plot up to 80 days after sowing at ten days interval. For standard soil application treatments, out of the recommended dose of fertilizers, 50 per cent of recommended nitrogen and potassium and entire dose of phosphorous were applied as basal dose. Remaining 50 per cent of recommended nitrogen was applied in two splits one at 30 days after sowing and another at 55-60 days just before panicle emergence along with 50 per cent of recommended potassium. The data were subjected to statistical analysis as suggested by Gomez and Gomez (1984) and results were compared with the onset of monsoon to bring the seedbed to fine tilth. During layout, small bunds were provided all around each plot and between irrigation channels. The experimental area was laid out as per the plan and the land within each individual plot was levelled manually to maintain uniform irrigation water application and aerobic rice seeds were dibbled at 25 cm x 25 cm apart. Recommended farmyard manure was applied at the rate of 10 tonnes/ha two weeks before sowing in all the treatments. The recommended dose of fertilizers (100:50:50 of NPK kg/ha and zinc sulphate @ 20 kg/ha) were applied.

RESULTS and DISCUSSION

Different root characteristics were studied (Table 1) to understand the behaviour as influenced by surface and drip system of irrigation. The root length was found relatively more in surface soil while the other observations on root volume and weight were found higher in drip plots. It indicates that the growth of roots was more and concentrated in plots receiving water continuously while surface irrigation provided the scope to roots to grow in search of water as its availability was not that frequent in these plots. In both the seasons the same results were obtained though in summer, root mass was found little higher. The study supports the finding of Parthasarathi et al (2013).

The plots applied with 100 or 125 per cent RDF through fertigation or conjunction of 25 per cent RDF through soil along with 75 or 100 per cent RDF through fertigation maintained higher major nutrients in both the seasons. As seen from the studies of both the seasons, nutrient uptake pattern increased with age till harvest for all the major elements. Among them nitrogen accumulation from the plants was highest followed by potassium and phosphorus.

The treatment 100 per cent RDF with surface irrigation recorded 82.09 and 86.18 kg N/ha while fertigated plots enhanced up to 119.17 and 124.11 kg N/ha for kharif and summer respectively. This trend remained same for potassium and phosphorus also. Potassium from 78.21 and 82.07 kg/ha (100% RDF plot with kg surface irrigation) up to 98.22 and 102.84 kg/ha (fertigated plots) and phosphorus from 14.50 and 14.88 kg/ha (100% RDF plot with surface irrigation) up to 20.35 and 21.03 kg/ha (fertigated plots) enhanced for kharif and summer seasons respectively. The data given in Fig 2 show that compared to application of 100 per cent RDF along with surface irrigation, plots supplied with 100 or 125 per cent RDF through fertigation or conjunction of 25 per cent RDF through soil along with 75 or 100 per cent RDF through fertigation maintained higher uptake and obviously these groups of treatments performed best for achieving yield among the treatments tested. Between the seasons tested, summer yields were comparatively more than that of kharif as well as nutrient content. The fertigation mode of application resulted into ready availability of nutrients in the root zone promoting uptake as per need and as a result the content of particular nutrients was also found relatively more compared to soil application wherein likely losses of nutrients due to various mechanisms limited the availability into the root zone causing lesser uptake. Gratez et al (1978) suggested that the faster discharge rates might improve the distribution of soluble nutrients particularly for surface rooting crops. Potassium ion is normally adsorbed at the cation exchange sites of the soil colloids. The results corroborate the findings of Chesti et al (2013). Tsujimoto et al (2009) reported that average mineralizable N at depths of 0-30 cm was linearly related to rice grain yields irrespective of management practices. Fageria and Baligar (2003) reported that in cereals including rice, N accumulation is associated with dry matter production and yield of grains.

Based on the amount of nutrients supplied and corresponding yield, nutrient use efficiency was calculated (Fig 1) and showed significant difference due to method of fertilizer application through soil and fertigation. Use efficiencies were higher at lesser applications of nutrient; with each addition of nutrient response increment was likely to reduce with respect to all nutrients because of nature of growth curve that followed sigmoid type as synthates re-orient for economic parts. In this context, the highest nitrogen use efficiency was observed in the plots receiving lesser quantity of fertilizers as the amount increased it decreased for all the major nutrients studied. The N use efficiency ranged from 39.30 to 68.92 kg/kg for kharif and 41.90 to 71.93 kg/kg in different treatments. The application quantity of P and K being the same (50 kg/ha), the use efficiency computations remained same in that the values ranged from 72.90 to 132.05 and 77.60 to 143.87 kg/ha respectively for kharif and summer. These results are in conformity with those of Hebbar et al (2004) and Shedeed et al (2009).

