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WATER WISE RICE CULTIVATION ON CALCAREOUS SOIL WITH THE ADDITION OF ESSENTIAL MICRONUTRIENTS

N. Sarwar, H. Ali, A. Ahmad*, E. Ullah*, S. Ahmad, K. Mubeen* and J. E. Hill**

Department of Agronomy, Bahauddine Zakariya University Multan, Pakistan
*Department of Agronomy, University of Agriculture Faisalabad, Pakistan
**Department of Plant Sciences, University of California Davis, USA
Corresponding Author: bajwa834@gmail.com

ABSTRACT

Increasing food production and water saving are the major challenges for rice growers at micronutrient deficient soil in Pakistan. Thus the field experiment was conducted focusing on two emerging deficient micronutrients (B and Zn) through soil application in different rice cultures. Application of boron and zinc was done alone and in combination with each other having control treatment in various rice cultures: Aerobic rice, flooded rice and intermittent flooding and drying. Experiment was conducted by using randomized complete block design with split plot arrangements keeping rice cultures in main plot while micronutrients in subplots. Study revealed that the yield attributes (Plant height, productive tillers, panicle length and 1000 kernel weight) of rice crop were significantly hassled when it was subjected to grow in aerobic condition without micronutrients application. However, crop was not affected significantly when it was grown in modified rice culture and performed as good as the normal flooded rice. Rice crop matured in intermittent flooded and drying condition enhanced paddy yield with combined micronutrients application as compared to aerobic culture and resulted in similar performance with flooded rice. Maximum water productivity (0.26, 0.21g/liter) and benefit cost ratio (1.89, 1.72) was recorded in modified rice culture.

Key words: water productivity, yield attributes, rice, boron and zinc.

INTRODUCTION

Most of the soil in Pakistan is alkalized and with high pH. Due to intensive cropping, deficiency of some micronutrients (boron and zinc) is common in many regions of the country. Transplanting of rice is prevalent in Pakistan which requires lot off water inputs to maintain flooding condition from transplanting to physiological maturity. Due to the shrinkage of world water resources farmers are forced to grow rice with limited available water. Lot off water saving technologies are under study like aerobic rice (Bouman *et al*. 2005), Saturated soil culture (Borell *et al*., 1997), Alternative wetting drying (Tabbal *et al*., 2002), System of rice intensification (Stoop, 2002). In Pakistan, water shortage has forced the farmer to shift rice cultivation from flooded to aerobic culture which also saves cost of raising nursery, transportation and transplanting of seedlings. Rice growers face the problems of skilled labor shortage which lead toward lower resultant yield in transplanted rice (Aslam *et al*., 2008). In aerobic rice, cultivars are grown under dry land condition as the other cereal crops are grown without maintaining water at standing condition. Basmati varieties are dominant on farmer fields in most of the country's rice tract due to its high market price which was developed specifically for flooded condition. Due to the emerging water shortage problem, rice growers don't have another option to grow basmati varieties in aerobic culture or with any other rice culture with reduced water inputs. This change in cultivation can change the nutrient dynamic in the soil which in turn may affect the crop performance especially fine genotypes. In Pakistan, soil is calcareous in nature with low organic matter and due to intensive cultivation deficiency of nutrients is increasing day by day especially zinc and boron (Rafique *et al*. 2006, 2008). Plant grown in aerobic field took less zinc than plants grown in flooded fields (Gao *et al*., 2006). It is highly related to comprehend the lower uptake of zinc and boron, reducing crop quality and quantity. Application of zinc resulted in improved yield as well grain zinc contents not only in rice but also in other crops like wheat, maize and sorghum (Sharawat *et al*., 2008, Khan *et al*., 2009).

