

**NUTRIENT MANAGEMENT PRACTICES FOR ENHANCING
THE PRODUCTIVITY OF AEROBIC RICE DURING SUMMER
IN HILL ZONE OF KARNATAKA**

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THE PRODUCTIVITY OF AEROBIC RICE DURING SUMMER
IN HILL ZONE OF KARNATAKA**

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IN

AGRONOMY

BY

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CERTIFICATE

This is to certify that the thesis entitled "NUTRIENT MANAGEMENT PRACTICES FOR ENHANCING THE PRODUCTIVITY OF AEROBIC RICE DURING SUMMER IN HILL ZONE OF KARNATAKA" submitted by Mr. NAGANAGOUDA S. CHANNAGOUDRA for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRONOMY to the University of Agricultural Sciences, Dharwad is a record of research work carried out by him during the period of his study in this University under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most important food crop. It is a staple food for more than half of the world's population. India is the second largest rice growing country with an area of 43.85 m ha with production of 104.79 mt (Anon., 2015). In Karnataka, rice is grown on 1.29 m ha with an annual production of about 3.66 mt and productivity of about 2,745 kg per ha which is little higher than national average (2,373 kg ha⁻¹).

Among the different method of rice cultivation, puddled transplanting is the predominant method of rice establishment in Asia which provides multiple benefits to rice including reduction in weed population, percolation losses and increased availability of nutrients (Sanchez, 1973). However, it deteriorates soil physical properties ultimately affecting the growth and productivity of succeeding crop adversely. The cost of production is also higher in transplanting method due to higher water requirement (1,500 mm) and labour intensive practices. All these factors have increased the interest of farmers to shift from the conventional practice of puddled transplanting to aerobic rice cultivation.

Aerobic rice cultivation is a cost effective crop establishment method where dry seed is drilled into the non-puddled soil and grown with less water. This method provides opportunities for saving irrigation water by 12 to 35 per cent and labour upto 60 per cent with similar or slightly lower yield of rice (Kumar and Ladha, 2011). The cost of production is also less because of reduction in cost of seed, land preparation, and transplanting. Hence, sustainable rice production methodology for the immediate future to address water scarcity and environmental safety in the scenario of global warming is aerobic rice.

Aerobic rice is a recent method of rice cultivation, which is aerobic input-responsive. It grows well in non-puddled soils with water content of 70 to 100 per cent of water-holding capacity throughout the cropping period. Aerobic rice is specifically developed rice, combining drought tolerance of upland rice variety and yield potential of lowland rice variety. Therefore, aerobic rice is "improved upland rice" in terms of yield potential and "improved lowland rice" in terms of drought tolerance. Aerobic rice varieties have the ability to maintain rapid growth in soils with moisture content at or above field capacity, and can produce yields upto 4-6 t per ha with a moderate application of fertilizer.

There is a 'yield gap' for rice in many countries. This is the difference between the potential yield determined by variety and climate and the yield achieved in farmer's fields. Studies predict that it may be due to nutrient mining and imbalanced fertilizers including micronutrients which resulted in progressive and possibly irreversible degradation of soils. Although, India has made considerable advances in agricultural research, but still the blanket recommendation of cultivation practices for adoption over larger areas are in vogue. These blanket recommendations are no more useful to enhance productivity and reduce the yield gap. Now, to enhance growth rate in productivity, proper nutrient management practices have to be developed in different agro-climatic conditions and adopted for enhancing the productivity of rice crop.

Among the micro nutrients, zinc plays an important role in the nutrition of rice. Zinc is one of the most essential micronutrient elements and is most commonly deficient in rice cultivating soils and gaining importance from the past few decades. Zinc deficiency in rice can be noticed from seedling stage in nursery and three weeks after transplanting in transplanted plots. To alleviate the Zinc

deficiency, different commercially available Zinc sources used are ZnSO₄, ZnO, ZnS, Zinc dirts and Zinc chelates. Boron is an important micronutrient, deficiency of which causes a severe reduction in the crop yield. It is considered to be involved in nucleic acid, carbohydrate, protein and indole acetic acid metabolisms, cell wall synthesis, membrane integrity and phenol metabolism. However, molecular basis of these roles is mostly unknown (Goldbach *et al.*, 2001).

The average per hectare use of fertilizer in paddy is 119.1 kg (81.7: 24.3:13.1 kg N:P₂O₅:K₂O ha⁻¹) (Anon., 2004). Imbalanced fertilizer recommendation or imbalanced/ inadequate availability of nutrients can lead to depletion of soil nutrient reserves and loss of plant nutrients supplied in excess. The knowledge of nutrient removal, nutrient uptake patterns by crops and capacity and availability of nutrients in the soil reservoir helps to formulate fertilizer recommendations. Soil feeding is the normal practice, but has limitations with respect to its availability to the plants. The elements such as phosphorus, potassium and most of the micronutrients are fixed in the soil complex while the more soluble nutrients such as nitrogen are easily leached down the soil. Foliar application is one such technique which reduces the losses of nutrients through immobilization, denitrification/volatilization and leaching especially with nitrogen and increases the utilization rate of nutrients (Amberger, 1996). It acts as a supplement to the recommended soil fertilizer application. The crop gets benefited from foliar applied nutrients when the roots are unable to meet the nutrient requirement of the crop at its critical growth stage.

Rice is also a major crop in the hill zone of Karnataka occupying nearly 79 per cent of the total net sown area of the zone. It is grown mainly as rainfed crop during *kharif* season in this zone. The area under rice during summer season is very less and is restricted to areas near by small reservoirs or ponds or wells. Aerobic rice cultivation may help in increasing area under rice during summer in hill zone of Karnataka. The yield of rice crop mainly depends on nutrient management practices together with its interaction to environmental factors, soil condition and availability of water. Aerobic rice cultivation is a new concept and very few efforts were made to work out nutrient management practices for aerobic rice in hill zone of Karnataka during summer season. Keeping these points in view, an experiment was planned to work out nutrient management practices to enhance the productivity of aerobic rice in hill zone of Karnataka with the following objectives.

1. To study the effect of different nutrient management practices on growth and yield of rice under aerobic conditions.
2. To study the effect of different nutrient management practices on soil fertility and uptake of micro and macro nutrients by aerobic rice
3. To work out the economics of aerobic rice as influenced by different nutrient management practices.

2. REVIEW OF LITERATURE

In the present investigation an attempt was made to study the nutrient management practices for enhancing the productivity of aerobic rice during summer season of 2014-15 in hill zone of Karnataka. The balanced fertilization is the key to crop production. In spite of liberal application of N, P and K fertilizer, normal growth of rice could not be obtained due to little appreciation of the use of micronutrients. High fertilizer responsive varieties can express their full yield potential only when limiting trace elements are also applied along with NPK fertilizers Available literature in consonance with the objectives of present study is reviewed in the following headings.

- 2.1 Effect of NPK (RDF) and FYM on growth and yield of rice.
- 2.2 Effect of micronutrients (Zn and B) and water soluble fertilizer on growth and yield of rice.
- 2.3 Uptake of micro and macro nutrients by rice as influenced by different nutrient management practices.
- 2.4 Economics of rice as influenced by different nutrient management practices.

2.1 Effect of NPK (RDF) and FYM on growth and yield of rice

Among several factors responsible for increase in rice production, adequate supply of essential nutrients in balanced way is one of the factors for getting good yield. This is particularly true for high yielding varieties and hybrids. Most of the nutrients required by the rice crop come from the soil but it is insufficient to meet the nutrient requirements for high rice yields. Balanced nutrition for direct seeded rice is of greater importance than application of a single nutrient source to restore the soil fertility over and above increasing the productivity. Some of the research findings for the balanced nutrition to get higher yields are listed below.

Mankotia and Shekar (2005) reported that fertilizer dose of 80, 40, 40 kg N, P₂O₅ and K₂O per ha can be reduced by 50 per cent with the application of 5 t FYM per ha. The paddy yield, however reduced significantly when 50 per cent of fertilizer dose was substituted with furrow applied vermicompost @ 1.25 t ha⁻¹ or when green manure crop was raised along with paddy (in 1:2 ratio) and turned down at 25 DAS.

Pandey *et al.* (2007) reported that application of NPK at 100, 60 and 40 kg per ha along with 10 tonnes of FYM in hybrid rice gave the higher grain yield (6.9 t ha⁻¹) and panicles per m² (269) which were comparable to that of 100, 60 and 40 kg ha⁻¹ NPK + FYM + 25 kg ZnSO₄ ha⁻¹ (7.1 t ha⁻¹ and 270 m⁻², respectively) or 150, 75 and 60 kg ha⁻¹ NPK + FYM (7.1 t ha⁻¹ and 272 m⁻², respectively).

Dass *et al.* (2009) reported that better growth and yield attributes occurred from the use of 50 per cent RDF + Gliricidia @ 2.5 t ha⁻¹ + Azotobactor @ 2.5 kg ha⁻¹ + PSB @ 2.5 kg ha⁻¹ resulted in the higher grain (2.01 t ha⁻¹) and straw (2.88 t ha⁻¹) yield of upland rice which were statistically on par with 100 per cent RDF, but significantly higher than all other treatments.

Siddaram *et al.* (2010) reported that application of recommended dose of fertilizer (100:50:50 kg N:P₂O₅:K₂O ha⁻¹) + 10 tonnes of FYM per ha recorded significantly higher growth parameters like plant height (63.1 cm), number of tillers (36.2 hill⁻¹), leaf area (1,602 cm² hill⁻¹) and dry matter production at harvest (151.1 g hill⁻¹).

Mahajan *et al.* (2011) reported that application of 150 kg N per ha in four splits with no-N at sowing resulted in 12, 24 and 5 per cent increase in panicle number per m², filled grains per panicle and 1000-grain weight, respectively, over the application of 120 kg N per ha in three split dose in aerobic rice.

Among the graded levels of nitrogen application (140, 120, 100 and 80 kg N ha⁻¹) in aerobic rice cultivation, application of 120 kg N per ha recorded significantly higher number of panicles per m² (173), filled grains per panicle (131), grain and straw yield (4.51 and 4.30 t ha⁻¹, respectively) compared to 100 and 80 kg N per ha but it was on par with 140 kg N per ha (Murthy *et al.*, 2012)

Rajanna *et al.* (2012) reported that application of recommended dose of fertilizer (100:50:50 kg N:P₂O₅:K₂O ha⁻¹) + 10 tonnes of FYM per ha recorded significantly higher growth indices like plant height (63.2), number of tillers per hill (35.7), leaf area (1509.8 cm² hill⁻¹) and leaf area index (2.42) as compared to other treatments.

Anilkumar and Suri (2014) reported that panicle length (25.7 cm) and number of tillers per m² (274.1) of upland rice were significantly higher with NPK applied at 90:45:45 kg per ha along with FYM at 5 t per ha compared to sole use of NPK at 90:45:45 kg per ha (25.3 cm and 255.2 m⁻², respectively) and NPK at 60:30:30 kg per ha + FYM at 5 t per ha (23.7 cm and 239 m⁻², respectively).

Pradhan *et al.* (2014) reported that application of 90 kg nitrogen per ha for aerobic rice recorded significantly higher plant height (86.5 cm), leaf area index (4.8), grain yield (3.96 t ha⁻¹) and biological yield (10 t ha⁻¹) compared to other treatments *viz.*, 40 and 60 kg nitrogen per ha but was on par with 110 kg nitrogen per ha.

Jana *et al.* (2015) reported that among the different nutrient management practices, application of N: P₂O₅: K₂O @ 80: 40: 40 kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹ has recorded highest grain yield (4.42 t ha⁻¹) and was found statistically on par with application of N, P₂O₅, K₂O @ 80, 40, 40 kg ha⁻¹ + FYM @ 5 t ha⁻¹ (4.22 t ha⁻¹).

2.2 Effect of micronutrients (Zn and B) and water soluble fertilizer on growth and yield of rice

The role of zinc application in improving crop productivity is most important as that of major nutrients in present day agriculture. Zinc is the third most limiting nutrient element in crop production after N and P. Zinc is essential for several enzyme systems that regulate various metabolic activities in plants. It is involved in auxin production, transformation of carbohydrates and regulation of sugar in plants (Gupta, 1995).

Ingle *et al.* (1997) reported that application of 15 kg zinc per ha through zinc sulphate along with N: P₂O₅: K₂O (100:50:50 kg ha⁻¹) fertilizers gave higher grain and straw yield of paddy and was found significantly superior over control and other treatments.

The highest grain yield of rice (4.5 t ha⁻¹) was attained in S + Zn + B treatment with a record of 41.8 per cent yield increase over control. While the application of S, zinc or boron alone brought 23.3, 21.7 and 14.6 % yield increase, respectively (Islam *et al.*, 1997).

Ranjha *et al.* (2001) reported that higher grain yield (53.67 g pot⁻¹), grains per panicle (111.33), and straw yield (57.73 g pot⁻¹) were obtained with application of zinc along with NPK and FYM which was superior over application of only NPK (46.63 g pot⁻¹, 104 and 50.48 g pot⁻¹, respectively), however it was on par with the application of NPK + FYM (52.19 g pot⁻¹, 108 and 55.83 g pot⁻¹, respectively).

Subbiah *et al.* (2001) reported that at Aduthurai (TN) in clay loam soils, the variety ADT 38 responded well to NPK fertilizer ratio of 2.5:1:1 (150:60:60 N:P₂O₅:K₂O kg ha⁻¹) in conjunction with 10 t ha⁻¹ of FYM and foliar spray of DAP (2 %) and potassium chloride (2 %) at booting and panicle initiation stages registering a maximum yield of 6.78 and 6.92 t per ha during 1996 and 1997, respectively, which were significantly superior to the grain yield obtained under 4:2:1 NPK ratio treatment (240:120:60 NPK kg ha⁻¹).

Beena and Balachandran (2002) found that application of ZnSO₄ at 10 kg per ha along with recommended NPK recorded higher grain and straw yield of rice (2604 and 3,293 kg ha⁻¹, respectively) compared to sole application of NPK (2,599 and 3,149 kg ha⁻¹, respectively).

Ramanathan *et al.* (2002) reported that in dry season, foliar spraying of 1 per cent Peak (mono potassium phosphate) twice at the end of tillering and panicle initiation gave significantly highest number of productive tillers per hill (9.9), while the control recorded the lowest number of productive tillers per hill (6.3).

Karak *et al.* (2006) reported that significant increase in grain yield, straw and grain zinc content were observed with foliar application of zinc as Zn-EDTA as compared to zinc application through ZnSO₄.

Nasir *et al.* (2006) reported that application of 10 kg ZnSO₄ per ha recorded significantly higher plant height (78.94 cm), number of tillers per hill (14.43), number of panicle bearing tillers (11.36), panicle size (24.31 cm), number of primary spikelets per panicle (70.22), number of secondary spikelets per panicle (64.43), 1000 grain weight (22.17 g), grain yield (2.98 t ha⁻¹) and straw yield (7.09 t ha⁻¹) compared to control.

Manjappa *et al.* (2008) reported that application of one per cent MOP spray at 60 DAP (6,305 kg ha⁻¹) followed by one per cent MOP spray 45 DAP (6,230 kg ha⁻¹) and one per cent MOP spray both at 45 and 60 DAP (6,249 kg ha⁻¹) and were found to be on par with each other but significantly superior over no spray (6,029 kg ha⁻¹).

Sridhara (2008) reported that application of zinc and iron at 20 kg per ha recorded significantly higher number of panicles per plant (12.5), number of grains per plant (143), panicle length (19.6 cm), panicle weight (2.5 g), yield per plant (29.3 g) and longer root length (17.6 cm), root weight (2.5 g), root number (81.6) and root volume (49.8 cm³ plant⁻¹) in BI 43 compared to control.

Mandal *et al.* (2009) reported that application of 10 kg Zn per ha (5.0 + 2.5 + 2.5 kg ha⁻¹) in three splits along with recommended dose of NPK (60:13:25 kg ha⁻¹) recorded significantly grain yield (42.5 t ha⁻¹) and straw yield (46.6 t ha⁻¹) as well as higher growth parameters.

