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Effect of nutrient and weed management on crop productivity and soil microbial properties in aerobic rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted during rainy (*kharif)* seasons of 2020 and 2021 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to study the effect of nutrient and weed management on crop productivity and soil microbial properties in aerobic rice (*Oryza sativa* L.). Experiment was conducted in factorial randomized complete block design and replicated thrice. Nutrient management factor comprised 3 levels, viz. Control, 100% and 75% RDF + Biofertilizer (BF) consortia; and weed management factor comprised 5 levels, viz. Weedy check, Pyrazosulfuran + Bispyribac + Almix, Bispyribac + mulch, *Sesbania* + hand weeding (HW) and weed free check. Significantly higher plant growth and grain yield (4.2 and 4.4 t/ha) and biological yield (11.6 and 11.6 t/ha) of rice were recorded with 100% RDF but these parameters were at par with 75% RDF+ BF consortia. However, soil microbial biomass carbon, nitrogen as well as soil microbial biomass phosphorus were recorded significantly higher with 75% RDF + BF. In weed management treatments significantly higher plant height, no. of tillers, grain yield and biological yield were recorded under weed free check over weedy check and *Sesbania* + HW but these were recorded at par with Pyrazosulfuran + Bispyribac + almix and Bispyribac + mulch. Soil microbial biomass was significantly higher with *Sesbania* + HW over weedy check, Pyrazosulfuran + Bispyribac + Almix and weed free check but were at par with Bispyribac + mulch. Hence, 75 % RDF + Biofertilizer consortia along with weed management through Bispyribac at 25 DAS + organic mulch (3 t/ha) may be recommended for enhancing crop productivity and soil microbial properties in aerobic rice.

Keywords: Aerobic rice**,** Crop nutrition, Soil microbial biomass, Yield, Weed management

Irrigated lowland rice (*Oryza sativa* L.) contributes to more than half of the world's rice production. However, puddle transplanted rice is resulting in lowering of water table, soil structure destruction, soil aggregates breakdown, water permeability reduction and hard pan creation which hinders growth of succeeding upland crop (Liu *et al.* 2015). Further erratic rainfall distribution, labour shortage and input constraints are forcing to search sustainable methods of rice production (Mishra *et al.* 2017). Aerobic rice cultivation is one of the best method as it is grown in upland, direct seeded, non-puddled and non-flooded conditions (Jana *et al.* 2018). Aerobic rice cultivation even after being ecofriendly, less water demanding and non labour intensive method results in reduced yield in comparison to traditional transplanted rice (Poornima *et al.* 2020, Gouda *et al.* 2021). Poor nutrient and weed management can be reason behind this. Aerobic rice, an exhaustive cereal crop mines nutrients from the soil extensively, more than the amount of fertilizer nutrients made available to the crops. Also, it has been realized that overdependence on fossil fuel derived fertilizers causes environmental pollution and thus sustainable crop production demands establishment of integrated nutrient management (INM) strategies like use of biofertilizers, etc. to supplement chemical fertilizers and sustain soil health.

Higher weeds population pressure caused weed shift to more difficultly controllable weeds in aerobic rice and initially the crop did not get a head start over weeds as in transplanted rice (Sen *et al.* 2018) causing yield loss to an extent of 70–80%. Integrated weed management is required to keep the weeds infestation below economic threshold level. Intercropping of Sesbania, its use as organic mulches and hand weeding helped in the weed suppression but herbicide application was the most effective and common method in rice (Jabran and Chauhan 2015). Non-judicious continuous herbicide use and intensive chemical fertilizers use may disturb the soil flora and fauna balance. Hence, judicious and efficient nutrient and weed management is desirable. Keeping the above facts in view an experiment was undertaken to study effect of nutrient and weed

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management on crop productivity and soil microbial properties in aerobic rice.