Boron is second emerging deficient nutrient in rice tract which is affecting crop impressively. Rashid *et al*. (2004) perceived the effect of boron on rice cultivars Super Basmati, Basmati-385 and KS-282 and reported 14-25% increase in paddy yield as compared with control. Rice crop behaved positively with optimum boron dose at 0.75 kg/ha (Rashid *et al*., 2004). Studies on boron fertilization explained that paddy yield consistently increased with boron application (Rakshit *et al*., 2002, PARC, 2002). Boron may stimulate the enzymatic activity, availability of sugar and respiration which leads toward improved pollen growth (Garge *et al*., 1979). In case of severe boron deficiency, root growth of plants ceases which leads toward the death of root tips. Paddy yield was significantly higher with the application of micronutrients (Zn, B and Mo) alone or in combination with each other (Hossain, *et al*., 2001). Concentration of Fe, B and Zinc contents increased significantly in rice grain with combined foliar application of these nutrients (Jin *et al*., 2008). Crop production and quality is desperately affecting with emerging deficient micronutrients (B and Zn) all over the world (Rashid and Ryan, 2004 and Rafique *et al*., 2008). Cultivation shift for fine genotypes from flooded to aerobic condition have raised another question for rice growers on micronutrient deficient soil. Although significant amount of water may save in this shift but it may not suitable for already existing genotypes which can lead toward poor crop performance. Present experiment was therefore designed to see the possible impact of changing rice cultivation systems with addition or missing of micronutrients on fine rice.

MATERIALS AND METHODS

The field study was conducted at Agronomic Research Farm, University of Agriculture, Faisalabad (31^0-25'N, 73^o-09'E) during growing seasons of year 2008 and 2009. Experiment was designed in randomized complete block with split plot arrangement having a net plot size of 2.20 m × 4 m and replicated thrice. The soil texture was sandy clay loam (51.16, 51.2 % sand, 22.83, 22.6 % Silt and 26.57, 26.6% Clay) with an average pH of 7.9, 8, total soluble salts 0.21, 0.22 % and organic matter 0.81, 0.74 in both the years respectively. In second year, same the experiment was repeated on the same piece of land. Nursery was raised in 3rd week of June with recommended seed rate and aerobic rice sowing was done at the same date using seed rate 75 kg per hectare with 20 cm apart rows by using hand drill. Nursery seedlings of 25 days older were uprooted manually from nursery plots and then transplanted in the main field on 25th and 27th July by keeping row to row distance of 20 cm during year 2009 and 2010, respectively. Basal application of boron (F_1) (3 kg per acre) and zinc (F_2) (5 kg per acre) alone and in combination (F_3) along with control treatment (F_0) was done in aerobic rice (T_1), flooded rice (T_2) and "Flooding for two weeks after transplanting and will be maintained at field capacity up to panicle initiation and again will be kept flooded starting from panicle initiation up to physiological maturity" (T_3). After transplanting, nitrogen at the rate of 140 kg ha^{-1}, 80 kg phosphorus ha^{-1} and 60 kg potash ha^{-1} were applied through soil application in the form of urea, diammonium phosphate and sulfate of potash, respectively. Whole amount of phosphorus (P) and potash (K) with 1/3 of nitrogen (N) was applied at the time of transplanting and at seed bed preparation in aerobic rice. Remaining dose of nitrogen fertilizer was applied in two equal splits at the time of booting and panicle initiations. Water depth was maintained at 3-4 cm during transplanting. Irrigation was stopped before one week of harvesting when the sign of physiological maturity was appeared. For weed control Butachlor 60 % EC @ 800 mL ha^{-1} was applied after 7-days of transplanting (Reddy 2004). Pre-emergence herbicide (Penoxolan @75ml/ha) was used in aerobic rice for controlling weeds. Carbofuran 10% GR was broadcasted (25 kg ha^{-1}) at 55 days after transplanting for protecting plants from insect pest. Measured amount of water was applied by using cut throat flume (90 cm x 20cm). Water applied was then calculated by total amount of water applied plus amount received through rainfall. Following formulae was used for calculating the time of application for required amount of water.

$$T = \frac{AD}{Q}$$

Where T represents application time (hours), A for field area (m^{-2}), D shows the depth of irrigation (m) and Q signed for flow rate (m^3/sec). Crop was harvested manually at maturity on 15th and 17th November during the year 2009 and 2010, respectively and then total biological yield was calculated. Manual threshing was done for each plot to calculate the per plot paddy yield. Area of m^{-2} was selected from each plot and then number of panicle bearing tillers were counted from all replications and average was computed. Twenty plants were tagged from each plot for measuring plant height and panicle length. Average of twenty plants was calculated afterward. MSTAT statistical computer package was used for data analysis and LSD at 5% probability was used for treatment's mean comparison (Steel *et al*., 1997).