The results of pot experiment conducted by Mohiti *et al.* (2011) revealed that significantly higher grain yield, straw yield and 100 grain weight (17.35, 21.6 and 2.08 g pot⁻¹, respectively) were recorded in the treatment which received 65 g K₂SO₄ to soil + spraying 5 per cent K₂SO₄ in every 10 days compared to control.

Keram *et al.* (2012) noticed maximum grain yield (4.66 t ha⁻¹), straw yield (5.44 t ha⁻¹) and harvest index (46.07) by soil application of 20 kg Zn per ha along with recommended NPK (120:60:40 kg N: P₂O₅:K₂O ha⁻¹) compared to control in wheat. The results of another experiment conducted by Yadi and Dastan (2012) showed that higher panicles per m² and harvest index was observed in 40 kg Zn ha⁻¹ as zinc sulphate (ZnSO₄) and the least was seen in control treatment.

Arif *et al.* (2012) reported that foliar application of zinc and boron (Zn @ 15 kg ha⁻¹ + B @ 7.5 kg ha⁻¹) were proved as the best dose for higher growth and yield response. The plant height, tillers per plant, panicle length, grains per plant, filled grains per plant, straw yield, grain yield and biological yield increased up to 29.75, 38.40, 28.19, 25.81, 36.52, 32.47, 38.27 and 31.79 per cent, respectively compared to control.

Shivay and Prasad (2012) reported that grain yield of rice increased with Zn application through foliage. Application of 1, 1.5 and 2 per cent of ZnO-coated Prilled urea significantly increased the grain yield of rice (4.23, 4.47 and 5.12 t ha⁻¹) over uncoated Prilled urea (3.95 t ha⁻¹).

Bhuyan *et al.* (2012) reported that foliar application of 2 % urea in rice bed planting recorded higher panicles per m² (22), grain number per panicle (25), 1000-grain weight (22 g) and 9.33 per cent yield increase over conventional method.

Jamshid *et al.* (2012) reported that Altop liquid fertilizer meant for rice, which has critical levels of macro and micronutrients, sprayed five times at seedling (2), tillering (1) and panicle (2) stages resulted in heavier grains, grain yield and straw yield (32.82 g, 6.1 t ha⁻¹ and 6.17 t ha⁻¹, respectively) followed by three sprays at the seedling (2) and tillering (1) stages (25.31 g, 4.5 t ha⁻¹ and 5.74 t ha⁻¹, respectively) compared to control (water spray) treatment (21.98 g, 1.7 t ha⁻¹ and 4.51 t ha⁻¹, respectively).

Abbas *et al.* (2013a) reported that higher thousand grain weight (25.7, 24.3, 24.3, 25.4 and 25.8 g, respectively) as well as paddy yield (12.6, 11.3, 10.9, 12.3 and 11.5 t ha⁻¹, respectively) were recorded with combined application of N:P:Zn:B (135:90:10:2 kg ha⁻¹) in the varieties *viz.*, IR6, IR8, DR92, DR83 and Shahkaar, respectively compared to without micronutrient application.

Jamila *et al.* (2013) reported that maximum paddy yield of 6.67 t ha⁻¹ was obtained when Zinc and Boron (8+2 kg ha⁻¹) was applied in combination and was found statistically at par with paddy yield of 6.55 t ha⁻¹ recorded in treatment where sole Boron (2 kg ha⁻¹) was applied and significantly lower grain yield of 5.66 t per ha was produced when Zinc, Boron and Iron (8 + 2+ 5 kg ha⁻¹) were applied in combination.

Stalin *et al.* (2014) reported that soil application of ZnSO₄.7H₂O (25 kg ha⁻¹) registered significantly the highest grain yield of 6,531 kg ha⁻¹ followed by 0.3 % Zn HEDP L (6,313 kg ha⁻¹) and soil application of zinc enriched FYM (6,308 kg ha⁻¹) which were found statistically on par with each other.

Fageria and Santos (2014) opined that boron-use efficiency (grain yield per unit boron rate) decreased significantly with increasing boron application rate in the range of 5 to 40 mg per kg of soil. Maximum grain yield was obtained with the addition of 26 mg boron per kg of soil. Similarly, maximum straw yield and panicle density were obtained with the addition of 22 and 24 mg boron per kg soil, respectively, over control.

Rani *et al.* (2014) reported that application of RDF along with two sprays of 19:19:19 (2.5 kg ha⁻¹) at tillering and panicle initiation stages + top dressing of MOP @ 80 kg per ha at panicle initiation stage found to give significantly higher grain yield (5611 kg ha⁻¹) as compared to control.

Dash *et al.* (2015) reported that highest grain yield of 69.3 q ha⁻¹ and 76.7 q ha⁻¹ were recorded during 2011 and 2012, respectively in the treatment (N:P:K + S + Zn + B). Among the secondary and micronutrients, omission of individual element such as S, Zn, B or combination of S, Zn and B reduced grain yield over the application of N + P + K + S + Zn + B by 25.1, 2.3, 14.4 and 18.6 per cent during first year and 19.8, 17.1, 32.6 and 19.4 per cent during second year respectively.

Debnath *et al.* (2015) reported significant increase in grain and straw yield due to Zn and B fertilization. The highest yield response to the tune of 39.25 q ha⁻¹ grain and 41.25 q ha⁻¹ straw was recorded with 15 kg borax per hectare. Per cent increase in grain and straw yield due to 15 kg borax over control was found to be 24.52 and 17.78 per cent, respectively. The results also showed positive response to different levels of Zn fertilization but maximum response was observed upto 20 kg ZnSO₄ per ha.

2.3 Uptake of micro and macro nutrients by rice as influenced by different nutrient management practices

Combined application of RDF + FYM + ZnSO₄ at 20 kg ha⁻¹ was found to increase significantly the uptake of N, P, K, S, Zn and Fe as compared to RDF alone (Vasudeva *et al.*, 2001). Similarly, Patil and Meisheri (2003) noticed that application of 25 kg ZnSO₄ per ha or 10 kg Zn chelate per ha recorded significantly higher zinc content and uptake by rice grain as well as straw.

Pandu *et al.* (2005) reported that total N uptake in leaf (31.1 kg ha⁻¹) and panicle (47.1 kg ha⁻¹) was significantly higher with N management at LCC-3 than recommended N management.

Chaity and Sarkar (2009) reported that foliar spray of 0.5 % KNO₃ and 0.406 % Ca(NO₃)₂ increased the uptake of N (49.8 and 52.6 kg ha⁻¹, respectively) in lowland rice over water spray treatment (42 kg ha⁻¹).

Keram *et al.* (2012) reported that maximum uptake of N (123.19 kg ha⁻¹), K (90.86 kg ha⁻¹) and zinc (327.74 g ha⁻¹) was recorded with soil application of 20 kg Zn per ha with recommended NPK (120:60:40 kg N:P₂O₅:K₂O ha⁻¹) compared to control in wheat.

Yanyan *et al.* (2012) reported that regardless of three cultivars, Zn concentration in brown rice was increased from 30.28 mg per kg in control to 33.75 mg per kg in foliar Zn-EDTA application; 35.07 mg per kg in foliar application of citrate and 38.45 mg per kg in foliar Zn-AA (Zn-amino acid) application. These represented increase of 11.46, 15.81, 27.26 and 31.58 per cent, respectively, as compared to control.

Abbas *et al.* (2013b) reported that boron content with the application of N + P @ 135+90 kg per ha, N + P + Zn @ 135 + 90 + 10 kg per ha and N + P + Zn + B @ 135 +90 + 10 + 2 kg per ha was 2.81 ± 0.14, 2.88 ± 0.07 and 4.08 ± 0.37 µg per g, respectively, in IR6; 2.49 ± 0.07, 2.62 ± 0.4 and 4.72 ± 0.45 µg per g, respectively, in IR8; 2.59 ± 0.15, 2.66 ± 0.29 and 3.88 ± 0.24 µg per g, respectively, in DR92; 1.88 ± 0.19, 2.06 ± 0.13 and 2.47 ± 0.09 µg per g, respectively, in DR83; 2.72 ± 0.05, 2.69 ± 0.13 and 4.08 ± 0.14 µg per g, respectively, in Shahkaar.

Saha *et al.* (2013) reported that application of Zinc to soil (Zn @ 20 kg ha⁻¹ as zinc sulphate heptahydrate (ZnSO₄. 7H₂O) as basal increased the Zn concentration in brown rice to the level of 5.0 mg per kg (17 %) over the control. Whereas, soil plus foliar applied Zn (Zn @ 20 kg ha⁻¹ as basal + two foliar sprays - one at pre-flowering and another at grain forming stage @ 0.5 % ZnSO₄. 7H₂O) increased the same to the tune of 27.8 mg per kg (95 %) than no Zn treatment.

Rani *et al.* (2014) reported that total P uptake did not show any significant variation among all treatments, except no fertilizer which recorded significantly lowest P uptake (10.3 kg ha^{-1}). Among the different treatments, the treatment receiving 160:80:80 N:P₂O₅:K₂O + Top dressing of 14: 35:14 @ 125 kg ha^{-1} at tillering and panicle initiation stages recorded highest total K uptake (96.0 kg ha^{-1}) but statistically at par with other treatments.

Rehman *et al.* (2014) reported that boron content (6.20 and 6.25 mg kg^{-1} in leaf, 2.35 and 2.36 mg kg^{-1} in grain) was maximum with application of $1.5 \text{ kg boron per ha}$ as compared to control (2.121 and 2.30 mg kg^{-1} in leaf, 1.68 and 1.75 mg kg^{-1} in grain) in Super basmati and Shaheen basmati, respectively.

2.4 Economics of rice as influenced by different nutrient management practices

Experiment conducted by Aravind Kumar and Prasad (2002) at Ranchi revealed that lower annual net returns of $\text{Rs. } 33,415 \text{ ha}^{-1}$ were obtained in rice-berseem crop sequence treated with 75 per cent NPK along with 10 tonnes of FYM per ha in both *kharif* and *rabi* seasons as compared to application of fertilizer alone with net returns of $\text{Rs. } 36,189 \text{ ha}^{-1}$.

Mondal *et al.* (2003) reported that higher benefit cost ratio of 1.82 was recorded with 75 per cent of RDF along with 4 tonnes of FYM ha^{-1} as compared to 100 per cent NPK alone (1.61).

Jena *et al.* (2006) reported that application of ZnSO₄ at 50 kg ha^{-1} was found to be the best which has recorded the higher net return ($\text{Rs. } 12,340 \text{ ha}^{-1}$) with B: C ratio of 1.25.

Manjappa *et al.* (2008) reported that maximum gross and net returns were realized with application of K through foliar spray (1 %) at 60 DAP ($\text{Rs. } 41,674$ and $27,505 \text{ ha}^{-1}$, respectively) followed by 45 DAP ($\text{Rs. } 40,979$ and $26,811 \text{ ha}^{-1}$, respectively) and both at 45 and 60 DAP ($\text{Rs. } 41,231$ and $26,965 \text{ ha}^{-1}$, respectively) and were found to be on par with each other but significantly superior over no spray ($\text{Rs. } 39,812$ and $25,741 \text{ ha}^{-1}$, respectively).

Chaity and Sarkar (2009) reported that foliar application of 0.406 per cent Ca(NO₃)₂ has recorded higher net returns ($\text{Rs. } 14,733$ per ha) with B:C ratio of 1.38. The lowest net return ($\text{Rs. } 8,713$ per ha) and B:C (0.86) was recorded in the water spray treatment.

Hussain *et al.* (2012) reported that soil application of boron at flowering stage of rice resulted in the maximum B:C ratio of 2.84 and minimum B:C ratio of 2.44 was obtained in the control.

Yogesh *et al.* (2013) reported that in aerobic rice, application of RDF + FYM @ 10 t ha^{-1} + ZnSO₄ @ 20 kg ha^{-1} + VAM + *Azospirillum* + PSB recorded significantly higher gross returns ($\text{Rs. } 44,637 \text{ ha}^{-1}$) and net returns ($\text{Rs. } 30,472 \text{ ha}^{-1}$), where as application of RDF alone recorded higher B: C ratio of 2.28.

Rani *et al.* (2014) reported that application of RDF + top dressing of 14: 35:14 + Spray of 19:19:19 at tillering and panicle initiation stages recorded higher gross and net returns ($\text{Rs. } 68,917$ and $26,357 \text{ ha}^{-1}$, respectively) followed by application of RDF alone ($\text{Rs. } 62,717$ and $24,157 \text{ ha}^{-1}$, respectively).

3. MATERIAL AND METHODS

A field experiment was conducted at the Agricultural Research Station (Paddy), Sirsi to investigate the effect of different nutrient management practices for enhancing the productivity of aerobic rice grown during summer season of 2014 - 15 in hill zone of Karnataka. The detailed information on different materials used and relevant techniques adopted during the course of investigation are described in this chapter.

3.1 Location of experimental site

The experiment was carried out at Agricultural Research Station (Paddy), Sirsi, Karnataka which lies between 11° 31' and 15° 46' North latitude and between 76° 31' and 76° 4' East longitude and at an altitude of 619 m above mean sea level. It is situated in the hill zone (zone IX) of Karnataka.

3.2 Climatic conditions

The ARS, Sirsi is located in hill zone (Zone IX) of Karnataka state. This zone receives the rainfall from both South West and North East monsoons which is well distributed from June to November with lower co-efficient of variation. The monthly mean meteorological data of rainfall, temperature and relative humidity recorded at ARS (Paddy), Sirsi for the experimental year as well as average of last 15 years from January to December are furnished in Table 1 and depicted in Fig. 1.

The average annual rainfall of the station was 2238.1 mm which was fairly well distributed from April to December. The mean maximum temperature varied from 26.6 °C (July) to 35.2 °C (April). Whereas, mean minimum temperature varied from 14 °C (January) to 22.1 °C (May). The mean monthly highest and lowest relative humidity was 88.3 per cent (August) and 67.1 per cent (February), respectively. During the experimental year (2015), a rainfall of 1500.8 mm was received with 88 rainy days which was 737.3 mm less than the normal. The rainfall during cropping period from February to May was 120.5 mm which was erratic during crop growth period. During the crop growth period, the highest and lowest maximum temperature was 33.3 °C (May) and 32.4 °C (February), respectively, while the highest and lowest minimum temperature was 21.3 °C (May) and 14.1 °C (February), respectively. The mean relative humidity was ranged from 57.6 per cent in February to 84.1 per cent during April.

3.3 Soil characteristics of experimental site

The soil of the experimental site was sandy clay loam and well drained. Composite surface soil sample was collected from 0 to 20 cm depth from the experimental site before start of the experiment and was analyzed for physical and chemical characteristics of soil. Soil having pH of 6.1, electrical conductivity (0.31 dS m⁻¹), organic carbon (0.69 %), available N (291.2 kg ha⁻¹): P₂O₅ (27.5 kg ha⁻¹): K₂O (146.4 kg ha⁻¹) and micro nutrients like zinc (1.98 ppm) and boron (0.58 ppm). The soil analysis data along with methods employed are presented in Table 2.

3.4 Cropping history of the experimental site

In the previous season, a general crop of rice was grown on the experimental site during *khariif* 2014-15.

3.5 Experimental details

3.5.1 Season

The field experiment was conducted during summer season of 2014 - 15 to study the nutrient management practices for enhancing productivity of aerobic rice in hill zone of Karnataka.

3.5.2 Treatment details

The following treatments were evaluated for their effect in enhancing the productivity of aerobic rice.

T ₁	RDF alone
T ₂	RDF + FYM (10 t/ha)
T ₃	T ₂ + ZnSO ₄ @ 25 kg/ha
T ₄	T ₂ + Borax @ 2 kg/ha
T ₅	T ₂ + ZnSO ₄ (25 kg/ha) + Borax (2 kg/ha)
T ₆	T ₃ + foliar spray of 13:0:45 (0.5 % at 45, 60 and 75 DAS)
T ₇	T ₄ + foliar spray of 13:0:45 (0.5 % at 45, 60 and 75 DAS)
T ₈	T ₅ + foliar spray of 13:0:45 (0.5 % at 45, 60 and 75 DAS)
T ₉	T ₃ + foliar spray of 19:19:19 (0.5 % at 45, 60 and 75 DAS)
T ₁₀	T ₄ + foliar spray of 19:19:19 (0.5 % at 45, 60 and 75 DAS)
T ₁₁	T ₅ + foliar spray of 19:19:19 (0.5 % at 45, 60 and 75 DAS)

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

3.5.3 Design of experiment

The experiment was laid out in Randomized Complete Block Design with three replications and eleven treatments. The plan of layout of the experiment is depicted in Fig. 2.