In the present study, the total water used in surface irrigation was 975 and 1,303 mm as against 584 and 746 mm for drip system (Table 2). It is observed from the data that yield variations occurred in tune with gradation of fertilizer. Surface irrigation with 75 or 100 or 125 per cent RDF application through soil resulted in grain yield variations from 36.45 to 49.63 and 38.49 to 52.38 q/ha respectively for kharif and summer and hence water use efficiency varied respectively from 37 to 50 and 29 to 40 kg/ha/cm of water (Tables 2, 3). On the similar lines, drip irrigated plots with different rates of fertilizers through fertigation

Table 1. Root characteristics of aerobic rice as influenced by fertilizer levels applied through conventional and fertigation methods at different growth stages

Treatment	Kharif 2016			Summer 2016		
	Length (cm)	Volume (cm^3/plant)	Dry weight (g/plant)	Length (cm)	Volume (cm^3/plant)	Dry weight (g/plant)
T_1: 75% RDF through fertigation	21.20	51.83	17.18	23.61	54.21	18.23
T_2: 100% RDF through fertigation	20.11	53.18	18.47	22.52	55.68	19.54
T_3: 125% RDF through fertigation	19.07	56.93	19.48	21.41	59.50	20.58
T_4: 50% RDF – soil application + 25% RDF – fertigation	23.97	47.23	14.55	26.69	49.64	15.62
T_5: 50% RDF – soil application + 50% RDF – fertigation	23.13	50.06	16.72	25.98	52.41	17.77
T_6: 50% RDF – soil application + 75% RDF – fertigation	21.66	53.50	18.21	24.14	55.80	19.31
T_7: 25% RDF – soil application + 50% RDF – fertigation	24.05	49.67	15.95	26.28	52.02	17.05
T_8: 25% RDF – soil application + 75% RDF – fertigation	21.17	55.83	19.13	23.52	58.11	20.21
T_9: 25% RDF – soil application + 100% RDF – fertigation	20.45	58.80	21.23	22.89	61.31	22.39
T_{10}: 75% RDF through soil application	25.39	42.15	13.14	27.68	44.61	14.39
T_{11}: 100% RDF through soil application	26.60	41.35	14.78	28.92	43.64	16.83
T_{12}: 125% RDF through soil application	28.30	39.59	17.51	30.51	41.92	18.78
SEm±	1.10	1.37	0.70	1.10	1.17	0.90
$CD_{0.05}$	3.23	4.03	2.11	3.30	3.43	2.66
CV (%)	8.3	5.0	7.6	7.8	4.6	9.0

RDF: 100:50:50 kg NPK/ha

recorded water use efficiency range from 81 to 117 and 67 to 95 ha/cm of water. The present study shows that better water use efficiency through fertigation was achieved.

The higher water use efficiency with drip system can be attributed to reduced water loss and efficient water use by the plants resulting in higher yield. The lower water use efficiency of aerobic rice with surface irrigation can be attributed to more evaporation loss of soil moisture due to more exposed wetting surface upon irrigation apart from reduced grain yield as compared to drip irrigation. Similar results were also reported by Pushpa et al (2007). The correlation and regression calculations were worked out for yield and to that of nutrient uptake. It is seen from the data that with high correlation coefficient, regressed yield by uptake was highly dependent (Table 4).

Higher crop yields are determined by ability of plants to produce high levels of photoassimilates and/or to partition large proportions of carbohydrate efficiently into harvestable organs. Variations accrued in nutrient uptake and growth due to application of treatments essentially reflects in achieving final harvestable yield (Table 3). Among the treatments in test, application of 25 per cent RDF through soil and 100 per cent RDF through fertigation resulted in higher grain yield (68.37 and 71.43 q/ha) and was statistically on par with treatments such as application of 100 or 125 per cent RDF through fertigation and conjunction of 25 per cent RDF through soil along with 75 or 100 per cent RDF through fertigation for grain (60 to 66 and 62 to 68 q/ha). Compared to 100 per cent RDF through soil application with surface irrigation, the maximum yield treatment on par treatments at higher hierarchy recorded 59-71 per cent enhancement. Application of straight fertilizers in combination with water soluble fertilizers was best alternative source to water soluble fertilizers alone. These findings are also in accordance with Anusha (2015).