MATERIALS AND METHODS

The field experiment was conducted during rainy (*kharif*) seasons of 2020–21 and 2021–22 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi. The site falls under Trans-Gangetic plains agroclimatic zone and climate is sub-tropical, semi-arid with prominent hot dry summers. During *kharif* season, the mean maximum temperature recorded was 35.5ºC and 34.0ºC and total rainfall was 689.1 mm and 1468.9 mm in 2020–21 and 2021–22, respectively. The soil of the field was alluvial, sandy clay loam with moderate water-holding capacity having *p*H 8.2 and electrical conductivity 0.22 dS/m. The soil was low in organic carbon (0.46%) and available nitrogen (218 kg/ha) and medium in available phosphorous (16.12 kg/ha) and available potassium (260 kg/ha). The experiment was laid out in factorial randomized complete block design with 3 replications and 15 treatment combinations. First factor, nutrient management comprised 3 levels, viz. N_1: Control (No fertilizer), N_2: 100% RDF (100% mineral fertilization) and N_3: 75% RDF + BF (75% mineral fertilization along with biofertilizer consortia) and second factor weed management comprised 5 levels, viz. W_1: Weedy check (no weed control measure applied), W_2: Pyrazosulfuran (pre-emergence) followed by (*fb*) Bispyribac + Almix (Chlorimuron + metsulfuron) at 25 DAS, W_3: Bispyribac at 25 DAS + organic mulch (3 t/ha), W_4: *Sesbania* seeds broadcasting to grow as intercrop + 1 hand weeding at 25 DAS and W_5: Weed free check (regular hand weeding to keep the plot weed-free). Biofertilizer consortia used included liquid formulation of *Azotobacter chroococcum,* Phosphate Solubilizing Bacteria (PSB), Potassium Solubilizing Bacteria (KSB) and Zinc Solubilizing Bacteria (ZnSB) biofertilizers specific to rice. Seeds were treated with biofertilizers using jaggery solution, dried in shade and then used for sowing. Recommended dose of fertilizer used for aerobic rice was 120 kg N/ha, 60 kg P_2O_5/ha and 60 kg K_2O/ha. Phosphorus in the form of DAP and potassium in form of MOP (full dose) was applied at the time of sowing and nitrogen in form of urea was applied in three equal splits, viz. at basal, active tillering and panicle initiation stages. Rice variety PS 2511 was used in the experiment and seed rate of 60 kg/ha used. Seeds were drilled at a depth of 4 cm with the row spacing of 22.5 cm by using ferti-seed drill. The crop was maintained like upland crop throughout the growing season and around 6 to 7 numbers of irrigations were given according to the prevailing weather conditions. Other agronomic practices were followed as per package of practices for the region. Herbicide commercial product and dose used was Saathi for Pyrazosulfuran @30 g a.i./ha (as pre-emergence), Nominee gold for Bispyribac @20 g a.i./ha (at 25 days after sowing) and Almix @4 g/ha for Chlorimuron + metsulfuron (at 25 days after sowing). Observations on plant growth, grain and biological yield were taken at physiological maturity stage of crop and microbiological parameters in soil were reported at the 50% flowering stage of the crop. Plant height was measured from the base of the plant to the tip of the spike and number of tillers per meter row length was taken from three different places and the average was calculated and expressed in number of tillers/m^2. For dry matter accumulation, plant samples were collected from the row length of 25 cm by leaving border rows, dried in shade for 2–3 days and then in oven at 60±2°C until the constant weight was obtained. The recorded dry weight was later expressed in g/m^2. Harvesting was done from the net plot area (4 × 2.5 m^2 marked by leaving border rows), harvested samples were sun-dried for three days and weighed for total biological yield. Thereafter the samples were threshed, cleaned and dried to obtain 14% content to measure grain yield and then expressed in tons per hectare (t/ha). Microbial biomass carbon, nitrogen and phosphorus were estimated from the freshly collected rhizospheric moist soil samples by the fumigation extraction method of Jenkinson and Powlson (1976), Brookes *et al.* (1985) and Brookes *et al.* (1982), respectively. Microbial biomass carbon and nitrogen results were calculated by titration and microbial biomass phosphorus was estimated chlorometrically. Minimum support price of rice for the respective year was used to calculate net returns. Experimental data was statistically analyzed by the standard technique of analysis of variance (ANOVA) and significance was tested by F-test at 5 % level of significance.

