STANDARDISATION OF PLANTING GEOMETRY IN AEROBIC RICE (*Oryza sativa* L.) UNDER DIFFERENT LEVELS OF DRIP FERTIGATION

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UNIVERSITY OF AGRICULTURAL SCIENCES, GKVK,

BENGALURU-560065

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in

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BENGALURU **JUNE, 2015**

Affectionately Dedicated to

My Beloved Parents, Brother, Sisters & Friends

DEPARTMENT OF AGRONOMY
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BENGALURU-560065

CERTIFICATE

This is to certify that the thesis entitled **"Standardisation of planting geometry in aerobic rice (*Oryza sativa* L.) under different levels of drip fertigation"** submitted by **Mr. Ranjith Kumar, T. M. PALB 3172** for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY** to the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University, under my guidance and supervision. This thesis has not previously formed the basis for award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
JUNE, 2015

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June, 2015 ***(Ranjith Kumar, T. M.)***

STANDARDISATION OF PLANTING GEOMETRY IN AEROBIC RICE (*Oryza Sativa* L.) UNDER DIFFERENT LEVELS OF DRIP FERTIGATION

RANJITH KUMAR, T. M.

ABSTRACT

Studies on **Standardisation of planting geometry in aerobic rice (*Oryza sativa L.*) under different levels of drip fertigation** was conducted during *Kharif* 2014 at ZARS, UAS, GKVK, Bengaluru. Experiment laid out in a factorial randomized complete block design with 13 treatments which were replicated thrice. The treatments constitutes 50 per cent of RDF (F_1), 75 per cent of RDF (F_2) and 100 per cent of RDF through Drip fertigation (F_3) with four planting geometry 25 cm x 10 cm, 25 cm x 15 cm, 25 cm x 20 cm and 25 cm x 25 cm, with a control i.e., planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF. The results revealed that, 100 per cent RDF through drip fertigation has recorded significantly higher productive tillers (601.73 m^{-2}), grain (6115 kg ha^{-1}) straw yield (8792 kg ha^{-1}) and (kg ha-cm^{-1}). Planting geometry of 25 cm x 15 cm recorded significantly higher productive tillers (516.61 m^{-2}), grain (5954 kg ha^{-1}) straw yield (8297 kg ha^{-1}) and WUE (80.66 kg ha-cm^{-1}). Interaction of planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation has recorded significantly higher productive tillers (719.47 m^{-2}), grain (6762 kg ha^{-1}), straw yield (9186 kg ha^{-1}) and WUE (91.59 kg ha-cm^{-1}). Planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation recorded higher gross, net returns and B: C ratio (₹ 121977, ₹ 75814 ha^{-1} and 2.64, respectively).

June, 2015

Department of Agronomy
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(N. Krishnamurthy)
Signature of the Chairperson

ಹನಿ ರಸಾವರಿ ಪದ್ಧತಿಯಲ್ಲಿ ಎರೋಬಿಕ್ ಭತ್ತದ ವಿವಿಧ ಅಂತರ ಮತ್ತು ರಸಗೊಬ್ಬರ ಪ್ರಮಾಣದ ನಿರ್ಧಿಷ್ಟತೆಯ ಪರೀಕ್ಷೆ

ರಂಜಿತ್ ಕುಮಾರ, ಟಿ. ಎಂ.