3.5.4 Plot size

Gross plot size: 4.6 m x 2.7 m

Net plot size: 3.6 m x 1.5 m

Spacing: 30 cm row spacing

3.6 Salient features of the variety used in the experiment

Variety MAS 946-1 developed by the University of Agricultural Sciences, Bengaluru in 2007 was used in the experiment. It matures in 120 to 125 days. This is a semi-tall variety having height of 100 to 105 cm height and tolerant to blast disease. It is having profuse rooting and high tillering capacity. The variety has medium slender grain type and with yield potential of 5 to 5.5 t ha⁻¹.

Table 1: Mean monthly meteorological data for the experimental year 2015 and the average of 16 years (2000-2015) of the Agriculture Research Station, Sirsi

Month	Rainfall (mm)		Rainy days (2015)	Mean temperature (°C)				Relative humidity (%)	
	Normal	2015		Maximum		Minimum		Normal	2015
				Normal	2015	Normal	2015		
January	3.5	0.0	0	31.2	29.6	14.0	12.7	72.0	63.3
February	2.5	0.0	0	33.3	32.4	14.6	14.1	67.1	57.6
March	16.5	9.7	1	34.8	33.7	18.0	19.0	70.1	77.0
April	40.0	35.8	2	35.2	34.1	20.7	19.9	69.5	84.0
May	63.6	75.0	5	33.3	33.3	22.1	21.3	73.2	77.6
June	499.8	645.8	17	28.6	29.0	21.2	20.9	84.1	85.5
July	704.2	233.9	24	26.6	27.3	21.0	21.8	88.1	86.1
August	496.7	235.0	22	26.8	27.1	20.8	21.1	88.3	86.2
September	226.9	142.0	11	28.2	28.6	20.6	20.9	80.2	83.6
October	144.6	54.8	4	30.1	31.0	20.2	19.7	79.9	78.1
November	31.2	68.8	2	30.2	29.8	17.2	18.6	75.5	76.4
December	8.6	0.0	0	29.6	31.3	14.6	16.5	72.5	77.7
Total	2,238.1	1,500.8	88						

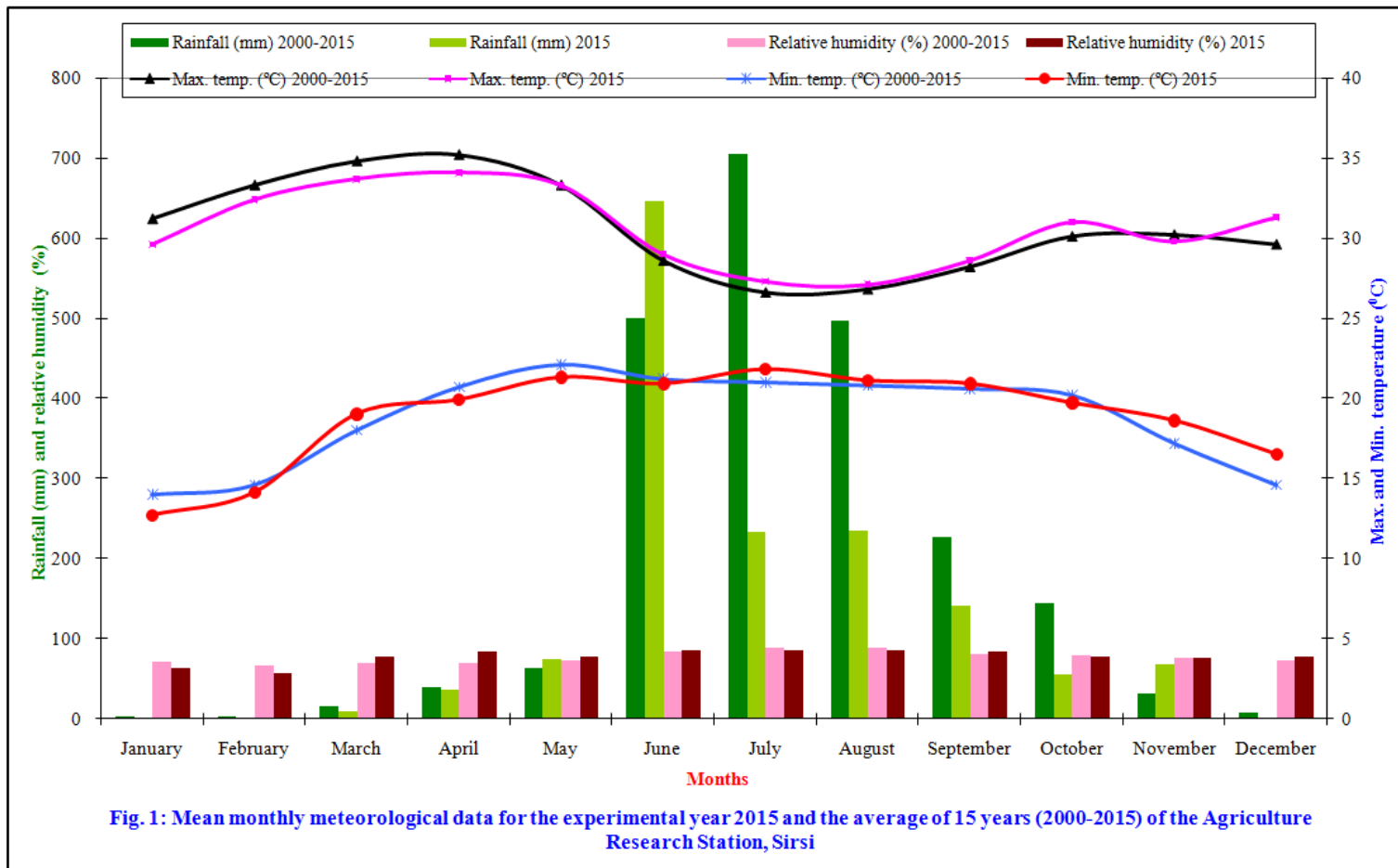


Fig. 1: Mean monthly meteorological data for the experimental year 2015 and the average of 15 years (2000-2015) of the Agriculture Research Station, Sirsi

Table 2. Physical and chemical properties of soil in the experimental site

Particulars	Values	Status	Method followed
Physical properties			
Coarse sand (%)	10.7		International pipette method (Piper, 1966)
Fine sand (%)	45.6		International pipette method (Piper, 1966)
Silt (%)	16.6		International pipette method (Piper, 1966)
Clay (%)	27.1		International pipette method (Piper, 1966)
Textural class	Sandy clay loam		
Chemical properties			
pH (1:2.5)	6.1	Neutral acidic	Potentiometry (Piper, 1966)
Organic carbon	0.69	Medium	Wet oxidation method/ Walkley and Black's method (Jackson, 1973)
EC (1:2.5) (dS m ⁻¹)	0.31	Normal	Conductivity bridge (Jackson, 1973)
Available N (kg ha ⁻¹)	291.2	Medium	Alkaline permanganate method (Subbiah & Asija, 1956)
Available P ₂ O ₅ (kg ha ⁻¹)	27.5	Medium	Olsen's method (Jackson, 1973)
Available K ₂ O (kg ha ⁻¹)	146.4	Medium	Neutral Ammonium acetate extract method (Jackson, 1973)
Available Zn (ppm)	1.98	Adequate	DTPA extractable method (Lindsay and Norvell, 1978)
Available B (ppm)	0.58	Adequate	Azomethine-H Method (Gupta 1979).

3.7 Cultivation practices

3.7.1 Land preparation

The land was ploughed once with mould-board plough and harrowed twice to bring the soil to a fine tilth. Stubbles of previous crop and weeds were collected and disposed off from the experimental area. Small bunds were formed around each plot to avoid movement of water from one plot to another. Plots were laid out as per the plan of the experiment.

3.7.2 Sowing

Seeds are sown by using seed drill with row spacing of 30 cm and seed rate was 18 kg per hectare.

3.7.3 Fertilizer application

Fertilizers were applied as recommended (75:75:87.5 kg N: P₂O₅: K₂O ha⁻¹ RDF, respectively) for rainfed lowland rice crop. At the time of sowing, complete dose of P₂O₅ and half the dose of N and K₂O were applied. Remaining 50 % N and K₂O were applied 25 per cent each at tillering and panicle initiation stages as top dressing in all treatments. The zinc and boron were applied at the time of sowing as per treatments. The nutrients were applied in the form of urea, diammonium phosphate, muriate of potash, zinc sulphate and borax.

3.7.4 Foliar application of fertilizers

The water soluble fertilizers *viz.*, 19:19:19 and 13:0:45 were applied through foliar @ 0.5 per cent at 45, 60 and 75 days after sowing (DAS) as per the treatments. For foliar spraying, 600 liters of water per ha was used.

3.7.5 Irrigation

Irrigation was provided to plots immediately after sowing. To avoid movement of fertilizer from one plot to another, each plot was irrigated separately and independently. Then subsequent irrigations were given to the crop in six to seven days depending on weather condition to keep the soil moist at field capacity. However, from flowering to grain filling stage, irrigations were given at an interval of three to four days in order to maintain higher moisture in soil. Irrigation was withheld 10 days before the crop maturity. Total 16 irrigations were given to the crop with the depth of 5 cm each and the total water consumed by the crop was 800 mm. The details of dates on which irrigation were given is given in Appendix I.

3.7.6 Weed management

In aerobic rice since weeds posed problem, regular weed management practices were undertaken. Butachlor 50 EC @ 1.25 a.i. per ha was sprayed one day after sowing as pre-emergence herbicide with the help of knapsack sprayer. The spray solution used was 600 litres of water per ha. Further, two intercultivation were taken at 20 and 40 DAS to control the remaining weeds.

3.7.7 Plant protection measures

During the crop period stem borer incidence was noticed and was controlled by using phorate @ 5 kg per ha at tillering stage.

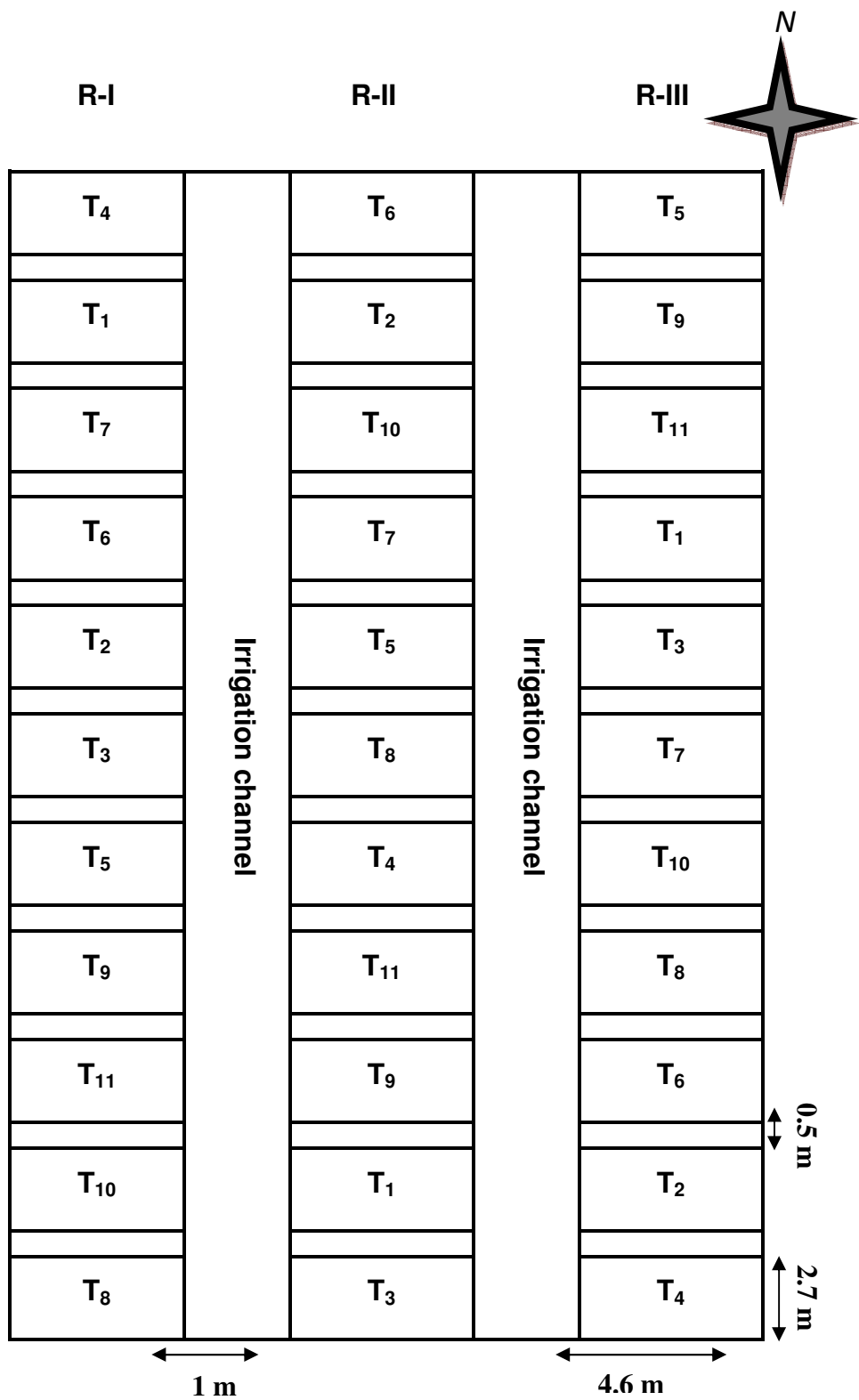


Fig. 2: Plan of layout of the experiment



Plate 1: General view of the experimental plot

3.7.8 Harvesting and threshing

The crop was harvested on 07-06-2015 after attaining the physiological maturity. Border rows were left as it is in all sides and remaining area was considered as net plot. Then crop was harvested treatment wise leaving the two border rows on each side of the plot and kept separately for sun drying. Hand threshing and winnowing was done to separate the grains after thorough sun drying. Treatment wise, grain and straw yield was recorded separately after attaining constant weight and finally expressed in kg per ha.

3.8 Collection of experimental data

Five plants were selected randomly and labelled in each net plot. Observation on plant height were made at 30, 60, 90 DAS and at harvest and observation on number of tillers per meter row length was taken at 30, 60, 90 DAS and at harvest from two different places of one meter row length selected in the net plot. Another 0.25 m row plants were removed at each stage from the area outside the net plot for recording dry matter production and from which leaf area was calculated before keeping it for oven drying and then which was converted to per meter. Ten panicles were selected at random from the area outside the net plot at harvest for recording yield components like panicle length, grain weight per panicle, number of filled and chaffy grains per panicle and 1000 grain weight.

3.8.1 Growth parameters

3.8.1.1 Plant height (cm)

Plant height was recorded at 30, 60 90 days after sowing (DAS) and at harvest from the base of plant to the tip of top most leaf from the selected five plants in the net plot and the mean was expressed in centimetres.

3.8.1.2 Number of tillers per meter row length

Total number of tillers per meter row length was counted at 30, 60 90 DAS and at harvest from selected two different places in net plot area of each treatment and mean was computed.

3.8.1.3 Leaf area (dm²)

The leaf area was worked out from the following procedure given by Yoshidha *et al.* (1976). From each 0.25 m row length, 10 sample leaves were selected and leaf area of sample leaves was measured using the length x width x correction factor (0.65) method. The green leaves from 0.25 m row length were removed separately. Then the sample leaves and other leaves were dried and weighed separately. The leaf area was calculated from using the formula and then converted to leaf area per m.

$$LA = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (dm² 0.25 m⁻¹)

Wa = Oven dry weight of all leaves (inclusive of 10 sample leaves) in g.

Wd = Oven dry weight 10 sample leaves.