Table 2. Total water used (mm) and water use efficiency (kg ha/cm) of aerobic rice as influenced by fertilizerlevels applied through conventional and fertigation methods

Treatment	Kharif 2016			Summer 2016		
	Irrigation water used	Total water used ($I_R + E_R$)	WUE	Irrigation water used	Total water used ($I_R + E_R$)	WUE
T_1: 75% RDF through fertigation	319.5	584.0	84.79	693.4	746.7	72.25
T_2: 100% RDF through fertigation	319.5	584.0	102.93	693.4	746.7	83.21
T_3: 125% RDF through fertigation	319.5	584.0	113.36	693.4	746.7	92.27
T_4: 50% RDF – soil application + 25% RDF – fertigation	319.5	584.0	65.48	693.4	746.7	54.13
T_5: 50% RDF – soil application + 50% RDF – fertigation	319.5	584.0	81.37	693.4	746.7	67.18
T_6: 50% RDF – soil application + 75% RDF – fertigation	319.5	584.0	97.76	693.4	746.7	81.64
T_7: 25% RDF – soil application + 50% RDF – fertigation	319.5	584.0	83.32	693.4	746.7	66.84
T_8: 25% RDF – soil application + 75% RDF – fertigation	319.5	584.0	110.09	693.4	746.7	91.82
T_9: 25% RDF – soil application + 100% RDF – fertigation	319.5	584.0	117.07	693.4	746.7	95.66
T_{10}: 75% RDF through soil application with surface irrigation	710	974.5	37.40	1,250	1,303.3	29.53
T_{11}: 100% RDF through soil application with surface irrigation	710	974.5	43.29	1,250	1,303.3	34.42
T_{12}: 125% RDF through soil application with surface irrigation	710	974.5	50.93	1,250	1,303.3	40.19

RDF: 100:50:50 kg NPK/ha, Effective rainfall during 2016= 264.46 mm

Table 3. Grain yield and straw yield of aerobic rice as influenced by fertilizer levels applied through conventional and fertigation methods

Treatment	Grain yield (q/ha)		Straw yield (q/ha)	
	Kharif	Summer	Kharif	Summer
T_1: 75% RDF through fertigation	49.52	53.95	63.22	65.59
T_2: 100% RDF through fertigation	60.11	62.13	69.17	71.55
T_3:125% RDF through fertigation	66.20	68.90	76.70	80.20
T_4: 50% RDF – soil application + 25% RDF – fertigation	38.24	40.42	48.55	50.85
T_5: 50% RDF – soil application + 50% RDF – fertigation	47.52	50.16	57.54	59.96
T_6: 50% RDF – soil application + 75% RDF – fertigation	57.09	60.96	68.28	70.57
T_7: 25% RDF – soil application + 50% RDF – fertigation	48.66	49.91	57.72	60.43
T_8 - 25% RDF – soil application + 75% RDF – fertigation	64.29	68.56	73.50	73.30
T_9: 25% RDF – soil application + 100% RDF – fertigation	68.37	71.43	77.92	81.71
T_{10}: 75% RDF through soil application with surface irrigation	36.45	38.49	42.29	44.66
T_{11}: 100% RDF through soil application with surface irrigation	42.19	44.86	49.91	52.26
T_{12}: 125% RDF through soil application with surface irrigation	49.63	52.38	59.53	64.48
SEm±	3.26	3.18	3.02	3.68
$CD_{0.05}$	9.57	9.34	8.88	10.80
CV (%)	11.3	10.4	8.5	9.8