ಸಾರಾಂಶ

ಹನಿ ರಸಾವರಿ ಪದ್ಧತಿಯಲ್ಲಿ ಎರೋಬಿಕ್ ಭತ್ತದ ವಿವಿಧ ಅಂತರ ಮತ್ತು ರಸಗೊಬ್ಬರ ಪ್ರಮಾಣದ ನಿರ್ಧಿಷ್ಟತೆಯ ಅಧ್ಯಯಿಸಲು ಕ್ಷೇತ್ರ ಪ್ರಯೊಗವನ್ನು 2014 ರ ಮುಂಗಾರಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಸಂಶೋಧನಾ ತಾಕು ಮರಳು ಮಿಶ್ರಿತ ಮಣ್ಣಿನಿಂದ ಕೂಡಿದ್ದು, ಮಣ್ಣಿನ ರಸಸಾರ (7.10), ಸಾವಯವ ಇಂಗಾಲ (0.63 ಪ್ರತಿಶತ), ಲಭ್ಯ ಸಾರಜನಕ, ರಂಜಕ ಮತ್ತು ಪೋಟ್ಯಾಷ ಮಧ್ಯಮ ಪ್ರಮಾಣದಲ್ಲಿದೆ. ಈ ಕ್ಷೇತ್ರ ಪ್ರಯೊಗದಲ್ಲಿ ಒಟ್ಟು 13 ಉಪಚಾರ ಸಂಯೋಜನೆಗಳನ್ನು ಮೂರು ಬಾರಿ ಪುನರಾವರ್ತನೆಗೊಂಡ ಅಪವರ್ತನೀಯ ಯಾದೃಚ್ಚಿಕ ಪೂರ್ಣಬ್ಲಾಕ್ ವಿನ್ಯಾಸ (ಆರ್‌ಸಿಬಿಡಿ) ದಲ್ಲಿ ಮಾಡಲಾಯಿತು. ಈ ಸಂಶೋಧನಾ ಪ್ರಯೊಗದಲ್ಲಿ ಮೂರು ರಸಗೊಬ್ಬರಗಳ ಪ್ರತಿಶತ ಶಿಫಾರಸ್ಸಿನ ಪ್ರಮಾಣ (50, 75 ಮತ್ತು 100 ಪ್ರತಿಶತ ಶಿಫಾರಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ) ಮತ್ತು 4 ವಿವಿಧ ಅಂತರದಲ್ಲಿ ಭತ್ತದ ನೇರ ಬಿತ್ತನೆ (25 ಸೆಂ. ಮೀ. x 10 ಸೆಂ. ಮೀ., 25 ಸೆಂ. ಮೀ. x 15 ಸೆಂ. ಮೀ., 20 ಸೆಂ. ಮೀ. x 20 ಸೆಂ. ಮೀ., ಮತ್ತು 25 ಸೆಂ. ಮೀ. x 25 ಸೆಂ. ಮೀ.) ಮತ್ತು 1 ನಿಯಂತ್ರಣದ ಉಪಚಾರಗಳನ್ನು ಹೊಂದಿದೆ. ಸಂಶೋಧನಾ ಫಲಿತಾಂಶದಿಂದ ತಿಳಿದು ಬಂದ ಅಂಶವೇನಂದರೆ, ಹನಿ ನೀರಾವರಿ ಪದ್ಧತಿಯ ಮೂಲಕ 100 ಪ್ರತಿಶತ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರಗಳನ್ನು ಒದಗಿಸುವುದರಿಂದ ಗಮನಾರ್ಹವಾದ ತೆಂಡೆಗಳ ಸಂಖ್ಯೆ (601.73 ಮೀ$^{-2}$), ಧಾನ್ಯ (8792 ಪ್ರತಿ ಹೆ. 6115 ಕಿ. ಗ್ರಾಂ. ಹೆ$^{-1}$), ಹುಲ್ಲಿನ ಇಳುವರಿ (8792 ಕಿ. ಗ್ರಾಂ, ಹೆ$^{-1}$) ಕಂಡುಬಂದಿರುತ್ತದೆ. ಬಿತ್ತನೆಯ ಅಂತರ (25 ಸೆಂ. ಮೀ. x 15 ಸೆಂ. ಮೀ.) ಮಾಡುವುದರಿಂದ ಹೆಚ್ಚಿನ ಉತ್ಪಾದಕ ತಂಡೆಗಳ ಸಂಖ್ಯೆ (516.61 ಮೀ$^{-2}$), ಧಾನ್ಯ (5954 ಕಿ. ಗ್ರಾಂ.) ಮತ್ತು ಹುಲ್ಲಿನ ಇಳುವರಿ (8297 ಕಿ. ಗ್ರಾಂ. ಹೆ$^{-1}$) ದಾಖಲಾಗಿರುತ್ತದೆ. ಬಿತ್ತನೆಯ ಅಂತರ 25 ಸೆಂ. ಮೀ. x 15 ಸೆಂ. ಮೀ. + 100 ಪ್ರತಿಶತ ಶಿಫಾರಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರವನ್ನು ಹನಿ ನೀರಾವರಿ ಮೂಲಕ ಉಪಚರಿಸಿದ ತಾಕುಗಳಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ಉತ್ಪಾದಕ ತಂಡೆಗಳ ಸಂಖ್ಯೆ (719.47 ಮೀ$^{-2}$), ಧಾನ್ಯ (6762 ಕಿ. ಗ್ರಾಂ. ಹೆ$^{-1}$) ಮತ್ತು ಹುಲ್ಲಿನ ಇಳುವರಿಯು (9186 ಕಿ. ಗ್ರಾಂ. ಹೆ$^{-1}$) ಕಂಡುಬಂದಿರುತ್ತದೆ ಮತ್ತು ಅತ್ಯಧಿಕ ಒಟ್ಟು ಆದಾಯವು (₹ 121977 ಹೆ$^{-1}$) ನಿವ್ವಳ ಆದಾಯ (₹ 75814 ಹೆ$^{-1}$) ಹಾಗೂ ಲಾಭ ವೆಚ್ಚ ಅನುಪಾತವು (2.64) ಇದೇ ಉಪಚಾರದಲ್ಲಿ ದಾಖಲಾಗಿರುತ್ತದೆ.