A = Area of 10 sample leaves in dm²

3.8.1.4 Dry matter accumulation (g per m row length)

Plants were uprooted from 0.25 m row length in a row adjacent to net plot rows at 30, 60, 90 DAS and at harvest. The root portion of the plant was removed. The total above ground portion (leaf and stem) of the plant samples dried in hot air oven at $65^{\circ} \pm 5^{\circ} \text{C}$ till constant weight was obtained. The mean dry weight was recorded and expressed in grams per 0.25 m row length and then converted to dry matter production per meter row length.

3.8.1.5 Root dry weight (g per m row length)

Roots of the plant removed for dry matter estimation were cut from the plant after washing in water and dried in hot air oven at $65^{\circ} \pm 5^{\circ} \text{C}$ for 48 hr (till attaining constant weight) and then converted to root dry weight per meter row length, the mean dry weight was recorded in gram.

3.8.1.6 Root volume (cc per m)

Before keeping for drying, the root volume was determined using water displacement method and expressed in 'cc'.

3.8.1.7 Root to shoot ratio

The root to shoot ratio was worked out by making use of dry weight of root and shoot used for dry matter estimation.

3.8.2 Yield and yield components

3.8.2.1 Productive tillers per meter row length

At harvest total number of productive tillers per meter row length was counted at two different places in net plot area and the mean was worked out.

3.8.2.2 Panicle length (cm)

The length of each panicle from ten randomly selected panicles was measured from the neck to tip of panicle and the mean was taken as length of the panicle in centimetres.

3.8.2.3 Grain weight per panicle (g)

The filled grains from the ten randomly selected panicles were removed and weighed and the average weight of grains per panicle was worked out and expressed in grams.

3.8.2.4 Number of filled grains per panicle

The total number of filled grains from the same ten randomly selected panicles was counted and the average was worked out.

3.8.2.5 Number of unfilled grains per panicle

The total number of unfilled grains from the same ten randomly selected panicles was counted and the average was worked out.

3.8.2.6 Chaffiness (per cent)

The per cent of chaffy grains was calculated by using the formula

$$\text{Chaffiness (\%)} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.8.2.7 Thousand grain weight (g)

Thousand grains were counted at random from the net plot grains of each plot and their weight was recorded in grams.

3.8.2.8 Grain yield (kg ha⁻¹)

The crop was harvested from the net plot area in each treatment, threshed, winnowed and weight of fresh grains was recorded. The moisture content of grains was determined at the time of recording their weights. Then the grain weights were adjusted to 14 per cent moisture using the formula of Gomez (1972). The grain yield was expressed in kg per ha.

3.8.2.9 Straw yield (kg ha⁻¹)

The weight of straw harvested from each net plot was recorded after complete drying under shade. The straw yield was also expressed in kg per ha.

3.8.2.10 Harvest Index (%)

The ratio of economic yield (grain yield) to the biological yield (grain and straw yield) was worked out as harvest index (Donald, 1962).

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.9 Chemical properties of soil

3.9.1 Soil sampling and analysis

Before the start of experiment, composite soil sample from 0-20 cm depth was collected from the experimental site and passed through 2 mm sieve and preserved for further analysis. Similarly, soil samples from 0-20 cm depth were collected from each plot after harvest of rice crop. The soils were dried in shade and processed to pass through 2 mm sieve and used for further analysis. The soil samples were analyzed for available nitrogen, phosphorus, potassium, zinc and boron content.

3.9.2 Available nitrogen (kg ha⁻¹)

The available nitrogen was estimated by alkaline permanganate oxidation method as outlined by Subbiah and Asija (1956) and expressed in kg per ha.

3.9.3 Available phosphorus (kg ha⁻¹)

The available phosphorus was determined by Olsen's method using spectrophotometer (660 nm wave length) as outlined by Jackson (1973) and it was expressed in kg per ha.

3.9.4 Available potassium (kg ha⁻¹)

The available potassium was extracted with neutral normal ammonium acetate (1 N NH₄ OAC) and the content of K in the solution was estimated by Flame photometer (Jackson, 1973) and it was expressed in kg per ha.

3.9.5 DTPA extractable zinc (ppm)

The available zinc in soil was extracted with DTPA solution and estimated by using atomic absorption spectrophotometer as per the procedure outlined by Lindsay and Norvell (1978) and it was expressed in ppm.

3.9.6 Estimation of Boron by Azomethine method

The available boron in soil was estimated by using azomethine-H method as per the procedure outlined by Gupta (1979) and it was expressed in ppm.

3.10 Plant analysis

The grain and straw samples collected from each treatment were oven dried and used for chemical analysis after harvesting and threshing. Nitrogen content was determined by digesting the plant samples with concentrated sulphuric acid and digestion mixture. The digested samples were distilled by Microkjeldhal method in an alkaline condition and titrated against sulphuric acid (Piper, 1966).

Phosphorus and potassium contents were determined after the samples were digested with triacid mixture (nitric acid + sulphuric acid + perchloric acid). Phosphorus content was determined by Vanadomolybdate phosphoric yellow colour method and observation was recorded at 430 nm using Spectrophotometer (Piper, 1966). Potassium content was determined from the same triacid digested extract with the Digital Flame Photometer (Piper, 1966).

Zinc content was determined in an aliquot of the triacid digested extract by using atomic absorption spectrometer method as described by Follett and Lindsay (1969). Boron content was estimated by azomethine - H method from using the same triacid digested extract. The uptake of nitrogen, phosphorus, potassium, zinc and boron by rice crop at harvest was computed by using the following formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)}}{100} \times \text{Dry weight (kg ha}^{-1}\text{)}$$

3.11 Economic analysis

In computing the economics, different variable cost items were considered. The cost includes expenditure on seed, organic manures, chemical fertilizers, plant protection chemicals and labour charges at prevailing market prices during 2015. Labour requirement was worked out on the basis of labourers engaged for performing different field operations. The cost of inputs in the local market (Appendix II) was considered for computing cost of cultivation (Appendix III). The price of outputs in the local market (Appendix II) and cost of cultivation were considered for computing net returns. Net returns and cost of cultivation were used for working out benefit cost ratio and computed by using the following formulae.

Gross return = Total value of the produce (both grain and straw).

Net returns = Gross returns - Cost of cultivation.

$$\text{B: C ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.12 Statistical analysis

The experimental data obtained were subjected to statistical analysis by adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in 'F' test was at 5 per cent. Critical difference (CD) values are given in the tables at 5 per cent level of significance, wherever the 'F' test was significant.

4. EXPERIMENTAL RESULTS

The results of the experiment conducted to study the effect of nutrient management practices for enhancing the productivity of aerobic rice during summer season of 2014 - 15 in hill zone of Karnataka at Agricultural Research Station (Paddy), Sirsi are presented in this chapter.

4.1 Growth parameters

4.1.1 Plant height (cm)

The data on plant height of aerobic rice recorded at 30, 60, 90 days after sowing (DAS) and at harvest as influenced by different nutrient management practices are presented in Table 3.

The differences in plant height due to different nutrient management practices were significant at all the growth stages except at 30 and 60 DAS. At both 90 DAS and at harvest, application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) recorded significantly higher plant height (63.9 and 67.7 cm, respectively) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (57.4 and 61.2 cm, respectively), RDF + FYM + ZnSO₄ (57.6 and 61.1 cm, respectively), RDF + FYM + borax (58.9 and 62.7 cm, respectively) and RDF + FYM + ZnSO₄ + borax (59.0 and 62.2 cm, respectively). The significantly lower plant height was recorded in RDF alone treatment (56.1 and 59.1 cm, respectively).

4.1.2 Number of tillers per meter row length.

The data on number of tillers per meter row length of aerobic rice recorded at 30, 60, 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.

The number of tillers per meter row length did not differ significantly due to different nutrient management practices at 30 DAS. However, the tillers per meter row length recorded at 60, 90 DAS and at harvest differed significantly due to different nutrient management practices. At harvest, maximum number of tillers per meter row length (152.2) were recorded in foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) + RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (129.3), RDF + FYM + ZnSO₄ (130.7), RDF + FYM + borax (133.3) and RDF + FYM + ZnSO₄ + borax (137.0). The significantly lower number of tillers per meter row length was recorded in RDF alone treatment (118.5). The trend in tillers per meter row length due to different nutrient management practices was similar at 60 and 90 DAS also.

4.1.3 Leaf area (dm² m⁻¹)

The data on leaf area of aerobic rice recorded at 30, 60, 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 5.

Higher leaf area (208.7 dm² m⁻¹) was recorded at 90 DAS with the foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) + RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + Borax (2 kg ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over all other treatments. The leaf area recorded in RDF + FYM (165.0 dm² m⁻¹), RDF + FYM + ZnSO₄ (170.1 dm² m⁻¹), RDF + FYM + borax (171.1 dm² m⁻¹) and RDF + FYM + ZnSO₄ + Borax (176.2 dm² m⁻¹) were found on par with each other. The significantly lower leaf area (149.5 dm² m⁻¹) was recorded in RDF alone treatment. The similar trend was observed in leaf area due to different nutrient management practices at 60 DAS and at harvest also.

Table 3. Plant height of aerobic rice as influenced by different nutrient management practices

Treatments	Plant height (cm) at			
	30 DAS	60 DAS	90 DAS	Harvest
T ₁ - RDF alone	17.9	38.3	56.1	59.1
T ₂ - RDF + FYM (10 t ha ⁻¹)	18.1	39.6	57.4	61.2
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	17.8	40.3	57.6	61.1
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	18.1	40.9	58.9	62.7
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	17.7	40.3	59.0	62.2
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	18.1	40.9	62.8	65.9
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	17.7	39.4	63.5	66.3
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	17.5	39.5	63.9	67.5
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	17.5	40.9	63.0	66.3
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	18.1	41.1	63.1	66.8
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	17.9	41.1	63.9	67.7
S.Em. ±	0.452	1.178	1.376	1.574
CD (p=0.05)	NS	NS	4.059	4.643

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

Table 4. Number of tillers per m row length of aerobic rice as influenced by different nutrient management practices

Treatments	Number of tillers per meter row length at			
	30 DAS	60 DAS	90 DAS	Harvest
T ₁ - RDF alone	47.0	116.8	120.7	118.5
T ₂ - RDF + FYM (10 t ha ⁻¹)	52.0	129.3	132.8	129.3
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	53.3	130.5	134.8	130.7
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	54.3	133.2	137.0	133.3
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	55.3	136.0	140.7	137.0
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	54.3	143.3	149.2	143.8
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	54.1	144.3	150.7	146.0
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	54.8	147.8	152.0	148.5
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	54.0	144.3	150.8	147.8
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	53.8	146.5	151.3	148.3
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	55.5	150.3	156.5	152.2
S.Em. ±	3.523	3.505	3.495	3.303
CD (p=0.05)	NS	10.34	10.31	9.744

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

4.1.4 Dry matter production (g m^{-1})

The data on dry matter production of aerobic rice recorded at 30, 60, 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 6.

The dry matter production did not differ significantly due to different nutrient management practices at 30 days after sowing. However, dry matter production recorded at 60 and 90 DAS and at harvest differed significantly due to different nutrient management practices. At harvest, higher dry matter production (284.8 g m^{-1}) was recorded with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) + RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (231.4 g m^{-1}), RDF + FYM + ZnSO₄ (241.8 g m^{-1}), RDF + FYM + borax (246.7 g m^{-1}) and RDF + FYM + ZnSO₄ + borax (259.1 g m^{-1}). The significantly lower dry matter production was recorded in RDF alone treatment (216.0 g m^{-1}). The trend in total dry matter production due to different nutrient management practices was also similar at 60 and 90 DAS.

4.1.5 Root volume (cc m^{-1}), root dry weight (g m^{-1}) and root to shoot ratio

The data on root volume, root dry weight and root to shoot ratio of aerobic rice recorded at 90 DAS as influenced by different nutrient management practices are presented in Table 7.

Significantly higher root volume (478.5 cc m^{-1}), root dry weight (73.0 g m^{-1}) and root to shoot ratio (0.29) was recorded with the application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) + RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (402.1, 59.0 and 0.27, respectively), RDF + FYM + ZnSO₄ (420.5, 60.4 and 0.26, respectively), RDF + FYM + borax (427.6, 61.3 and 0.26, respectively) and RDF + FYM + ZnSO₄ + borax (433.0, 61.6 and 0.26, respectively). While, significantly lower root volume (397.6 cc m^{-1}), root dry weight (54.6 g m^{-1}) and root to shoot ratio (0.27) was observed in RDF alone treatment.

4.2 Yield and yield parameters of rice

The data on yield and yield parameters viz., productive tillers per meter row length, panicle length (cm), grain weight per panicle (g), number of filled grains per panicle, number of unfilled grains per panicle, per cent filled grains, 1000 grain weight (g), grain yield (kg ha⁻¹), straw yield (kg ha⁻¹) and harvest index (%) as influenced by different nutrient management practices are presented in Tables 8 to 9.

4.2.1 Productive tillers per meter row length

The data on productive tillers per meter row length of aerobic rice as influenced by different nutrient management practices are presented in Table 8.

The variation in productive tillers per meter row length of aerobic rice due to different nutrient management practices was significant. Foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) + RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) recorded significantly higher number of productive tillers (143.7) per meter row length and it was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (122.7), RDF + FYM + ZnSO₄ (125.5), RDF + FYM + borax (128.2) and RDF + FYM + ZnSO₄ + Borax (131.7). However, the lower number of productive tillers per meter row length was observed with application of RDF alone treatment (113.2).

Table 5. Leaf area of aerobic rice as influenced by different nutrient management practice

Treatments	Leaf area (dm ² m ⁻¹) at			
	30 DAS	60 DAS	90 DAS	Harvest
T ₁ - RDF alone	16.2	55.1	149.5	54.4
T ₂ - RDF + FYM (10 t ha ⁻¹)	16.5	59.7	165.0	63.8
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	16.5	61.6	170.1	73.8
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	16.8	61.1	171.1	73.0
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	16.8	63.9	176.2	83.1
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	16.7	74.4	199.0	99.4
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	16.7	76.8	199.3	95.8
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	16.9	78.9	206.0	106.6
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	16.8	81.2	199.8	99.6
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	16.7	85.8	204.2	99.7
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	17.1	82.5	208.7	107.7
S.Em. ±	0.55	2.77	9.46	4.11
CD (p=0.05)	NS	8.16	27.90	12.13

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

Table 6. Dry matter production of aerobic rice as influenced by different nutrient management practices

Treatments	Dry matter production (g m ⁻¹) at			
	30 DAS	60 DAS	90 DAS	Harvest
T ₁ - RDF alone	13.8	57.2	202.9	216.0
T ₂ - RDF + FYM (10 t ha ⁻¹)	14.1	62.3	215.7	231.4
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	14.7	62.5	228.5	241.8
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	14.7	63.5	232.1	246.7
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	14.8	65.9	238.2	259.1
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	14.4	68.7	242.5	267.7
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	13.6	70.3	247.5	271.3
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	14.9	72.7	249.5	281.6
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	14.6	70.4	247.7	269.5
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	14.5	70.9	250.6	272.8
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	14.9	73.0	252.3	284.8
S.Em. ±	0.63	2.29	9.35	6.89
CD (p=0.05)	NS	6.76	27.59	20.33

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

Table 7. Root volume, root dry weight and root to shoot ratio of aerobic rice as influenced by different nutrient management practices at 90 DAS

Treatments	Root volume (cc m ⁻¹)	Root dry wt. (g m ⁻¹)	Shoot dry wt. (g m ⁻¹)	Root : Shoot
T ₁ - RDF alone	397.6	54.6	202.9	0.27
T ₂ - RDF + FYM (10 t ha ⁻¹)	402.1	59.0	215.7	0.27
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	420.5	60.4	228.5	0.26
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	427.6	61.3	232.1	0.26
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	433.0	61.6	238.2	0.26
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	461.2	71.1	242.5	0.29
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	465.0	69.0	247.5	0.28
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	473.6	72.7	249.5	0.29
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	470.0	71.8	247.7	0.29
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	472.6	70.3	250.6	0.28
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	478.5	73.0	252.3	0.29
S.Em. ±	12.23	2.74	9.35	0.016
CD (p=0.05)	36.07	8.09	27.59	NS

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

4.2.2 Panicle length (cm)

The data on panicle length of aerobic rice as influenced by different nutrient management practices are presented in Table 8.