RESULTS

Productive tillers (m^{-2}): Data showed that rice cultures and application of micronutrients (B and Zn) had significant effect on productive tillers in both the years (Table-1). Comparison of mean values showed that during year 2008, rice crop grown with flooded condition enhanced productive tillers over aerobic rice cultures but behaved similarly with intermittent rice culture. Comparison of micronutrients application showed that rice crop produced higher productive tillers with combined application of boron and zinc. Productive tillers were significantly reduced and resulted in minimum value where we missed the application of both micronutrients. In second year, also the maximum tillers were counted with combined micronutrients application while it was statistically similar with the treatment where we just applied zinc. Combined effect of different rice cultures with application of micronutrients (B and Zn) was also found to be significant. It's obvious from the results that productive tillers were significantly enhanced in flooded rice culture with combined application which was found to be statically similar with intermittent flooding and drying rice culture. Productive were significantly reduced with missing micronutrients application in all rice cultures while it was also statistically similar with the treatments having just boron application. In second year, there was no statistically difference was recorded for maximum tillers produced with combined application or with just zinc. It's interesting to mention here that application of zinc alone or in combination with boron, improved the productive tillers in all rice cultures while the boron seems to be having little effect on number of tillers count.

Panicle length (cm): Panicle length is an important yield parametrs as longer the panicle more will be number of kernels which ultimately lead toward better yield. It is obvious from the data that all treatments had significant effect on panicle length in both the years. In year 2008, comparison of mean values for different rice cultures showed that longer panicles were seen in flooded and intermittent flooded and drying rice cultures. Crop grown in aerobic condition shorter the panicle length and resulted in shortest value. Comparison of fertilizer/ micronutrients treatments showed that highest panicle length was found with combined application while rice grown without micronutrient application significantly reduced panicle length. Comparison among boron and zinc application for panicle length showed that there was no statistically difference was recorded as they behaved similarly. In second year shortest panicle was recorded in control treatment that was statistically similar with treatment having just boron addition. Interaction among different treatments was found to be non-significant in both the years (Table-2).

1000-kernel weight (g): Kernel/grain weight is an important yield contributors which depend on genetic makeup and least effected by growing conditions (Ashraf *et al*., 1999). Data showed that 1000-kernel weight was affected significantly by different rice culture and with micronutrients application in both the years (2008-09). Comparison of mean values showed that in 2008, significantly the heavier kernels were recorded in flooded rice which was similar with T_3 (intermittent flooding and drying) while the crop grown in aerobic culture recorded lighter grains. In micronutrients application point of view it's clear from the data that the lighter grains were found in control treatment where we missed application of all micronutrients. Application of both micronutrients enhanced grain weight with sole or in combined application while the heaviest grains were recorded with combined application. Combined effect of different rice cultures with micronutrients was found to be non-significant in both the years (Table-3).

Paddy yield (t ha^{-1}): It is evident from the data that paddy yield was significantly affected with the rice cultures as well as with the basal application of fertilizer (B and Zn) in fine rice. Comparison of mean values showed that in 2008, significantly the maximum paddy yield was recorded in flooded rice that was similar with intermittent flooding and drying. Basal application of fertilizer resulted in improved yield and the maximum value was found with combined application while the minimum paddy yield was recorded in control treatment. Combined effect of rice culture with fertilizer was found to be significant. In 2008, maximum paddy yield was recorded in flooded and intermittent flooding and drying (5.02, 4.81) respectively, with the combined application of boron and zinc. Almost the similar results were seen during second year of experimentation (Table-4).

Water Productivity (g/liter): Water productivity showed that how efficiently the water was used for crop production. Data showed that the maximum water use efficiency was recorded in intermittent flooding and drying while it was similar with flooded rice culture. Water use efficiency was reduced in aerobic rice culture due to the lesser yield. There was no statistically difference was recorded among rice culture during year 2008 while the effect of rice cultures was significant in second year. Water productivity was significantly higher in intermittent flooding and drying condition while it was similar with flooded rice culture. Aerobic rice significantly reduced water productivity in second year of experimentation and resulted in minimum value as

Table-1: Number of Productive tillers as affected by boron and zinc in different rice cultures during 2008 and 2009.