RESULTS AND DISCUSSION

Growth parameters: Growth of paddyin terms of plant height, no. of tillers/m^2 and dry matter accumulation was influenced significantly by nutrient and weed management during both the years (Table 1). 100% RDF recorded significantly higher plant height (109.0 and 110.2 cm) and no. of tillers/m^2 at harvest in comparison to control but these were at par with 75% RDF+ biofertilizer consortia (BF) during both the years. Treatment with 100% RDF recorded 18.6% and 20.6% taller plants than control and 32.2% and 51.8% more no. of tillers/m^2 in comparison to control at harvest during 2020 and 2021, respectively. Accumulation of dry matter was also significantly higher with 100% RDF in comparison to control but was at par with 75% RDF + BF during both the years. Higher supply of nutrients in 100% RDF and increased availability of nutrients with biofertilizer consortia (BF) application in 75% RDF + BF might have enhanced plant metabolic activity, thus photosynthesis and cell division which all together increased growth and dry matter of aerobic rice. Similar findings were reported by Meena and Singh (2018) and Poornima *et al.* (2020). Weed management treatments significantly influenced the growth of aerobic rice. Weed-free check under weed management recorded significantly higher plant height, no. of tillers/m^2 and dry matter accumulation during both the years at harvest in comparison to weedy check and *Sesbania* + HW but the results were at par with application of Pyraz + Bis + Almix and Bis + mulch. Plant height with weed-free check was

Table 1 Effect of nutrient and weed management practices on growth, yields attributes and yield of aerobic rice

Treatment	Plant height (cm) at harvest		No. of tillers/ m^2 at harvest		Dry matter accumulation (g/m^2) at harvest		Weight of panicle (g)		No. of grains/ panicle		1000-grain weight (g)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Nutrient management (NM)												
Control	91.9	91.4	281.0	269.1	723.6	693.7	2.38	2.36	77	76	20.0	19.4
100% RDF	109.0	110.2	371.5	408.6	791.6	811.8	3.31	3.36	103	114	21.2	21.5
75% RDF+BF	104.0	104.8	362.1	399.3	776.1	798.3	3.16	3.21	100	108	21.0	21.1
SEm±	1.9	2.0	4.4	4.4	13.0	13.2	0.06	0.06	1.9	1.9	0.3	0.4
LSD (P≤0.05)	5.6	5.8	12.7	12.6	37.7	38.3	0.17	0.18	5.6	5.6	1.0	1.1
Weed management (WM)												
Weedy check	92.3	93.0	292.3	313.2	708.2	710.3	2.7	2.7	86	91	19.6	19.6
Pyraz + Bis + Almix	106.0	106.4	351.6	372.4	784.8	789.9	3.0	3.1	97	102	21.1	21.0
Bis + mulch	103.0	103.0	347.7	368.5	774.7	780.2	3.0	3.0	95	101	20.7	20.6
Sesbania + HW	97.2	98.0	335.9	356.7	745.5	748.9	2.9	2.9	91	98	20.7	20.6
Weed free check	109.6	110.2	363.5	384.3	805.8	810.5	3.2	3.2	98	105	21.5	21.6
SEm±	2.5	2.6	5.6	5.6	16.8	17.1	0.1	0.1	2.5	2.5	0.4	0.5
LSD (P≤0.05)	7.2	7.5	16.3	16.3	48.7	49.5	0.2	0.2	7.3	7.2	NS	NS
NM × WM	NS	NS	S	S	NS	NS	NS	NS	NS	NS	NS	NS

BF, Biofertilizer consortia, Pyrazosulfuran (pre-em) fb Bispyribac + (Chlorimuron + metsulfuron) Almix at 25 DAS, Bispyribac 25 g/ha at 25 DAS + organic mulch (3 t/ha) and *Sesbania* broadcasting + 1 HW at 25 DAS.

18.75% and 18.49% higher, no. of tillers/m^2 was 24.4% and 22.7% higher and 13.8% and 14.1% higher dry matter was accumulated with weed-free check in comparison to weedy check. This might be due to better weed suppression under these treatments and absence of weeds would have cleared the way for crop plant to use sunlight, water, space and nutrients efficiently and grow profusely. Nutrient and weed management had a significant interaction effect on the no. of tillers/m^2 at harvest during both years. 100% RDF treatment of nutrient management recorded maximum of tillers/m^2 at harvest during both years with all the weed management treatments but was closely followed by 75% RDF + BF (Fig 1). Similar results were reported by Singh *et al.* (2013) and Sen *et al.* (2018).