Significantly higher panicle length (18.5 cm) was recorded with the foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (15.9 cm), RDF + FYM + ZnSO₄ (16.2 cm), RDF + FYM + borax (16.3 cm) and RDF + FYM + ZnSO₄ + Borax (16.9 cm). The significantly lower panicle length (15.5 cm) was observed with application of RDF alone.

4.2.3 Number of filled grains per panicle

The data on number of filled grains per panicle of aerobic rice as influenced by different nutrient management practices are presented in Table 8.

The differences in number of filled grains per panicle due to different nutrient management practices were significant. Among the different treatments, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) recorded significantly higher filled grains per panicle (69.3) and was found on par with all other treatments having foliar spray but significantly superior over application of RDF + FYM (56.8), RDF + FYM + ZnSO₄ (58.6), RDF + FYM + borax (59.6) and RDF + FYM + ZnSO₄ + borax (62.5). The significantly lower number of filled grains per panicle were recorded in RDF alone treatment (51.0).

4.2.4 Number of unfilled grains per panicle

The data on number of unfilled grains per panicle of aerobic rice as influenced by different nutrient management practices are presented in Table 8.

The number of unfilled grains per panicle (8.1) recorded was significantly lower in foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) + RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹). The number of unfilled grains recorded with RDF + FYM (13.3), RDF + FYM + ZnSO₄ (12.4), RDF + FYM + borax (11.0) and RDF + FYM + ZnSO₄ + borax (10.3) was found on par. The number of unfilled grains per panicle was significantly higher in RDF alone (15.7) treatment.

4.2.5 Grain weight per panicle (g)

The data on grain weight per panicle of aerobic rice as influenced by different nutrient management practices are presented in Table 8.

The variation in grain weight per panicle due to different nutrient management practices was significant. Among the different treatments, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) recorded significantly higher grain weight per panicle (2.56 g) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (2.14 g), RDF + FYM + ZnSO₄ (2.21 g), RDF + FYM + borax (2.26) and RDF + FYM + ZnSO₄ + Borax (2.29 g). However, significantly lower grain weight per panicle was recorded in RDF alone (2.05 g).

Table 8. Yield attributing parameters of aerobic rice as influenced by different nutrient management practices

Treatments	Productive tillers m ⁻¹	Panicle length (cm)	Number of filled grains panicle ⁻¹	Number of unfilled grains panicle ⁻¹	Grain weight panicle ⁻¹	Per cent filled grains (%)	1000 grain wt. (g)
T ₁ - RDF alone	113.2	15.5	51.0	15.7	2.05	75.8	22.91
T ₂ - RDF + FYM (10 t ha ⁻¹)	122.7	15.9	56.8	13.3	2.14	81.1	23.61
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	125.5	16.2	58.6	12.4	2.21	82.5	23.76
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	128.2	16.3	59.6	11.0	2.26	84.4	23.78
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	131.7	16.9	62.5	10.3	2.29	86.0	24.14
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	138.2	17.6	65.7	9.8	2.42	87.0	24.47
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	140.3	17.7	66.2	8.5	2.45	88.6	23.94
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	142.8	18.5	69.0	8.2	2.53	89.4	24.49
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	142.3	17.4	65.2	8.3	2.51	88.8	24.03
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	141.5	17.7	66.5	8.2	2.52	89.0	24.28
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	143.7	18.5	69.3	8.1	2.56	89.5	24.93
S.Em. ±	3.397	0.462	2.01	0.898	0.06	1.144	0.564
CD (p=0.05)	10.02	1.362	5.929	2.649	0.177	3.374	NS

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

4.2.6 Per cent filled grains

The data on per cent filled grains of aerobic rice as influenced by different nutrient management practices are presented in Table 8.

The per cent filled grains of aerobic rice were significantly influenced by different nutrient management practices. Among different treatments, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) recorded significantly higher per cent of filled grains (89.5 %) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (81.1 %), RDF + FYM + ZnSO₄ (82.5 %), RDF + FYM + borax (84.4 %) and RDF + FYM + ZnSO₄ + borax (86.0 %). The significantly lower per cent of filled grains was recorded in RDF alone treatment (75.8 %).

4.2.7 1000 grain weight (g)

The data on 1000 grain weight of aerobic rice as influenced by different nutrient management practices are presented in Table 8.

The variation in 1000 grain weight of aerobic rice due to different nutrient management practices was not significant. However, numerically higher thousand grain weight (24.93 g) was recorded with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) + RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and lower thousand grain weight was recorded in RDF alone treatment (22.91 g).

4.2.9 Grain yield (kg ha⁻¹)

The data on grain yield of aerobic rice as influenced by different nutrient management practices are presented in Table 9.

The differences in grain yield of aerobic rice due to different management practices were found significant. Among the different treatments, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) recorded significantly higher grain yield (3,765 kg ha⁻¹) and was found on par with all other treatments having foliar spray. The grain yield recorded in RDF + FYM (3,265 kg ha⁻¹), RDF + FYM + ZnSO₄ (3,377 kg ha⁻¹), RDF + FYM + borax (3,321 kg ha⁻¹) and RDF + FYM + ZnSO₄ + borax (3,407 kg ha⁻¹) were found on par with each other but significantly superior over that of RDF alone (2,753 kg ha⁻¹).

4.2.10 Straw yield (kg ha⁻¹)

The data on straw yield of aerobic rice as influenced by different nutrient management practices are presented in Table 9.

Significantly higher straw yield (4,420 kg ha⁻¹) was recorded with the foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and was on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (3,951 kg ha⁻¹), RDF + FYM + ZnSO₄ (4,037 kg ha⁻¹), RDF + FYM + borax (4,000 kg ha⁻¹) and RDF + FYM + ZnSO₄ + borax (4,056 kg ha⁻¹). However, significantly lower straw yield (3,346 kg ha⁻¹) was recorded in RDF alone treatment.

Table 9. Grain yield, straw yield and harvest index of aerobic rice as influenced by different nutrient management practices

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
T ₁ - RDF alone	2,753	3,346	45.1
T ₂ - RDF + FYM (10 t ha ⁻¹)	3,265	3,951	45.3
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	3,377	4,037	45.6
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	3,321	4,000	45.4
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	3,407	4,056	45.7
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	3,636	4,395	45.3
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	3,630	4352	45.5
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	3,716	4,395	45.8
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	3,642	4,377	45.4
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	3,623	4,321	45.6
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	3,765	4,420	46.0
S.Em. ±	81.98	110.1	0.009
CD (p=0.05)	241.8	324.8	NS

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

4.2.11 Harvest index (%)

The data on harvest index of aerobic rice as influenced by different nutrient management practices are presented in Table 9.

The results revealed that there was no significant difference in harvest index among the treatments. However, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) recorded the numerically higher harvest index (46.0 %) and lowest was found in RDF alone treatment (45.1 %).

4.3 Nutrient uptake (kg ha⁻¹) by aerobic rice crop at harvest

The data on nutrient uptake at harvest by aerobic rice as influenced by different nutrient management practices are presented in Tables 10 to 14.

4.3.1 Macro nutrient uptake

4.3.1.1 Nitrogen uptake (kg ha⁻¹)

The data on nitrogen uptake at harvest by aerobic rice as influenced by different nutrient management practices are presented in Table 10.

The differences in nitrogen uptake by aerobic rice due to different nutrient management practices were found significant. Among the different treatments, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) has recorded the highest uptake of nitrogen in grain, straw and total nitrogen (62.9, 33.1 and 96.0 kg ha⁻¹, respectively) which was found on par with all other treatments having foliar spray but significantly superior over all other treatments. The nitrogen uptake by grain, straw and total uptake in RDF + FYM (52.7, 23.0 and 75.7 kg ha⁻¹, respectively), RDF + FYM + ZnSO₄ (53.9, 25.1 and 79.0 kg ha⁻¹, respectively), RDF + FYM + borax (53.6, 26.1 and 79.7 kg ha⁻¹, respectively) and RDF + FYM + ZnSO₄ + borax (56.0, 27.7 and 83.7 kg ha⁻¹, respectively) were found on par with each other. However, significantly lower uptake of nitrogen by grain, straw and total uptake (44.2, 20.3 and 64.5 kg ha⁻¹, respectively) were recorded in application of RDF alone treatment.

4.3.1.2 Phosphorus uptake (kg ha⁻¹)

The data on phosphorus uptake at harvest by aerobic rice as influenced by different nutrient management practices are presented in Table 11.

Significantly higher uptake of phosphorus by grain, straw and total uptake (8.4, 10.6 and 19.0 kg ha⁻¹, respectively) was registered with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (6.7, 7.9 and 14.6 kg ha⁻¹, respectively), RDF + FYM + ZnSO₄ (6.9, 8.7 and 15.6 kg ha⁻¹, respectively), RDF + FYM + borax (7.0, 8.4 and 15.4 kg ha⁻¹, respectively) and RDF + FYM + ZnSO₄ + borax (7.2, 8.9 and 16.1 kg ha⁻¹, respectively). However, significantly lower phosphorus uptake by grain, straw and total uptake (5.9, 6.6 and 12.5 kg ha⁻¹, respectively) was recorded in RDF alone treatment.

Table 10. Nitrogen uptake by aerobic rice at harvest as influenced by different nutrient management practices

Treatments	Nitrogen uptake (kg ha ⁻¹)		
	Grain	Straw	Total
T ₁ - RDF alone	44.2	20.3	64.5
T ₂ - RDF + FYM (10 t ha ⁻¹)	52.7	23.0	75.7
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	53.9	25.1	79.0
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	53.6	26.1	79.7
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	56.0	27.7	83.7
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	59.0	28.5	87.5
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 75 DAS)	59.3	30.1	89.4
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	61.0	32.1	93.1
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	60.5	29.8	90.3
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	60.5	30.6	91.1
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	62.9	33.1	96.0
S.Em. ±	1.329	1.014	1.845
CD (p=0.05)	3.92	2.991	5.443

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

Table 11. Phosphorus uptake by aerobic rice at harvest as influenced by different nutrient management practices

Treatments	Phosphorus uptake (kg ha ⁻¹)		
	Grain	Straw	Total
T ₁ - RDF alone	5.9	6.6	12.5
T ₂ - RDF + FYM (10 t ha ⁻¹)	6.7	7.9	14.6
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	6.9	8.7	15.6
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	7.0	8.4	15.4
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	7.2	8.9	16.1
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	8.0	9.6	17.6
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 75 DAS)	8.1	9.4	17.5
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	8.2	9.8	18.0
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	8.3	10.2	18.5
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	8.3	10.5	18.8
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	8.4	10.6	19.0
S.Em. ±	0.31	0.314	0.478
CD (p=0.05)	0.913	0.926	1.409

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

4.3.1.3 Potassium uptake (kg ha^{-1})

The data on potassium uptake at harvest by aerobic rice as influenced by different nutrient management practices are presented in Table 12.

The variation in potassium uptake by aerobic rice due to different nutrient management practices was found significant. Among the different treatments, the highest uptake of potassium by aerobic rice grain, straw and total uptake (20.6 , 81.4 and 102.0 kg ha^{-1} , respectively) were recorded with the foliar application of $13:0:45$ (0.5% at 45 , 60 and 75 DAS) along with RDF ($75:75:87.5 \text{ kg N:P}_2\text{O}_5:\text{K}_2\text{O ha}^{-1}$) + FYM (10 t ha^{-1}) + ZnSO_4 (25 kg ha^{-1}) + borax (2 kg ha^{-1}) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (17.1 , 62.8 and 79.9 kg ha^{-1} , respectively), RDF + FYM + ZnSO_4 (17.5 , 66.8 and 84.3 kg ha^{-1} , respectively), RDF + FYM + borax (17.4 , 67.2 and 84.6 kg ha^{-1} , respectively) and RDF + FYM + ZnSO_4 + borax (18.2 , 71.7 and 89.9 kg ha^{-1} , respectively). However, significantly lower potassium uptake by grain, straw and total uptake (14.3 , 54.8 and 69.1 kg ha^{-1} , respectively) was recorded in RDF alone treatment.

4.3.2 Micronutrient uptake

4.3.2.1 Zinc uptake (g ha^{-1})

The data on zinc uptake at harvest by aerobic rice as influenced by different nutrient management practices are presented in Table 13.

The differences in zinc uptake by aerobic rice due to different nutrient management practices were found significant. Among the different treatments, foliar application of $19:19:19$ (0.5% at 45 , 60 and 75 DAS) along with RDF ($75:75:87.5 \text{ kg N:P}_2\text{O}_5:\text{K}_2\text{O ha}^{-1}$) + FYM (10 t ha^{-1}) + ZnSO_4 (25 kg ha^{-1}) + Borax (2 kg ha^{-1}) recorded the higher uptake of zinc by grain, straw and total uptake (426.7 , 545.2 and 971.9 g ha^{-1} , respectively) and were on par with all other treatments having foliar spray along with soil application of ZnSO_4 but significantly superior over that of treatments which were not applied with ZnSO_4 . However, zinc uptake by grain, straw and total uptake in RDF + FYM (328.0 , 381.9 and 709.9 g ha^{-1} , respectively), RDF + FYM + ZnSO_4 (373.5 , 429.1 and 802.6 g ha^{-1} , respectively), RDF + FYM + borax (341.4 , 400.4 and 741.8 g ha^{-1} , respectively) and RDF + FYM + ZnSO_4 + Borax (380.3 , 455.9 and 836.2 g ha^{-1} , respectively) was found on par with each other. The significantly lower uptake of zinc by grain, straw and total uptake was recorded with RDF alone (266.1 , 310.0 and 576.1 g ha^{-1} , respectively) treatment.

4.3.2.2 Boron uptake (g ha^{-1})

The data on boron uptake at harvest by aerobic rice as influenced by different nutrient management practices are presented in Table 14.

Significantly higher uptake of boron by grain, straw and total uptake (70.8 , 105.5 and 176.3 g ha^{-1} , respectively) was registered with foliar application of $19:19:19$ (0.5% at 45 , 60 and 75 DAS) along with RDF ($75:75:87.5 \text{ kg N:P}_2\text{O}_5:\text{K}_2\text{O ha}^{-1}$) + FYM (10 t ha^{-1}) + ZnSO_4 (25 kg ha^{-1}) + Borax (2 kg ha^{-1}) and was found on par with all other treatments having foliar spray along with soil application of borax but significantly superior over that of treatments which were not applied with borax.

Table 12. Potassium uptake by aerobic rice at harvest as influenced by different nutrient management practices

Treatments	Potassium uptake (kg ha ⁻¹)		
	Grain	Straw	Total
T ₁ - RDF alone	14.3	54.8	69.1
T ₂ - RDF + FYM (10 t ha ⁻¹)	17.1	62.8	79.9
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	17.5	66.8	84.3
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	17.4	67.2	84.6
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	18.2	71.7	89.9
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	19.4	78.8	98.2
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 75 DAS)	19.6	79.2	98.8
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	20.6	81.4	102.0
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	19.3	77.6	96.9
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	19.4	78.1	97.5
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	20.5	80.9	101.4
S.Em. ±	0.479	1.94	2.228
CD (p=0.05)	1.412	5.723	6.573

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

Table 13. Zinc uptake by aerobic rice at harvest as influenced by different nutrient management practices

Treatments	Zinc uptake (g ha ⁻¹)		
	Grain	Straw	Total
T ₁ - RDF alone	266.1	310.0	576.1
T ₂ - RDF + FYM (10 t ha ⁻¹)	328.0	381.9	709.9
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	373.5	429.1	802.6
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	341.4	400.4	741.8
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	380.3	455.9	836.2
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	411.8	492.2	904.0
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 75 DAS)	387.0	460.7	847.7
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	422.4	525.5	947.9
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	418.5	520.7	939.2
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	374.7	478.6	853.3
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	426.7	545.2	971.9
S.Em. ±	9.629	20.37	26.54
CD (p=0.05)	28.41	60.08	78.31

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

However, lower boron uptake by grain, straw and total uptake with RDF + FYM (55.1, 85.8 and 140.9 g ha⁻¹, respectively), RDF + FYM + ZnSO₄ (56.6, 88.7 and 145.3 g ha⁻¹, respectively), RDF + FYM + borax (61.7, 90.3 and 152.0 g ha⁻¹, respectively) and RDF + FYM + ZnSO₄ + borax (62.6, 95.7 and 158.3 g ha⁻¹, respectively) were found on par with each other. The significantly lower uptake of boron by grain, straw and total uptake was recorded in RDF alone treatment (42.4, 68.4 and 110.8 g ha⁻¹, respectively).