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ಬೇಸಾಯಶಾಸ್ತ್ರ ವಿಭಾಗ
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(ಕೃಷ್ಣಮೂರ್ತಿ, ಎನ್.)
ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

"Influence of Planting Geometry on Growth and Yield of Aerobic Rice (*Oryza Sativa L.*) Under Drip Fertigation"

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Introduction :

- ✓ Rice (*Oryza sativa* L.) is the most important staple food crop in Asia and it occupies the prime place among the food crops after wheat.
- ✓ Irrigated rice has very low water use efficiency as it consumes 3000-5000 litres of water to produce 1 kg of rice .
- ✓ Aerobic rice is a new development in water saving technology where rice is grown like other upland cereals with supplement irrigation.
- ✓ Drip irrigation systems is highly efficient for water application and best suited for fertigation.
- ✓ At present, information on the suitability of fertigation levels and planting geometry in drip irrigated aerobic rice cultivation is meagre.
- ✓ Hence, finding out the optimum plant population per unit area under different levels of drip fertigation is of major importance.

Objective:

- To study the effect of planting geometry on growth and yield of aerobic rice under drip fertigation.

Material and methods:

Crop : Rice.

Location : ZARS, GKVK, Bangalore.

Season: *Kharif* 2014.

Plot size:

Gross plot: 4.5 m X 6.0 m = 27.0 m^2

Net plot: 3.5 m X 3.0 m = 10.50 m^2

Design: Factorial RCBD

No. of Treatments: 13

No. of Replications: 3

Variety : BI-33 (Anagha)

Fertilizer dose: 100:50:50 kg NPK ha^{-1}

FYM: 10 t ha^{-1}

Treatment details:

Factor -F: Fertilizer levels through drip fertigation

F_1: 50 % of RDF through Drip fertigation

F_2: 75 % of RDF through Drip fertigation

F_3:100 % of RDF through Drip fertigation

Factor-S: Planting geometry

S_1: 25 cm x 10 cm

S_2: 25 cm x 15 cm

S_3: 25 cm x 20 cm

S_4: 25cm x 25 cm

Control- 25 cm x 25 cm spacing with surface irrigation and soil application of RDF.

* RDF- Recommended dose of fertilizers.

Results:

Table 1: Growth and yield of drip fertigated aerobic rice as influenced by planting geometry and fertilizer levels.