Yield and yield attributes: Yield attributes, viz. weight of panicle, no. of grains/panicle were significantly influenced by both nutrient and weed management but 1000-grain weight was influenced significantly by nutrient management only (Table 1). Yield attributes were reported significantly higher under 100 % RDF over control but were at par with 75 % RDF + BF. 100% RDF recorded 39.1% and 42.4% heavier panicle in comparison to control and 33.8% and 50% more no. of grains/panicle in comparison to control during 2020 and 2021, respectively. Similar trend was recorded in grain and biological yield of aerobic rice (Table 2). 100 % RDF recorded 39.7% and 53.2% higher yield over control and 6.6% and 5.8% higher yield over 75% RDF + BF during 2020 and 2021, respectively. However, the grain and biological yield with 75% RDF + BF was not significantly different from the yield under 100% RDF. Increased and balanced availability of nutrients and higher nutrient uptake under 100% RDF and 75% RDF + BF might have enhanced the

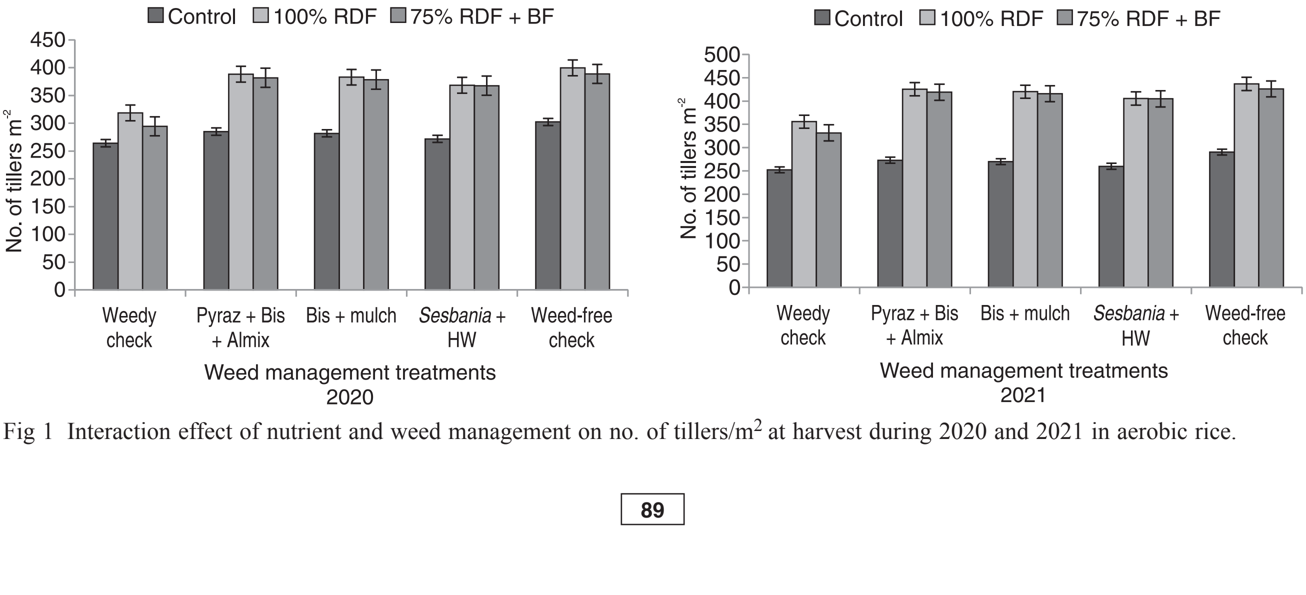

Fig 1 Interaction effect of nutrient and weed management on no. of tillers/m^2 at harvest during 2020 and 2021 in aerobic rice.