4.4 Available nutrient content in soil after harvest of crop

The data on available nutrients in the soil such as nitrogen, phosphorus, potassium zinc and boron after harvest of aerobic rice as influenced by different nutrient management practices are presented in Table 15.

4.4.1 Available nitrogen (kg ha⁻¹)

The data on available nitrogen content of soil after harvest of aerobic rice as influenced by due to different nutrient management practices are presented in Table 15.

The variation in available nitrogen in the soil after harvest of aerobic rice due to different nutrient management practices was significant. The available nitrogen in the soil after harvest of aerobic rice was maximum in RDF + FYM (276.3 kg ha⁻¹) treatment followed by RDF alone (274.4 kg ha⁻¹), RDF + FYM + ZnSO₄ (270.7 kg ha⁻¹), RDF + FYM + borax (266.9 kg ha⁻¹) and RDF + FYM + ZnSO₄ + borax (263.2 kg ha⁻¹) which were found on par with each other. The lowest available nitrogen (244.5 kg ha⁻¹) was recorded with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹).

4.4.2 Available phosphorus (kg ha⁻¹)

The data on available phosphorus content of soil after harvest of rice crop differed significantly as influenced by different nutrient management practices are presented in Table 15.

The available soil phosphorus after harvest of aerobic rice differed significantly due to different nutrient management practices. The available phosphorus in the soil after harvest of aerobic rice was maximum in RDF + FYM (22.1 kg ha⁻¹) treatment followed by RDF alone (21.4 kg ha⁻¹), RDF + FYM + ZnSO₄ (19.8 kg ha⁻¹), RDF + FYM + borax (20.6 kg ha⁻¹) and RDF + FYM + ZnSO₄ + borax (19.1 kg ha⁻¹) which were found on par with each other. However, significantly lowest available phosphorus (16.8 kg P₂O₅ ha⁻¹) was registered with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + Borax (2 kg ha⁻¹).

4.4.3 Available potassium (kg ha⁻¹)

The data on available potassium content of soil after harvest of aerobic rice as influenced by different nutrient management practices are presented in Table 15.

The differences in available potassium in soil after harvest of aerobic rice due to different nutrient management practices were found significant. The available potassium in the soil after harvest of aerobic rice was maximum in RDF + FYM (141.6 kg ha⁻¹) treatment followed by RDF (136.4 kg ha⁻¹), RDF + FYM + ZnSO₄ (136.8 kg ha⁻¹), RDF + FYM + borax (133.6 kg ha⁻¹) and RDF + FYM + ZnSO₄ + borax (132.0 kg ha⁻¹) and were found on par with each other. The lowest available potassium (125.6 kg ha⁻¹) was recorded with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹).

Table 14. Boron uptake by aerobic rice at harvest as influenced by different nutrient management practices

Treatments	Boron uptake (g ha ⁻¹)		
	Grain	Straw	Total
T ₁ - RDF alone	42.4	68.4	110.8
T ₂ - RDF + FYM (10 t ha ⁻¹)	55.1	85.8	140.9
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	56.6	88.7	145.3
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	61.7	90.3	152.0
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	62.6	95.7	158.3
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	62.9	96.3	159.2
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 75 DAS)	68.6	98.6	167.2
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	69.8	102.1	171.9
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	63.8	96.6	160.4
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60and 75 DAS)	69.2	102.2	171.3
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	70.8	105.5	176.3
S.Em. ±	2.913	4.666	6.684
CD (p=0.05)	8.593	13.76	19.72

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

Table 15. Available macro and micro nutrients as influenced by different nutrient management practices after harvest of aerobic rice

Treatments	Macro nutrients (kg ha ⁻¹)			Micro nutrients (ppm)	
	Nitrogen	Phosphorus	Potassium	Zinc	Boron
T ₁ - RDF alone	274.4	21.4	136.4	1.55	0.51
T ₂ - RDF + FYM (10 t ha ⁻¹)	276.3	22.1	141.6	1.81	0.54
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	270.7	19.8	136.8	2.06	0.56
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	266.9	20.6	133.6	1.55	0.62
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	263.2	19.1	132.0	2.08	0.63
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	261.3	17.2	130.0	2.10	0.52
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	257.6	17.9	128.0	1.46	0.61
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	252.0	15.6	127.2	2.02	0.60
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	250.1	16.8	128.4	2.03	0.50
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	248.3	17.6	126.0	1.40	0.61
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	244.5	16.8	125.6	2.02	0.593
S.Em. ±	6.535	0.933	2.495	0.066	0.021
CD (p=0.05)	19.28	2.752	7.359	0.193	0.061
Initial	291.2	27.5	146.4	1.98	0.58

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

4.4.4 Available zinc (ppm)

The data on available zinc content of soil after harvest of aerobic rice as influenced by different nutrient management practices are presented in Table 15.

The variation in available zinc in the soil after harvest of aerobic rice due to different nutrient management practices was found significant. Among the different treatments, foliar application of 13:0:45 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) has recorded higher available zinc in soil (2.10 ppm) followed by application of ZnSO₄ along with RDF + FYM (2.06 ppm) and was found on par with application of ZnSO₄ along with RDF + FYM + foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) (2.03 ppm). However, significantly lower available zinc was recorded in RDF + FYM + borax along with foliar application of 19:19:19 and 13:0:45 (1.40 and 1.46 ppm, respectively).

4.4.5 Available boron (ppm)

The data on available boron content of soil after harvest of aerobic rice as influenced by different nutrient management practices are presented in Table 15.

Significantly higher available boron (0.63 ppm) was registered with application of RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) and was found on par with application of borax along with foliar spray but significantly superior over that of RDF alone (0.51 ppm), RDF + FYM (0.54 ppm) and in treatments which were not applied with borax. However, significantly lower available boron (0.50 ppm) was recorded with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹).

4.5 Economics

4.5.1 Gross returns (Rs. ha⁻¹)

The data pertaining to gross return (Rs. ha⁻¹) of aerobic rice as influenced by different nutrient management practices are presented in Table 16.

The differences in gross returns of aerobic rice due to different nutrient management practices were significant. Among the different treatments, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) registered significantly higher gross returns (Rs. 65,321 ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (Rs. 56,883 ha⁻¹), RDF + FYM + ZnSO₄ (Rs. 58,722 ha⁻¹), RDF + FYM + borax (Rs. 57,815 ha⁻¹) and RDF + FYM + ZnSO₄ + borax (Rs. 59,222 ha⁻¹). However, significantly lower gross returns (Rs. 47,988 ha⁻¹) was recorded in RDF alone treatment.

4.5.2 Net returns (Rs. ha⁻¹)

The data pertaining to net return (Rs. ha⁻¹) of aerobic rice as influenced by different nutrient management practices are presented in Table 16.

Table 16. Economics of aerobic rice as influenced by different nutrient management practices

Treatments	Gross returns (₹ ha ⁻¹)	Cost of cultivation (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B:C
T ₁ - RDF alone	47,988	23,430	24,558	2.05
T ₂ - RDF + FYM (10 t ha ⁻¹)	56,883	28,430	28,453	2.00
T ₃ - T ₂ + ZnSO ₄ @ 25 kg ha ⁻¹	58,722	29,805	28,917	1.97
T ₄ - T ₂ + Borax @ 2 kg ha ⁻¹	57,815	28,710	29,105	2.01
T ₅ - T ₂ + ZnSO ₄ (25 kg ha ⁻¹) + Borax (2 kg ha ⁻¹)	59,222	30,085	29,137	1.97
T ₆ - T ₃ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	63,327	31,605	31,722	2.00
T ₇ - T ₄ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	63,148	30,510	32,638	2.07
T ₈ - T ₅ + 13:0:45 (0.5 % at 45, 60 and 75 DAS)	64,531	31,885	32,646	2.02
T ₉ - T ₃ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	63,383	31,605	31,778	2.01
T ₁₀ - T ₄ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	62,994	30,510	32,484	2.06
T ₁₁ - T ₅ + 19:19:19 (0.5 % at 45, 60 and 75 DAS)	65,321	31,885	33,436	2.05
S.Em. ±	1,259		1,259	0.042
CD (p=0.05)	3,714		3,714	NS

Note: RDF (75:75:87.5 N:P₂O₅:K₂O kg ha⁻¹)

Foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P₂O₅:K₂O ha⁻¹) + FYM (10 t ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + borax (2 kg ha⁻¹) registered significantly higher net returns (Rs. 33,436 ha⁻¹) and was found on par with all other treatments having foliar spray but significantly superior over that of RDF + FYM (Rs. 28,453 ha⁻¹), RDF + FYM + ZnSO₄ (Rs. 28,917 ha⁻¹), RDF + FYM + borax (Rs. 29,105 ha⁻¹) and RDF + FYM + ZnSO₄ + borax (Rs. 29,137 ha⁻¹). However, significantly lower net returns (Rs. 24,558 ha⁻¹) was recorded in RDF alone treatment.

4.5.3 Benefit:Cost ratio

The data pertaining to benefit: cost ratio of aerobic rice as influenced by different nutrient management practices are presented in Table 16.

The variation in benefit cost ratio of aerobic rice due to different nutrient management practices was found not significant. However, foliar application of 13:0:45 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P:K ha⁻¹) + FYM (10 t ha⁻¹) + borax (2 kg ha⁻¹) was recorded higher B:C ratio (2.07) closely followed by the foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF (75:75:87.5 kg N:P:K ha⁻¹) + FYM (10 t ha⁻¹) + borax (2.06). The lowest B:C ratio was recorded in RDF + FYM + ZnSO₄ (1.97) and RDF + FYM + ZnSO₄ + borax (1.97) treatment.

5. DISCUSSION

The rice ecosystem is increasingly threatened by water shortage due to decreasing resources and increased competition from other sectors such as urban and industrial users. A recent water saving technology is to grow rice aerobically, that is in non puddle situation and non flooded soil with irrigation. The aerobic rice production is one such alternative method, which requires less water than that of lowland rice and the lack of suitable nutrient management practices resulted in lower productivity of aerobic rice. In hill zone of Karnataka, rice is grown during summer season in areas near by reservoirs or ponds or wells by transplanting method under puddle condition. In such situation adoption of aerobic rice method may help in bringing more area under cultivation with the limited water available in ponds or reservoirs. As aerobic rice cultivation is a new concept in hill zone of Karnataka, there is a need to work out nutrient management practices for aerobic situation. Keeping these points in view an experiment was conducted to work out the nutrient management practices for enhancing productivity of aerobic rice during summer season in hill zone of Karnataka. The results of the experiment are discussed in detail in this chapter along with causes for variation among different nutrient management practices.

In the present study crop was experienced favourable weather condition during its growth (Table 1). A total rainfall of 120.5 mm was received during the crop growth period, which was little less than the normal (122.6 mm). The mean monthly maximum temperature (33.4°C) and mean monthly minimum temperature (18.6°C) were little lesser than their respective normal values and relative humidity was higher (74 %) than average relative humidity during crop growth period. As the rice was grown by aerobic method during summer season, crop was irrigated by using borewell water. The crop was irrigated at an interval of 6 - 7 days during vegetative stages and at interval of 3 - 4 days at reproductive stage. During crop period totally 16 irrigations were given with the depth of 5 cm and which accounted to about 910.8 mm (including RF of about 110.8 mm) of irrigation water as compared to conventional method (1500 mm). Two irrigations were skipped in the month of April and May due to rainfall received (45 and 75 mm, respectively) in these two months. Hence, cultivation of rice by aerobic method could save about 598.2 mm of water which can be used for bringing some more area under rice cultivation.

5.1 Effect of nutrient management practices on growth, yield and yield attributes of aerobic rice

The variation in grain and straw yield of aerobic rice was significant due to different nutrient management practices (Table 9). The grain and straw yield recorded with RDF + FYM was 3265 and 3951 kg per ha, respectively, which was found significantly superior over that of RDF alone (2,753 and 3,346 kg ha⁻¹, respectively). There was no further significant increase in grain and straw yield of aerobic rice with the additional application of ZnSO₄ (3,377 and 4,037 kg ha⁻¹, respectively) or borax (3,321 and 4,000 kg ha⁻¹, respectively) or combination of ZnSO₄ and borax (3,407 and 4,056 kg ha⁻¹, respectively). Among the different treatments, treatment having foliar spray of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax has recorded significantly higher grain and straw yield (3,765 and 4,420 kg ha⁻¹, respectively) and was found significantly superior over all other

treatments except the treatments with foliar application of either 19:19:19 or 13:0:45. The grain and straw yield (2,753 and 3,346 kg ha⁻¹, respectively) recorded with RDF alone was significantly lower when compared to all other treatments. Among the treatments having FYM or zinc or boron along with RDF, higher grain and straw yield (3,407 and 4,056 kg ha⁻¹, respectively) were recorded in RDF + FYM + ZnSO₄ + borax. However, the differences were not significant. The increase in grain and straw yield of aerobic rice in treatments having foliar spray might be due to better absorption of foliar applied nutrients by leaves directly and in turn increased the rate of photosynthesis. This might have resulted in higher accumulation of dry matter which in turn resulted in higher grain and straw yield in treatments having foliar application of nutrients. The extent of increase in grain yield in treatment combinations having 19:19:19 spray was ranging from 32.3 to 36.8 per cent, whereas, with 13:0:45 spray was ranging from 32.1 to 35.0 per cent as compared to RDF alone. The results are in close conformity with findings of Subbaiah *et al.* (2001) who reported that variety ADT 38 responded well to NPK and foliar spray of DAP (2 %) and potassium chloride (2 %) at booting and panicle initiation stages registering a maximum yield and Manjappa *et al.* (2008) who recorded significantly highest mean grain yield with foliar KNO₃ application when applied 60 days after planting. Similarly, Rani *et al.* (2014) who reported that significantly higher grain yield was recorded with RDF + spray of 19:19:19 @ 2.5 kg ha⁻¹ at tillering and panicle initiation stages.

The variation in yield could be traced back to improved growth parameters like, plant height, leaf area, number of tillers per meter row length and total dry matter production in aerobic rice. These growth parameters were increased significantly with the application of RDF + FYM along with ZnSO₄ or borax or ZnSO₄ + borax compared RDF alone and further enhancement was observed when the foliar application of 19:19:19 or 13:0:45 was compared with RDF + FYM + zinc + boron (Tables 3 to 6). The pre requisite for getting higher yields in any crop is higher total dry matter production (TDM) and it's partitioning into various plant parts coupled with maximum translocation of photosynthesis to the sink. Total dry matter accumulation (TDMA) is the sum of dry matter accumulation in individual plant parts which depends on the moisture, nutrients and availability of light.

Among the different nutrient combinations, foliar application of 19:19:19 (0.5 %) along with RDF + FYM + ZnSO₄ + borax has recorded higher total dry matter production (73.0, 252.3 and 284.8 g m⁻¹ at 60, 90 DAS and at harvest, respectively). The increased total dry matter accumulation (Table 6) was mainly due to higher plant height (41.1, 63.9 and 67.7 cm at 60, 90 DAS and at harvest, respectively), number of tillers per meter row length (150.3, 156.5 and 152.2 at 60, 90 DAS and at harvest, respectively), leaf area (82.5, 208.7 and 107.7 dm² m⁻¹ at 60, 90 DAS and at harvest, respectively) and also increased root volume (478.5 cc m⁻¹) and root dry weight (73.0 g m⁻¹) observed in the aerobic situation and was found on par with foliar application of 13:0:45 along with combined application of RDF + FYM + zinc sulphate + borax. The increased growth parameters with foliar application of water soluble fertilizers might be due to increased translocation and assimilation of nutrients in the plant. These results are in agreement with those of Alston (1979) who reported better vegetative growth of wheat with foliar application of N. Similarly, Soylu *et al.* (2005) and Arif *et al.* (2006) reported significant increase in plant height of wheat crop with foliar application of different nutrients individually or in combination.