Treatment	TDM m^{-2} (g)	Tillers m^{-2} (no's)	Productive tillers m^{-2} (no's)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Fertilizer level					
F_1	1660.81	404.67	330.55	4823	6927
F_2	2206.54	510.38	424.69	5538	7810
F_3	3159.08	731.96	601.73	6155	8792
S.Em±	135.02	17.66	12.45	226	242
CD at 5%	394.12	51.55	36.35	660	708
Planting geometry					
S_1	2316.85	552.71	447.7	5416	7750
S_2	2663.69	597.58	516.61	5954	8297
S_3	2356.47	547.57	450.84	5482	7863
S_4	2031.56	498.15	394.13	5167	7463
S.Em±	155.91	20.39	14.38	261	280
CD at 5%	455.09	59.53	41.97	762	817
Treatment combination					
F_1S_1	1415.14	380.8	283.84	4486	6474
F_1S_2	1943.88	418.67	377.67	5349	7369
F_1S_3	1752.02	417.07	342.93	4966	7268
F_1S_4	1532.18	402.13	317.76	4489	6596
F_2S_1	2168.27	506.67	432.6	5656	7861
F_2S_2	2558.87	579.41	452.69	5753	8336
F_2S_3	2122.24	492.32	411.73	5487	7651
F_2S_4	1976.78	463.13	401.73	5254	7394
F_3S_1	3367.14	770.67	626.67	6105	8914
F_3S_2	3488.32	794.67	719.47	6762	9186
F_3S_3	3195.16	733.33	597.87	5994	8671
F_3S_4	2585.71	629.18	462.91	5759	8398
Control	1265.7	324.27	248.8	4028	6356
S.Em±	270.04	35.32	24.91	452	485
CD at 5%	788.24	103.1	72.7	1321	1416

Note: F: Fertilizer levels,F_1: 50 % RDF, F_2: 75 % RDF, F_3:100 % RDF
S: Spacing S_1: 25 cm x 10 cm S_2: 25 cm x 15 cm , S_3: 25 cm x 20 cm, S_4: 25 cm x 25 cm. TDM-total dry matter.

- ➢ Higher growth parameters *viz.* number of tillers (794.67 m^{-2}) and dry matter (3488 g m^{-2}) were recorded with a spacing of 25 cm x 15 cm and 100 % RDF through drip fertigation, and which was on par with spacing of 25 cm x 10 cm and 100 % RDF through drip fertigation (770.67 m^{-2} and 3367.14 g m^{-2}, respectively).
- ➢ Significantly higher number of productive tillers (719.47 m^{-2}), grain yield (6762 kg ha^{-1}) and straw yield (9186 kg ha^{-1}) was observed with a spacing of 25 cm x 15 cm with 100 % RDF through drip fertigation, and which was on par with spacing of 25 cm x 10 cm with 100 % RDF through drip fertigation (626.67, 6105 kg ha^{-1}, 8914 kg ha^{-1}, respectively).

Dry sowing of aerobic rice

Over view of experiment

25 cm x 15 cm spacing.

25 cm x 25 cm spacing

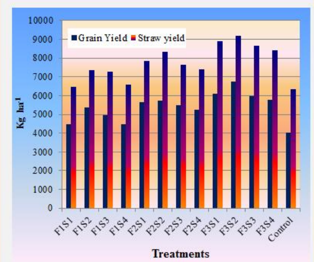

Figure 1: Grain yield and straw yield as influenced by spacing and fertilizer levels under drip fertigation.

Discussion :

- ✓ Superiority in growth parameters of aerobic rice under higher population and drip fertigation with 100% RDF was attributed to higher number of tillers which lead to higher photosynthates and contributed to higher dry matter production (Ray *et al.*, 2000)
- ✓ Dry matter production in drip fertigation was mainly due to continuous supply of nutrients besides maintaining optimum water availability which lead to higher uptake of nutrients.
- ✓ Higher grain and straw yield in 100% RDF through fertigation with more population is attributed to more number of productive tillers m^{-2} and higher dry matter due to more nutrient uptake under drip fertigation. (Vanitha and Dass, 2014).