Table 2 Effect of nutrient and weed management practices on soil microbial biomass carbon (MBC), nitrogen (MBN) and phosphorus (MBP)

Treatment	Grain yield (t/ha)			Biological yield (t/ha)			Net returns (₹/ha)		MBC (µg/g soil)		MBN (µg/g soil)		MBP (µg/g soil)	
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	2020	2021	2020	2021	2020	2021
Nutrient management (NM)														
Control	3.0	2.9	2.9	9.9	8.8	9.3	30707	31167	144.0	141.4	20.24	19.96	8.55	8.45
100% RDF	4.2	4.4	4.3	11.6	11.6	11.6	46976	55346	219.5	230.5	22.21	22.67	10.91	11.12
75% RDF + BF	4.0	4.1	4.0	11.3	11.2	11.2	43300	51635	228.3	245.2	22.98	23.09	11.13	11.26
SEm±	0.1	0.1	0.1	0.2	0.2	0.2	1774	2033	1.8	1.9	0.18	0.18	0.09	0.09
LSD (P≤0.05)	0.3	0.3	0.3	0.5	0.6	0.5	5140	5888	5.1	5.5	0.51	0.51	0.25	0.25
Weed management (WM)														
Weedy check	3.2	3.1	3.1	9.8	8.9	9.3	32990	35946	194.0	201.0	21.36	21.46	10.06	10.14
Pyraz + Bis + Almix	4.0	4.1	4.0	11.4	11.2	11.3	45845	52441	189.5	195.4	21.10	21.15	9.94	9.99
Bis + mulch	3.9	3.9	3.9	11.2	11.0	11.1	43467	49955	200.2	209.8	22.22	22.27	10.26	10.36
Sesbania + HW	3.6	3.7	3.6	10.7	10.2	10.4	37628	44223	206.2	217.7	22.43	22.67	10.55	10.62
Weed-free check	4.1	4.2	4.1	11.7	11.4	11.5	41710	47681	196.4	204.7	21.93	21.97	10.18	10.28
SEm±	0.1	0.1	0.1	0.2	0.3	0.2	2291	2624	2.3	2.4	0.23	0.23	0.11	0.11
LSD (P≤ 0.05)	0.4	0.4	0.4	0.6	0.7	0.7	6636	7601	6.6	7.0	0.65	0.66	0.32	0.33
NM × WM	S	S	NS	NS	NS	NS	-	-	NS	NS	NS	NS	NS	NS

BF, Biofertilizer consortia, Pyrazosulfuran (pre-em) fb Bispyribac + (Chlorimuron + metsulfuron) Almix at 25 DAS, Bispyribac 25 g/ha at 25 DAS + organic mulch (3 t/ha) and *Sesbania* broadcasting + 1 HW at 25 DAS.

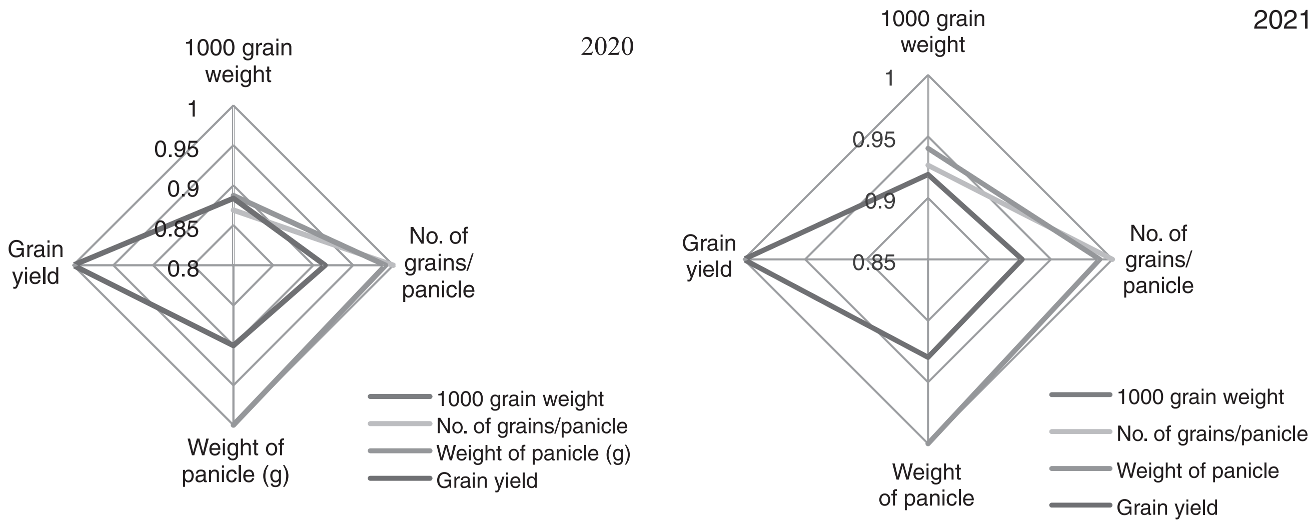

Fig 2 Correlation between yields attributes and grain yield of aerobic rice during 2020 and 2021.