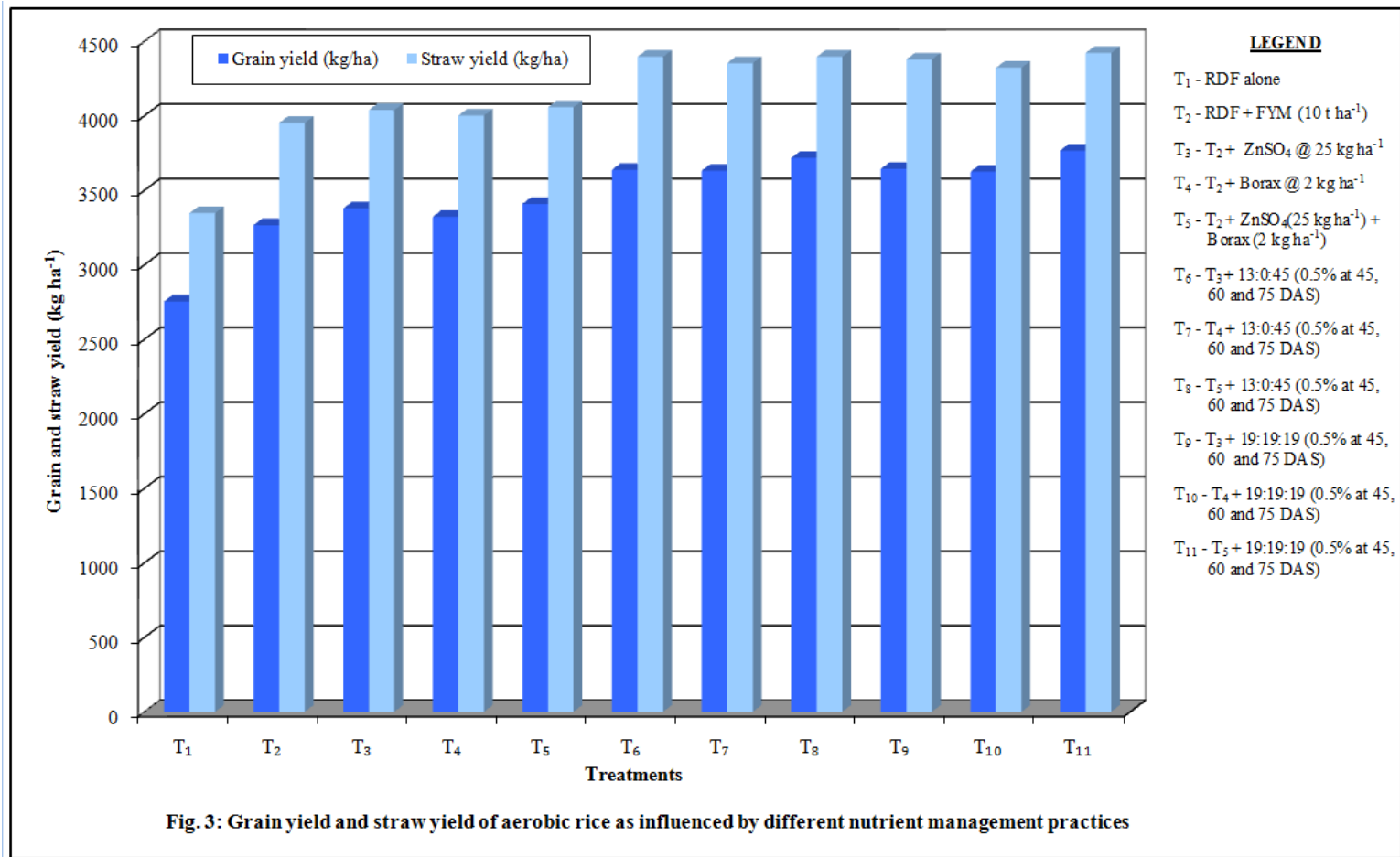


Fig. 3: Grain yield and straw yield of aerobic rice as influenced by different nutrient management practices



T₁ - RDF alone



T₂ - RDF + FYM



T₃ - RDF + FYM + ZnSO₄ + Borax



T₄ - RDF + FYM + ZnSO₄ + Borax + 19:19:19 @ 0.5%

Plate 2: Crop growth at 75 DAS under different treatment combinations



T₁ - RDF alone



T₂ - RDF + FYM



T₃ - RDF + FYM + ZnSO₄ + Borax



T₄ - RDF + FYM + ZnSO₄ + Borax + 19:19:19 @ 0.5%

Plate 3: Crop growth at 110 DAS under different treatment combinations

Similarly, Arif *et al.* (2010) also concluded that the exogenous potassium application had a significant effect on tillering in rice. However, significantly lower plant height, leaf area, number of tillers per meter row length and total dry matter production was observed in RDF alone or RDF + FYM or RDF + FYM + ZnSO₄ or RDF + FYM + borax or RDF + FYM + ZnSO₄ + borax without foliar spray. This might be due to lack of availability of nutrients at critical stages of plant growth under aerobic situation.

The improved growth parameters resulted in improved yield components *viz.*, number of productive tillers per meter row length, number of filled grains per panicle, grain weight per panicle and test weight. The foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax has recorded significantly higher in number of productive tillers per m row length (143.7), number of filled grains per panicle (69.3), grain weight per panicle (2.56 g) and test weight (24.93 g). Significantly lowest number of tillers per meter row length (113.2), number of filled grains per panicle (51.0), grain weight per panicle (2.05 g) and test weight (22.91 g) in RDF alone treatment. These results are in agreement with those of Ramos *et al.* (1999) who found that soil application of NPK along with one per cent mono potassium phosphate (Peak) sprayed twice resulted in the highest number of productive tillers per m². Similar trend of higher number of grains and longer panicle was also reported by Beecher *et al.* (2006). This increase might be due to the additional availability of nutrients till later growth stages of aerobic rice. The increase in yield components in treatments having foliar spray might be due to better absorption of foliar applied nutrients by leaves directly where they are needed, and increased rate of photosynthesis in the leaves, which might have resulted in higher accumulation of dry matter which in turn resulted in higher grain and straw yield when foliar nutrients applied at critical stages.

5.2 Effect of nutrient management practices on uptake of macro and micro nutrients by aerobic rice

The uptake of N, P, K, zinc and boron by aerobic rice at harvest by rice grain, straw and total was more in the treatments having foliar application of either 19:19:19 or 13:0:45 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax compared to RDF alone, RDF + FYM and RDF + FYM along with soil application of zinc or boron or both (Tables 10 to 14).

Application of zinc and boron in combination with recommended dose of fertilizer (RDF) and foliar application of 19:19:19 or 13:0:45 were found to increase the total nitrogen, phosphorus and potassium uptake by aerobic rice over RDF alone. The maximum and significant total N (96.0 kg ha⁻¹), P (19.0 kg ha⁻¹) and K (101.4 kg ha⁻¹) uptake was recorded with treatment comprising foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax and was found significantly higher than the treatments without foliar application of nutrients. The increased uptake of NPK in this treatment was mainly due to the higher root volume and root dry weight (Table 7) which might have helped in better absorption of nutrients in turn resulted in increased growth parameters *viz.*, plant height, number of tillers per meter row length, leaf area and total dry matter accumulation. This is due to easy availability of nutrients at critical stages of crop growth and also higher biological yield resulted in higher uptake of nutrients. The instances of increase in uptake of major nutrients by application of zinc and boron along with NPK were reported by Malakouti (2008). Similar results were also reported by Chaity and Sarkar (2009) who reported that foliar spray of 0.5 % KNO₃ and 0.406 % Ca(NO₃)₂ increased the uptake of N (49.8 and 52.6 kg ha⁻¹, respectively) in lowland rice over water spray treatment (42 kg ha⁻¹).

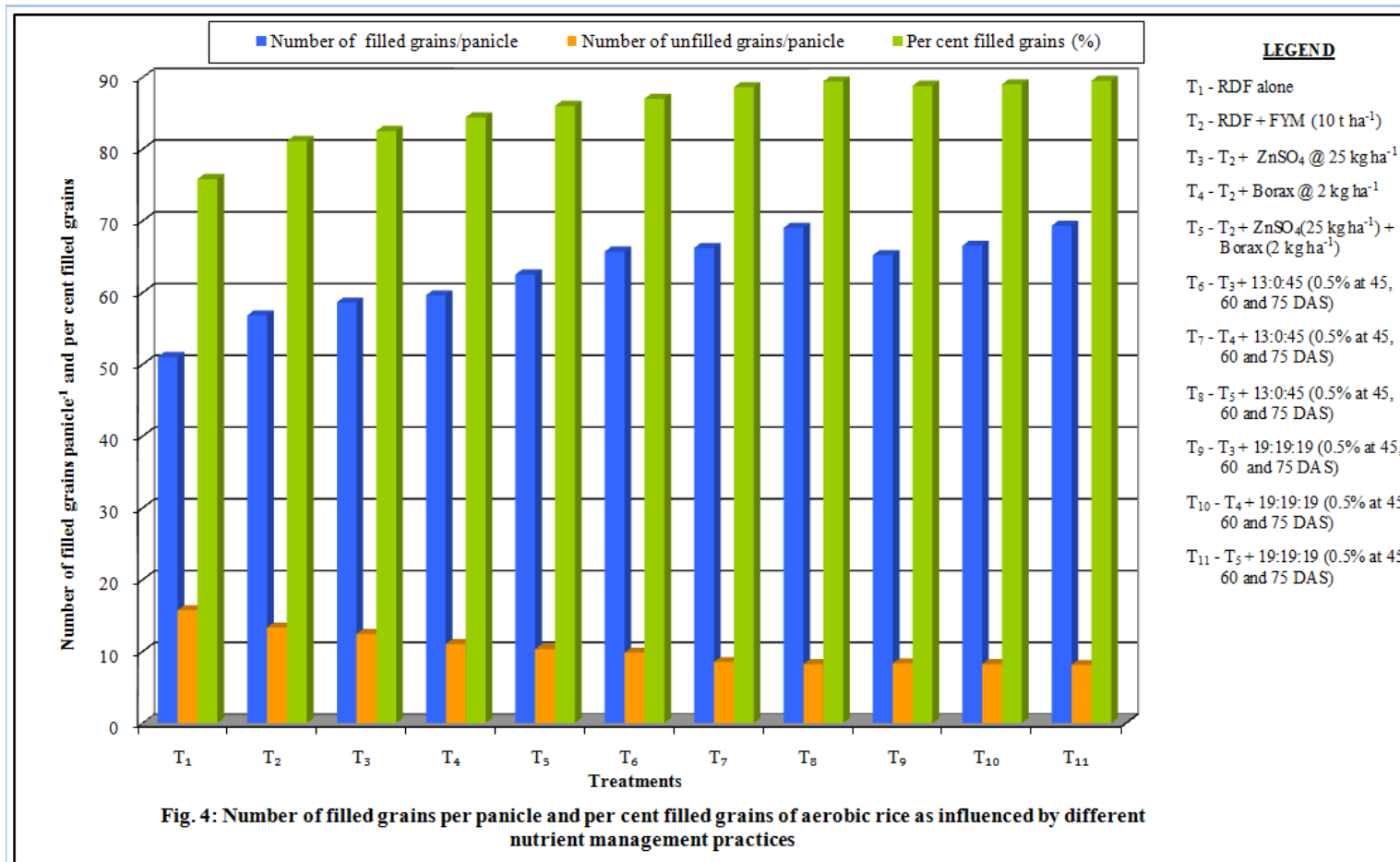


Fig. 4: Number of filled grains per panicle and per cent filled grains of aerobic rice as influenced by different nutrient management practices



T₁ - RDF alone



T₂ - RDF + FYM



T₃ - RDF + FYM + ZnSO₄ + Borax



T₄ - RDF + FYM + ZnSO₄ + Borax + 19:19:19 @ 0.5%

Plate 4: Crop growth at harvest under different treatment combinations

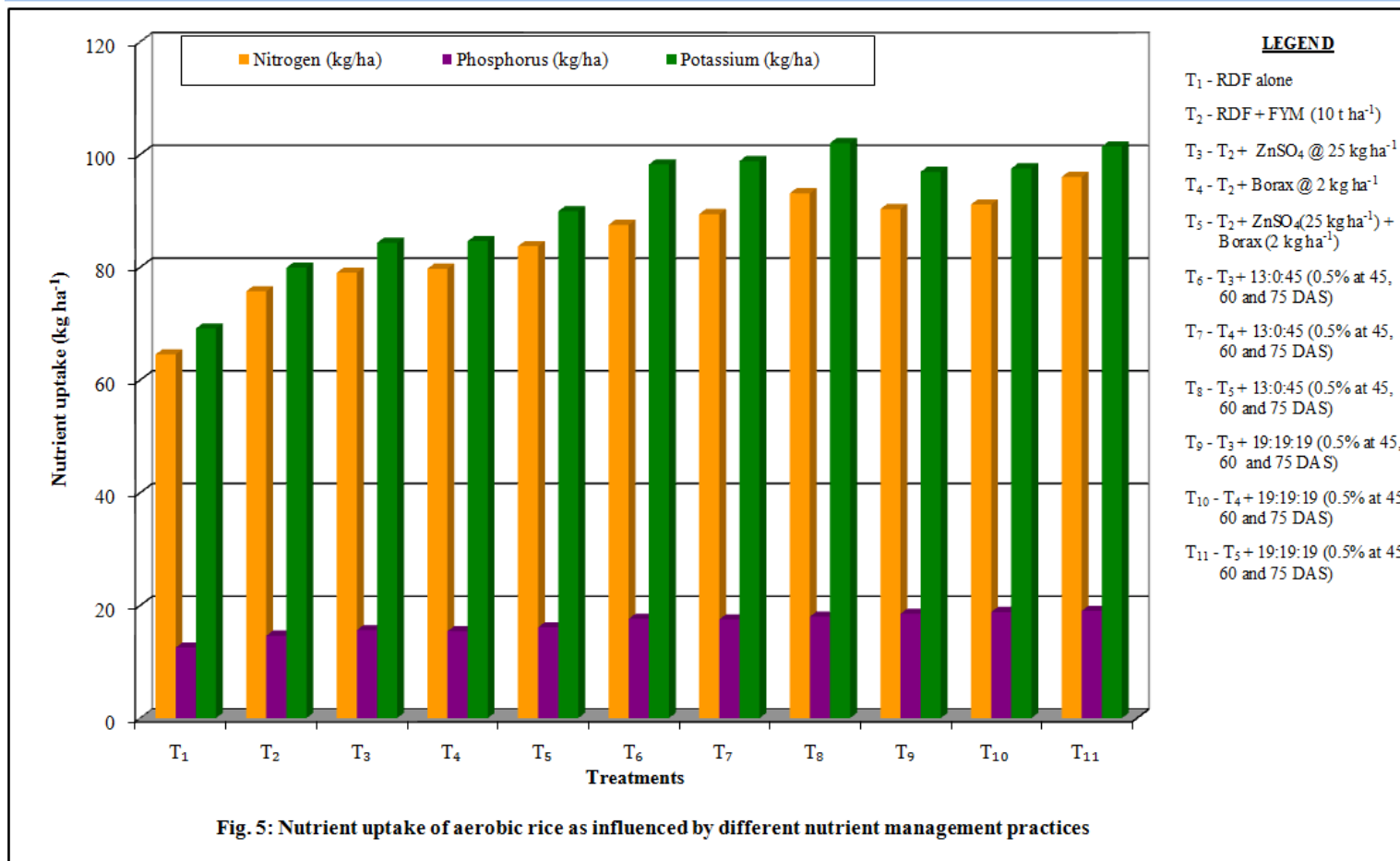


Fig. 5: Nutrient uptake of aerobic rice as influenced by different nutrient management practices