	2008				2009			
Fertilizer	**Rice cultures**				**Rice cultures**			
	T_1	**T_2**	**T_3**	**Mean**	**T_1**	**T_2**	**T_3**	**Mean**
F_0	139.16e	143.83e	148.17e	143.72C	123.87c	127.30c	136.81c	129.33B
F_1	149.17e	153.17e	151.17e	151.17C	142.83c	146.51c	141.17c	143.50B
F_2	195.22d	242.28bc	235.27c	224.25B	193.55b	240.61a	233.60a	222.59A
F_3	194.22d	266.61a	260.33ab	240.39A	194.22b	250.28a	253.67a	232.72A
Mean	169.44B	201.47A	198.74A		163.62B	191.17A	191.31A	

$LSD_{0.05}$ (rice cultures) 2008=9.37; $LSD_{0.05}$ (fertilizer) 2008=13.99; $LSD_{0.05}$ (rice culture x fertilizer) 2008=24.19; $LSD_{0.05}$ (rice cultures) 2009=3.03; $LSD_{0.05}$ (fertilizer) 2008=14.46; $LSD_{0.05}$ (rice cultures x fertilizer) 2008=25.04

Table-2: 1000 kernel weight (g) as affected by boron and zinc in different rice cultures during 2008 and 2009.

Fertilizer	2008				2009			
	Rice cultures				Rice cultures			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
F_0	15.99$^{N.S}$	16.03	14.99	15.67C	11.37$^{N.S}$	12.86	11.73	11.99C
F_1	17.39	17.77	17.73	17.63B	12.53	14.20	14.47	13.73B
F_2	17.36	18.00	17.97	17.78B	12.53	14.43	14.48	13.81B
F_3	18.69	19.74	19.72	19.38A	13.86	16.17	16.29	15.44A
Mean	17.36B	17.88A	17.60AB		12.57B	14.42A	14.24A	

LSD0.05 (rice cultures) 2008=0.34; LSD0.05 (fertilizer) 2008=0.92; LSD0.05 (rice cultures) 2009=0.26; LSD0.05 (fertilizer) 2008=0.72

Table-3: Panicle length (cm) as affected by boron and zinc in different rice cultures during 2008 and 2009.

Fertilizer	2008				2009			
	Rice cultures				Rice cultures			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
F_0	21.88	29.22	28.55	26.55C	19.88	27.22	26.55	24.55C
F_1	27.88	29.89	29.89	29.22B	23.75	27.22	27.55	26.18BC
F_2	27.88	30.16	30.02	29.35B	25.88	28.16	28.02	27.35B
F_3	29.39	31.89	32.56	31.28A	27.39	30.39	31.23	29.67A
Mean	26.76B	30.29A	30.26A		24.22B	28.25A	28.34A	

LSD0.05 (rice cultures) 2008=0.65; LSD0.05 (fertilizer) 2008=1.67; LSD0.05 (rice cultures) 2009=1.77; LSD0.05 (fertilizer) 2008=1.71

Table-4: Paddy yield (t/ha) as affected by boron and zinc in different rice cultures during 2008 and 2009.

Fertilizer	2008				2009			
	Rice cultures				Rice cultures			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
F_0	2.20d	2.74cd	2.68cd	2.54C	1.68g	2.76d	2.46de	2.30C
F_1	2.54cd	3.86b	3.80b	3.40B	1.98f	3.27c	3.24c	2.83B
F_2	2.73cd	4.19b	4.05b	3.65B	1.99f	3.52bc	3.31c	2.94B
F_3	2.89c	5.02a	4.81a	4.24A	2.30e	4.07a	3.86ab	3.41A
Mean	2.59B	3.95A	3.83A		1.99B	3.41A	3.22A	

$LSD_{0.05}$ (rice cultures) 2008=0.95; $LSD_{0.05}$ (fertilizer) 2008=0.36; LSD0.05 (rice culture x fertilizer) 2008=0.62; LSD0.05 (rice cultures) 2009=0.402; LSD0.05 (fertilizer) 2008=0.15; $LSD0_{.05}$ (rice cultures x fertilizer) 2008=0.26

Table-5: Water productivity (g/liter) as affected by boron and zinc in different rice cultures during 2008 and 2009.