RDF: 100:50:50 kg NPK/ha

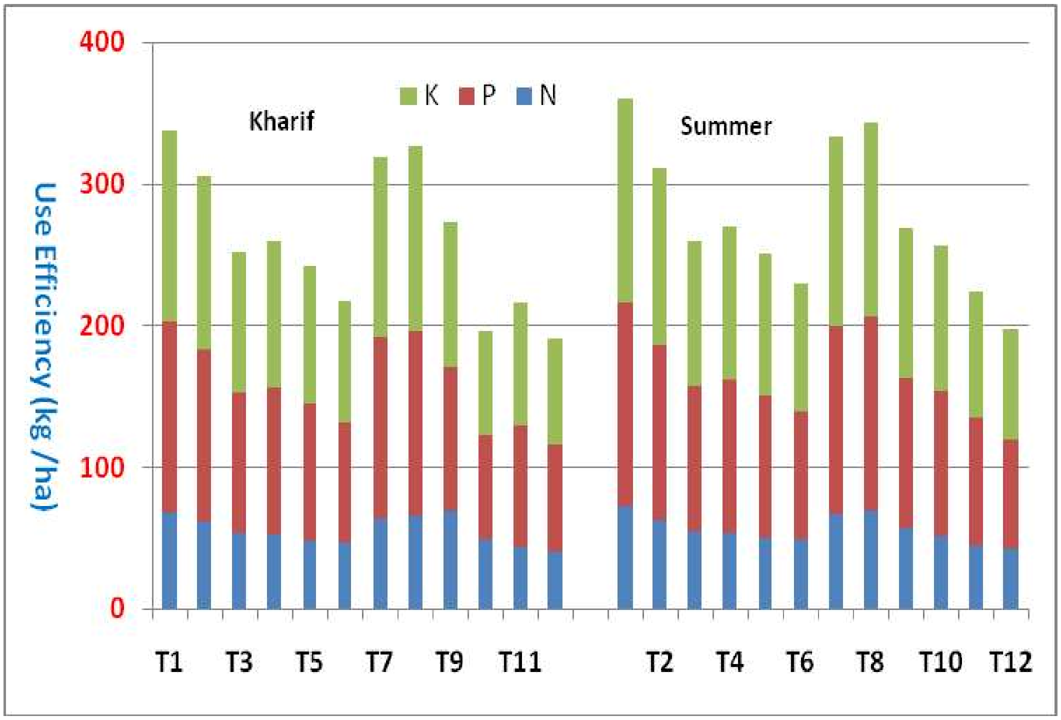

Fig 1. Nutrient use efficiency (kg/ha) of aerobic rice as influenced by fertilizer levels applied through conventional and fertigation methods

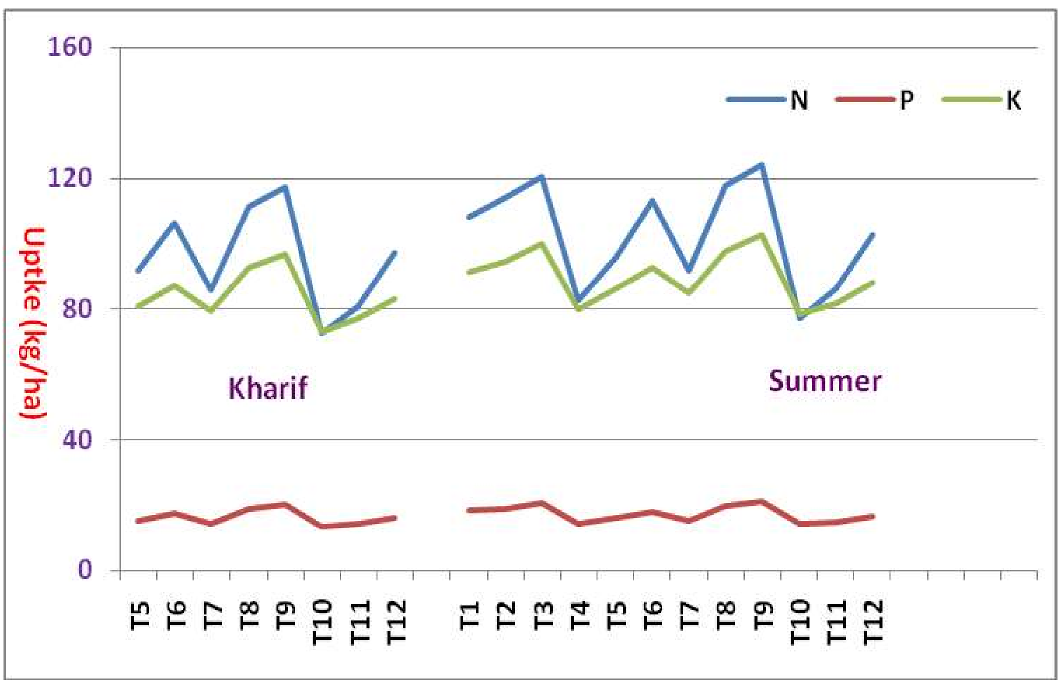

Fig 2. Major Nutrient uptake (kg/ha) of aerobic rice as influenced by fertilizer levels applied through conventional and fertigation methods

Table 4. Regression response for grain yield and major nutrient uptake

Year	Response curve	R	R^2
Summer	$Y = -25.390 + 0.764\, x_1$	0.910	0.829
	$Y = -27.874 + 4.676\, x_2$	0.887	0.787
	$Y = -57.847 + 1.233\, x_3$	0.804	0.647
	$Y = -38.256 + 0.429\, x_1 + 2.013\, x_2 + 0.137\, x_3$	0.936	0.877
Kharif	$Y = -24.469 + 0.769\, x_1$	0.909	0.827
	$Y = -24.819 + 4.563\, x_2$	0.821	0.674
	$Y = -59.612 + 1.296\, x_3$	0.810	0.657
	$Y = -32.220 + 0.592\, x_1 + 1.209\, x_2 + 0.057\, x_3$	0.920	0.846

Y= Grain yield, x_1= N uptake, x_2= P uptake, x_3= K uptake; The independent variable x refers to the parameters listed in serial number, Y is dependent variable; Grain yield in kg/ha; Correlation significant at P= 0.01= 0.413, Correlation significant at P= 0.05= 0.321

CONCLUSION

From the study it is concluded that application of 25 per cent RDF through soil and 75 per cent RDF through fertigation or else 100 per cent RDF through fertigation was found better for both kharif and summer season under sandy loam texture type of soil.

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