yield attributes by diverting photosynthates efficiently from source to sink and thus yield of aerobic rice. Correlation of yield attributes with yield provides the evidence for the results as depicted through correlation coefficient in radar diagram. Grain yield was highly correlated with no. of grains/panicle and weight of panicle (>0.9) during both the years. No. of grains/panicle and panicle weight also were strongly correlated (>0.98) (Fig 2). Poornima *et al.* (2020) and Gouda *et al.*(2021) also reported similar results. Yield attributes, viz. weight of panicle, no. of grains/panicle, grain and biological yield were significantly higher under weed-free check over weedy check and *Sesbania* + HW but were not significantly different from Pyraz + Bis + Almix and Bis + mulch treatment. However, 1000-grain weight was not significantly affected by weed management treatments. Such trend in findings might be due to timely and effective weed control by continuous hand weeding or herbicide which might have helped to keep the weed population below the economic threshold level and thus weed control for a longer period in aerobic rice. Unchecked weed growth in weedy check treatment might have exploited the water and nutrients and thus crop production reduced, whereas in weed-free check unlimited availability of these crop production factors might have increased yield attributes, viz. weight of panicle, no. of grains/panicle and grain and biological yield. Similar findings were recorded by Jabran *et al.* (2012) and Chakraborti *et al.* (2017).

Soil microbiological properties: Soil microbiological properties in terms of microbial biomass carbon (MBC), microbial biomass nitrogen (MBN) and microbial biomass phosphorus (MBP) were influenced significantly by the nutrient and weed management practices during both the years, however the interaction was non-significant (Table 2). 75% RDF + BF recorded significantly higher microbial biomass carbon (228.3 in 2020 and 245.2 in 2021 μg/g soil), microbial biomass nitrogen and microbial biomass phosphorus in comparison to control and 100% RDF, however microbial biomass phosphorus during 2020 with 75% RDF + BF was reported at par with 100% RDF. Addition of biofertilizer consortia, i.e. live population of nutrient cycling microbes might have acted on the existing organic matter to get food substrate, favourable habitat and soil environment and thus proliferated heavily resulting in microbial biomass enhancement under the treatment (75% RDF+ BF). Similar results were reported by Ghosh *et al.* (2020). In case of weed management *Sesbania* + HW recorded significantly higher microbial biomass carbon, microbial biomass nitrogen and microbial biomass phosphorus over Pyraz + Bis + Almix, weedy check and weed-free check but the results were at par with Bis + mulch during both the years except for microbial biomass carbon during 2021. *Sesbania* initially as intercrop added fresh below ground active root biomass and later as green-leaf manure and mulch added above ground shoot biomass and which in turn acts as food substrate for microorganisms and thus helps to increase their population and biomass in soil. The results are in line with findings of Singh *et al.* (2022).

Economics: Net returns were recorded significantly higher with 100% RDF which were at par with 75% RDF + BF during both the years of experimentation. Among weed management practices significantly higher net returns were recorded with Pyraz + Bis + Almix which were at par with Bis + mulch and weed-free check treatment.

It may be concluded that 100% RDF recorded higher plant growth, yield attributes and yield but results were at par with 75% RDF + Biofertilizer (BF) consortia. Treatment with 75% RDF + BF consortia was superior in terms of soil microbial biomass enhancement. In case of weed management, Pyraz + Bis + Almix and Bis + mulch recorded higher growth, yield attributes and yield after weed-free check and were economically feasible too. Bispyribac + mulch treatment gave highest microbial parameters followed by *Sesbania* + HW. Thus, 75% RDF + Biofertilizer consortia along with weed management through Pyrazosulfuran (pre-em) fb Bispyribac + Almix (Chlorimuron + metsulfuron) at 25 DAS or Bispyribac + organic mulch (3 t/ha) can be recommended for enhancing growth, productivity, profitability and soil microbial properties of aerobic rice.

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