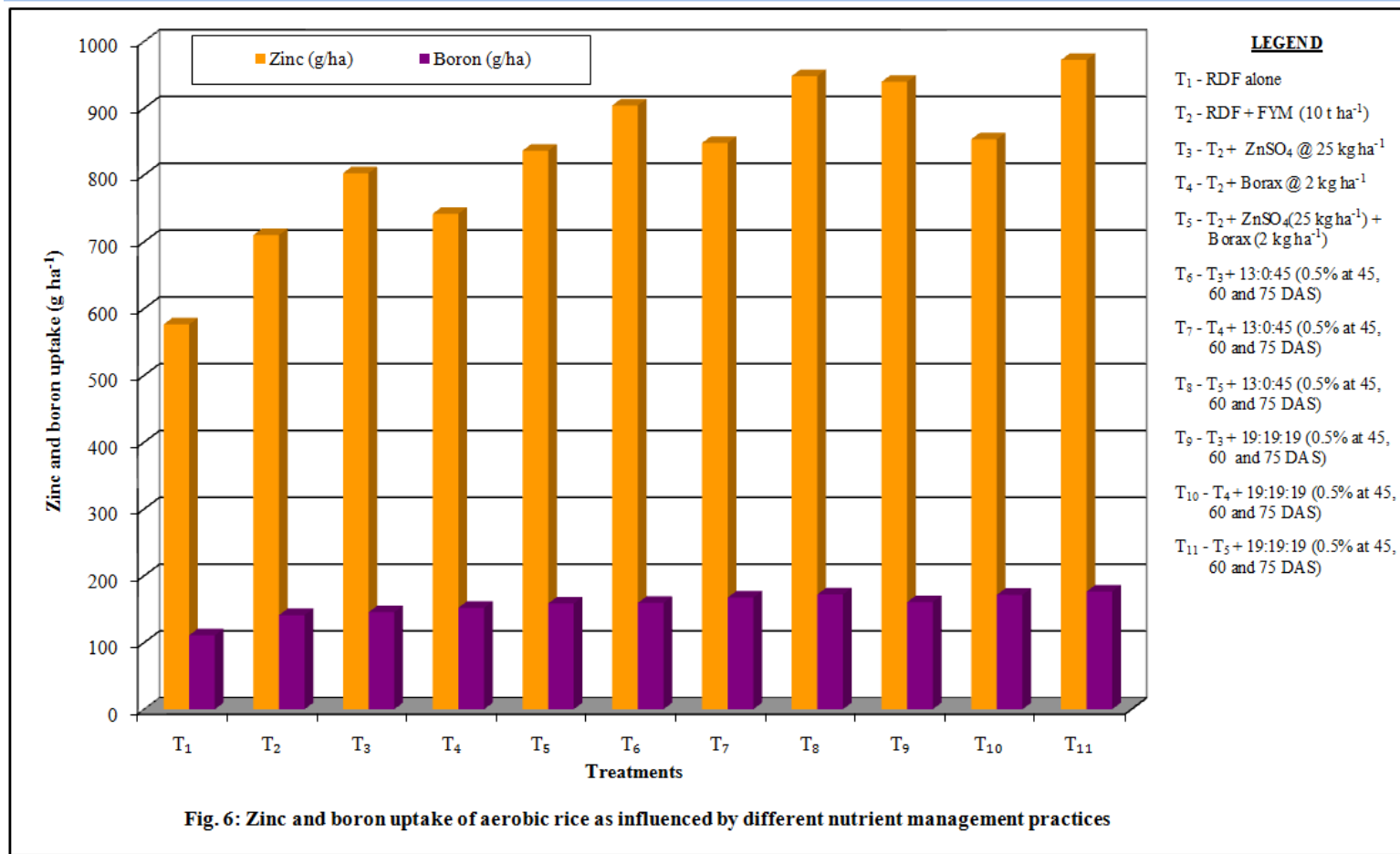


Fig. 6: Zinc and boron uptake of aerobic rice as influenced by different nutrient management practices

In general, zinc and boron uptake by aerobic rice was more in treatments having zinc and boron, respectively compared to treatments without zinc and boron. (Tables 13 and 14). Among the different treatments, foliar application 19:19:19 and 13:0:45 along with RDF + FYM + ZnSO₄ + borax recorded significantly higher uptake of zinc (971.9 and 948.0 g ha⁻¹, respectively) and boron (176.38 and 171.95 g ha⁻¹, respectively) and were found on par with other treatments having foliar spray component. Significantly lower uptake of zinc (576.2 g ha⁻¹) and boron (110.80 g ha⁻¹) was found in RDF alone. Higher uptake of boron in treatments having boron or combinations of zinc and boron and higher uptake of zinc in treatments having zinc or combination zinc and boron along with foliar application of either 19:19:19 or 13:0:45 + RDF + FYM application may be due to more availability of zinc and boron for crop uptake. These results are in agreement with those of Abbas *et al.* (2013b) who reported that higher boron content recorded with N:P:Zn:B as compared control. Similar results were also reported by Saha *et al.* (2013) who reported that application of zinc to soil (Zn @ 20 kg ha⁻¹ as zinc sulphate heptahydrate) as basal increased the Zn concentration in brown rice to the level of 5.0 mg per kg (17 %) over the control.

5.3 Effect of nutrient management practices on available macro and micro nutrients after harvest

Soil was analyzed for available nitrogen, phosphorus, potassium, zinc and boron concentration after the harvest of the crop. In general, the available nitrogen, phosphorus and potassium status of soil was low as compared to their initial values. Whereas, the available zinc and boron content was more than the initial values in treatments where zinc and boron were applied.

The soil available nitrogen, phosphorus and potassium were found maximum in RDF + FYM (276.3, 22.1 and 141.6 kg ha⁻¹, respectively) and was found to be significantly higher compared to treatments with foliar application of either 19:19:19 or 13:0:45 along with RDF + FYM + zinc + boron (Table 15). The decreased available nitrogen, phosphorus and potassium in treatments having foliar spray was mainly due to increased uptake by the crop and the increased uptake was due to increased biological (grain + straw) yield. The extractable P₂O₅ in soil was more in FYM applied treatment but it was decreased in the treatments which were produced higher biological yield and least available phosphorus was observed where zinc was applied due to antagonistic effect between zinc and phosphorus as compared to other treatments. Available zinc in the soil was higher in the treatments received ZnSO₄. These results are well supported by Chaudhry *et al.* (1981) and Duraisamy *et al.* (1986). Similar results were also reported by Prasad *et al.* (2010) and Rathod *et al.* (2012). Similar trend was also observed in case boron where higher available boron was recorded in the treatments having boron fertilizer compared to treatments having no boron application.

5.4 Effect of nutrient management practices on economics of aerobic rice

The economic returns measure the profitability of the crop production. The price of inputs and farm produce change from time to time and place to place thus profitable nutrient management system in crop production also varies accordingly. In the present investigation, foliar application of 19:19:19 (0.5 %) along with RDF + FYM + ZnSO₄ + borax has recorded significantly higher gross (Rs.

65,321 ha⁻¹) and net (Rs. 33,436 ha⁻¹) returns and was found significantly superior to all other treatments except treatments with foliar application of either 19:19:19 or 13:0:45. The gross (Rs. 47,988 ha⁻¹) and net (Rs. 24,558 ha⁻¹) returns recorded with RDF alone were significantly lower when compared to all treatments. Among the treatments having FYM or zinc or boron along with RDF, higher gross and net returns were recorded in RDF + FYM + zinc + boron (Rs. 59,222 and 29,137 ha⁻¹, respectively). However, the differences were not significant among these treatment combinations. The increased gross and net returns in different treatments were mainly due to increased grain and straw yield in respective treatments. Similar results are reported by Rani *et al.* (2014) who reported that maximum net returns were obtained when RDF was supplemented with 14:35:14 and 19:19:19. The benefit:cost ratio did not differ significantly among the different nutrient management practices though significant differences were observed with respect to gross and net returns. The B:C ratio recorded in RDF + FYM (2.00) was lower when compared to that of RDF alone (2.05). This was mainly because of increased cost incurred towards FYM. Further, reduction in B:C ratio was observed in treatments having zinc application along with RDF + FYM (1.97). This is again was due to increased cost of cultivation because of higher cost of ZnSO₄. The B:C ratio was found to increase with foliar application of 19:19:19 or 13:0:45 along with RDF + FYM + borax treatments (2.06 and 2.07, respectively). Hence, by considering the net returns and B:C ratio it was realised that application of 19:19:19 or 13:0:45 spray along with RDF + FYM + zinc + boron was found to be better nutrient management option for rice under aerobic situation in hill zone of Karnataka.

Practical utility

The results obtained in the present study on nutrient management practices for enhancing productivity of aerobic rice during summer season of 2014 - 2015 in hill zone of Karnataka indicated the following points of practical importance.

- Foliar application of water soluble fertilizers (19:19:19 or 13:0:45) at critical stages (45, 60 and 75 DAS) of crop growth along with micronutrient (zinc and boron) application increased the grain (3,765 kg ha⁻¹) and straw (4,420 kg ha⁻¹) yield and as well as net returns (Rs. 33,436 ha⁻¹) in aerobic method of rice cultivation.
- Aerobic rice cultivation saves about 579.2 mm of irrigation water and with this quantity of water another 0.6 ha of aerobic rice can be grown.

Future line of work

- There is need to evaluate potentiality of other varieties suited to aerobic cultivation in hill zone condition.
- Need to evaluate frequency of sprays to maximize the yield of aerobic rice in hill zone condition.

6. SUMMARY AND CONCLUSIONS

A field experiment was conducted to study the nutrient management practices for enhancing the productivity of aerobic rice in hill zone of Karnataka at Agricultural Research Station (Paddy), Sirsi during summer season of 2014-15. The experiment was laid out in Randomized Complete Block Design with 11 treatments. A brief summary of the findings are presented in this chapter.

The growth parameters such as plant height (67.7 cm), number of tillers per meter row length (152.2), leaf area (107.7 dm² m⁻¹) and total dry matter production (284.8 g m⁻¹) recorded at harvest were significantly higher with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax.

Significantly higher root volume (478.5 cc m⁻¹) and root dry weight (73.0 g m⁻¹) were recorded in foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax.

Significantly higher productive tillers per meter row length (143.7), panicle length (18.5 cm) and grain weight per panicle (2.56 g) at harvest were recorded with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax and it was found on par with foliar application of 13:0:45 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax compared to treatments without foliar application.

Among the different treatments, foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax recorded higher grain (3765 kg ha⁻¹) and straw (4420 kg ha⁻¹) yield of aerobic rice. However, there was no significant difference among the foliar application of either 19:19:19 or 13:0:45 (0.5 %) along with RDF + FYM + ZnSO₄ or borax or ZnSO₄ + borax but significantly superior over treatments which are not applied with foliar fertilizers.

Significantly higher uptake of major and micro nutrients was recorded with foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax.

Significantly higher available macro nutrients after harvest were recorded in RDF + FYM. The lower available macro (NPK) nutrients after harvest recorded in foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax. However, available zinc and boron were found maximum in respective zinc and boron applied treatments compared to all other treatments.

The higher gross returns (Rs. 65,321 ha⁻¹) and net returns (Rs. 33,436 ha⁻¹) were recorded in foliar application of 19:19:19 (0.5 % at 45, 60 and 75 DAS) along with RDF + FYM + ZnSO₄ + borax and were found on par with all other treatments having foliar spray component. The differences in B:C ratio of aerobic rice due to different nutrient management practices were not significant.

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Appendix I. Quantity of irrigation given to the crop (5 cm depth)

Sl. No.	Date of irrigation	Depth of water given (mm)
1.	03-02-2015	50
2.	18-02-2015	50
3.	27-02-2015	50
4.	07-03-2015	50
5.	14-03-2015	50
6.	21-03-2015	50
7.	28-03-2015	50
8.	04-04-2015	50
9.	11-04-2015	50
10.	15-04-2015	50
11.	29-04-2015	50
12.	04-05-2015	50
13.	09-05-2015	50
14.	13-05-2015	50
15.	21-05-2015	50
16.	26-05-2015	50
	Rainfall	120.5
Total		920.5

Appendix II: Prices of inputs and outputs

Items	Rate (₹/kg/l)
1. Seeds	
❖ MAS 946-1	30
2. Fertilizers (75:75:87.5:25:2 kg N:P:K:Zn:B ha⁻¹)	
❖ Urea	5.8
❖ DAP	23.8
❖ MOP	16
❖ ZnSO ₄	55
❖ Borax	140
❖ FYM	500 / t
3. Chemicals	
❖ Butachlor	200
❖ Phorate	50
4. Foliar nutrients (19:19:19 / 13:0:45 @ 0.5 %)	
❖ 19:19:19	100
❖ 13:0:45	100
5. Labor wages	
❖ Men	200.00 per day
❖ Women	200.00 per day
❖ Bullock pair with men	850.00 per day
6. Output	
❖ Rice grain	1,500 / q
❖ Rice straw	2,000 / t

Appendix III: Treatment wise cost of cultivation (` ha⁻¹)

Particulars	quantity kg/labour/ ha	Rate	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁
land preparation													
Harrowing	2	850	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
hand sowing	5	200	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Seed cost rice 18 kg/ha	18	30	540	540	540	540	540	540	540	540	540	540	540
weedicide butachlor (2.5 l/ha)	2.5	200	500	500	500	500	500	500	500	500	500	500	500
Fertilizers and manures cost													
Urea	99	5.8	574.2	574.2	574.2	574.2	574.2	574.2	574.2	574.2	574.2	574.2	574.2
DAP	163	23.8	3,879.4	3,879.4	3,879.4	3,879.4	3,879.4	3,879.4	3,879.4	3,879.4	3,879.4	3,879.4	3,879.4
MOP	146	16	2,336	2,336	2,336	2,336	2,336	2,336	2,336	2,336	2,336	2,336	2,336
ZnSO ₄	25	55			1,375		1,375	1,375		1,375	1,375		1,375
borax	2	140				280	280		280	280		280	280
FYM	10	500		5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
After care													
intercultivation	1	850	850	850	850	850	850	850	850	850	850	850	850
Hand weeding	8	200	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
insecticide (phorate 5 kg/ha) + labor wages	5	50	450	450	450	450	450	450	450	450	450	450	450
foliar application of 19:19:19 and 13:0:45 + labor wage	3	100						1,800	1,800	1,800	1,800	1,800	1,800
Harvesting and threshing of rice	50	200	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Total			23,429.6	28,429.6	29,804.6	28,709.6	30,084.6	31,604.6	30,509.6	31,884.6	31,604.6	30,509.6	31,884.6

NUTRIENT MANAGEMENT PRACTICES FOR ENHANCING THE PRODUCTIVITY OF AEROBIC RICE DURING SUMMER IN HILL ZONE OF KARNATAKA

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2016

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ABSTRACT

A field experiment was conducted to study the nutrient management practices for enhancing the productivity of aerobic rice in hill zone of Karnataka during summer 2014-15 at Agricultural Research Station (Paddy), Sirsi, University of Agricultural Sciences, Dharwad. There were 11 treatment combinations having spray of two different water soluble fertilizers viz., 19:19:19 and 13:0:45 (0.5 %) ; soil application of micronutrients viz., zinc as zinc sulphate (25 kg ha^{-1}) and boron as borax (2 kg ha^{-1}) along with recommended dose of fertilizer (RDF) ($75:75:87.5 \text{ kg N, P}_2\text{O}_5 \text{ and K}_2\text{O ha}^{-1}$) and RDF + farm yard manure (FYM) (10 t ha^{-1}). The experiment was laid out in randomized complete block design with three replications.

Foliar application of 19:19:19 along with RDF + FYM + ZnSO_4 + borax has recorded significantly higher grain and straw yield ($3,765$ and $4,420 \text{ kg ha}^{-1}$, respectively) and yield parameters like productive tillers (143.7), filled grains per panicle (69.3) and grain weight per panicle (2.56 g). Whereas, significantly lower grain ($2,753 \text{ kg ha}^{-1}$) and straw ($3,346 \text{ kg ha}^{-1}$) yield was recorded in RDF alone treatment.

Total uptake of nitrogen (96 kg ha^{-1}), phosphorus (19 kg ha^{-1}), potassium (101.4 kg ha^{-1}), zinc (971.9 g ha^{-1}) and boron (176.4 g ha^{-1}) was also significantly higher in treatment having foliar application of 19:19:19 along with RDF + FYM + ZnSO_4 + borax and was found on par with all other treatments receiving foliar spray of either 19:19:19 or 13:0:45. Similarly, higher net returns (Rs. $33,436 \text{ ha}^{-1}$) was recorded in foliar application of 19:19:19 along with RDF + FYM + ZnSO_4 + borax and was found significantly superior over all other treatments except the treatments with foliar application of either 19:19:19 or 13:0:45.