Treatments	Water productivity		Mean
Rice cultures	2008	2009	
T_1	0.20b	0.15b	0.18
T_2	0.24ab	0.20a	0.22
T_3	0.26a	0.21a	0.24
LSD	0.056	0.02	
Fertilizers			
F_0	0.17c	0.15c	0.16
F_1	0.23b	0.19b	0.21
F_2	0.25b	0.20b	0.22
F_3	0.29a	0.23a	0.26
LSD	0.023	0.02	

[1]Table-6: Economic return as affected by boron and zinc in different rice cultures during 2008 and 2009.

Treatments	Variable cost (Rs. ha^{-1})	Gross Income (Rs. ha^{-1})	Total Expenditure (Rs. ha^{-1})	Net Benefit (Rs. ha^{-1})	BCR
2008					
Rice cultures					
T_1	15612	83690	60082	23618	1.39
T_2	23075	128375	73425	54950	1.75
T_3	19775	126750	67025	59725	1.89
Fertilizers					
F_0	0	84500	65344	19156	1.29
F_1	550	110500	65894	44606	1.68
F_2	950	119166	66294	52872	1.80
F_3	1500	137583	66844	70739	2.05
2009					
Rice cultures					
T_1	16992	89062	65717	23345	1.36
T_2	25230	127500	79555	47945	1.60
T_3	21630	123750	72005	51745	1.72
Fertilizers					
F_0	0	90000	70800	19200	1.27
F_1	562	108750	71362	37388	1.52
F_2	1063	116250	71864	44386	1.62
F_3	1625	132500	72426	60074	1.83

One US $= 90 rupees

[1](T_1) Aerobic rice, (T_2) Flooded rice, (T_3) Flooding for two weeks after transplanting and then maintained at field capacity up to panicle initiation and again kept flooded starting from panicle initiation up to physiological maturity, (F_0) Control, (F_1) Boron, (F_2) Zinc and (F_3) Boron + Zinc.

compared with other rice cultures. As regarding fertilizer application, in 2008, the highest water use efficiency was recorded with combined micronutrients application while the minimum was recorded in control. Almost similar trend was found in year 2009 for fertilizer application.

Economic Return: Data recorded revealed that rice grown with intermittent flooding and drying condition was economically more sound (<BCR) as compared with aerobic rice culture while the flooded rice behaved similarly. Application of micronutrients was also found to be economical having more benefit cost ratio (BCR) as compared to control. Maximum BCR was recorded with combined application of micronutrients as compared to sole application. Similar trend was recorded in second year (2009).

DISCUSSION

Due to the shrinkage of the water resources and with increasing cost of labor charges farmers are shifting rice cultivation from flooded to aerobic condition (Pandey and Velasco, 2002). Transplanted rice require labor for uprooting the nursery and then transplanting into the main field so there is option to avoid these charges to grow rice by direct seeding. Direct seeding requires significantly less labor and low water inputs but there may be the risk of low yield as we are lacking best suited genotypes in this condition. Aim of this manuscript was to compare the yield and economic performance of different rice cultures with the addition of various micronutrients. Our results indicated that shifting cultivation from flooded to aerobic significantly reduced the yield components and ultimately the final yield of fine rice.

Aerobic rice culture significantly reduced the yield due to its decreasing yield parameters which might be due to water or nutrient stress at various growth stages. Results indicated that crop performance was improved as compared to aerobic rice culture in intermittent culture while similar with flooded rice. This comparison showed that rice crop does not need flooded condition for whole growth period so there is chance to save the water with proper management practices while its direct shift to aerobic can decrease yield. Although we can save a huge amount of water in aerobic rice cultivation but we have to compromise for the yield losses as well. Rice crop significantly reduced productive tillers and 1000-grain weight when it was grown in aerobic condition. These results are in agreement with some previous studies (Grigg *et al*., 2000, Singh *et al*., 2005, Peng *et al*., 2006). The crop performance was improved when it was matured in flooded condition as well with modified irrigation treatment as compared with aerobic rice. In flooded condition mostly nutrients are available in soil solution but its availability decreased in aerobic condition as the nutrients dynamics is totally different than flooded rice (Gao *et al*., 2006).

Productive tillers were enhanced with the micronutrients application and maximum effect was observed with combined application. Comparison of zinc with boron for enhancement of tillers revealed that the boron had little effect on productive tillers while application of zinc had positive impact. Boron application had mostly effect on grain quality as compared to crop growth. Enhanced yield of rice grains was observed with boron application as it may linked with higher availability of sugar, improved enzymatic activity which resulted in improved growth of pollens (Garge*et al*., 1979). Rashid *et al*., (2009) observed the increasing trend in plant height, number of tillers, 1000-grain weight and paddy yield with boron application in rice crop. There might be a one of the reason of increased yield attributes is the improved availability of other macro (N, P) nutrients due to their synergistic effect with boron and zinc. As previous studies showed that application of nutrients (Zn, B and S) on sorghum and maize (Sharawat*et al*., 2008) and on maize, castor, groundnut and mung (Rego*et al*., 2007) resulted in improved yield and nutrient contents with N andP application in all crops.

Irrigation water is a crucial input for crop production which should be used wisely for sustainable crop production. Experiment showed that huge amount of water can be saved by shifting cultivation from flooded to aerobic condition but it can also decrease yield linearly. It seems to be unsuitable for indigenous basmati fine variety due to lesser yield but we may go for aerobic cultivation after developing aerobic genotypes. Water wise rice cultivation is highly concern in Pakistan due to shortage of water. We find that intermittent flooding and drying can be a good option for water saving cultivation as it gave similar results with flooded rice culture with considerable water saving. Application of micronutrients with macro as well in water saving rice cultivation can broader its positive impact on yield. As we already facing the problem of deficiency of micronutrients like boron and zinc which may increase due to this shift so addition of micronutrients should be a important component in water saving rice cultivation. In conventional rice cultivation method or in flooded rice culture lot of water goes useless which can be saved with proper agronomic management. Results were harmony with Zulkarnain *et al*., (2009) who explained that growth and yield was improved in flooded rice but most of the water was wasted. Transplanted rice matured with saturated condition enhanced the crop performance which improved the growth and yield attributes (Tabbal *et al*., 2002 and Javaid *et al*., 2012). In limited supply of water, plant reduced growth which resulted in inferior yield because some of the rice activities like photosynthesis may reduce.

Adaptation of any technology depends on its economics which become more important in case of Pakistanis farmer as they are more economic conscious due to having less available resource. In this experiment intermittent flooding and drying rice culture was found to be more economical due to having more yields with minimum expenses. Although flooded rice recorded more yield but that was not found to be best economically due to having more expenses. Lesser benefits were recorded in aerobic rice due to its reduced yield. There was less expense was recorded while growing rice in aerobic culture due to labor saving and less water used but it also resulted in decreased yield and ultimately the net benefit. Application of micronutrients is highly cost effective as more benefits can be gain with less expense. Crop require micronutrients in little amount but if they are deficient in soil, the yield can be decreased drastically. Application of micronutrients resulted in improved performance in all rice cultures while its effect is wider in case of flooded or in intermittent flooding and drying condition. Boron and Zinc are two cheaper micronutrients as compared to other fertilizer and so its application is highly economical due to having positive yield and quality impacts. In another hand the importance of these nutrients can be increased in water saving cultivation as we can eliminate the effect of water stress with proper/timely application.

Aerobic rice might be a good option for water wise rice production but it decreases crop performance linearly due to decrease in water inputs for existing basmati genotypes. It requires specific aerobic varieties which can adjust in that specific environment without yield decline. In present scenario as we are in populous country, we cannot compromise with yield so biotechnologist should develop aerobic varieties first for this successful shift.

Conclusions: After the keen observations of experimental results it is concluded that intermittent flooding and drying condition with combined micronutrients application (B and Zn) can be a good and economical option for water saving rice cultivation. Shifting cultivation directly from flooded to aerobic for super basmati can increase yield losses which can be broader with missing micronutrients application.

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