Summary :

Growth and yield parameters of aerobic rice under drip fertigation varied significantly due to different planting geometry and fertilizer levels. Planting geometry of 25 cm x15 cm with 100% RDF recorded significantly higher growth parameters *viz* total dry matter accumulation (3488 g m^{-2}), number of tillers (794.67 m^{-2}) and yield parameters ,productive tillers (719.47 m^{-2}), grain yield and straw yield (6762 kg ha^{-1}, 9186 kg ha^{-1}).

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Dr. S. T. Bhairappanavar.
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I INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food crop in Asia and it occupies the enviable prime place among the food crops after wheat. Human consumption accounts 85 per cent of total production of rice and it deserves a special status among cereals as world's most important wetland crop. This global grain provides 20 per cent of world's dietary energy supply, while wheat and maize supplies 19 and 5 per cent, respectively (Anon., 2010). Considering these facts "International year of rice-2004 AD" had the slogan of "Rice is life".

More than 90 per cent of the world's rice is produced and consumed in Asia, where 60 per cent of the earth's population lives. In the world, rice occupies an area of 147 million hectare with a production of 525 million tonnes. In India, it is grown in an area of 46.19 million hectare with a production of 106.29 million tonnes and productivity of 2462 kg ha^{-1}. In Karnataka, rice is grown in an area of 1.34 million hectares with an annual production of 3.95 million tonnes with productivity of 3098 kg ha^{-1} (Anon., 2014).

The shrinking water resources and competition from other sectors, the share of water allocated to irrigation is likely to decrease by 10 to 15 per cent in the next two decades. One of the ways of alleviating water scarcity is by enhancing its use efficiency. Water is precious and one has to treat it as costly commodity as our agriculture and many industries depends largely on it.

According to National Commission on Agriculture, the utilization of water for purposes other than irrigation is expected to raise to 27 per cent of available fresh water and only 71 per cent of fresh water will be available for irrigation (Anon., 1976). Therefore, sources of water are to be used efficiently (Yadav, 2002). Limited supply of water necessitates a shift in the production from attainment of potential yield per unit of land to potential yield per unit of water. Vagaries of monsoon and declining water table due to over exploitation have resulted in shortage of fresh water supplies for agricultural use, which calls for an efficient use of this resource.

Rice consumes around 4000-5000 litres of water to produce one kg grain, which is three times higher than other cereals (Anon., 2014). Rice is a semi- aquatic plant and the farmers are habituated to irrigate as much water as possible through continuous land submergence based on a wrong notion that yield could be increased with increased water use. Traditional rice production system not only leads to wastage of water but also causes environmental problems and reduces fertilizer use efficiency. Attempts to increase water productivity either by reducing water consumption or by increasing the yields will automatically facilitate higher growth in agricultural production, as substantial quantity of saved water could be used to irrigate other areas (Papadopoulos, 1997). Further, anaerobic condition favours the release of greenhouse gasses specially methane, contributing to climate change.

The fact that rice is the only cereal which can grow in deep water does not necessarily mean rice plants must be grown only in ponded water. Now we are under pressure to develop water saving technologies in rice. Saturated soil culture, intermittent irrigation, alternate wetting and drying and aerobic rice are irrigation related technologies which save water in rice. Rice does develop well in water, but recent developments demonstrate that rice can also be grown in dry soils under non flooded conditions called "Aerobic rice".

The "aerobic" plant for tropical Asia is expected to yield 6 to 7 t ha^{-1} under a rice crop management system that will provide only half as much water as requires today (Cantrell and Hettel, 2004). Aerobic rice is broadly defined as "a production system in which, direct seeding of high yielding and input responsive rice cultivars with aerobic adaptation grown in non-puddle, non-flooded and non-saturated soil during the entire growing cycle". It is a new concept of reducing water requirement of rice in which rice is grown like an upland crop with high inputs and supplementary irrigations, when rainfall is insufficient. The total water requirement from sowing to harvest is estimated to 650 to 830 mm under aerobic condition and 1350 mm under flooded condition. And water productivity will be increased from 20 to 40 per cent (Castaneda *et al.*, 2005). Further, water use in aerobic rice is about 60 per cent less than that of low land rice and water productivity being 1.6 to 1.9 times higher. Methane emission is reducing under aerobic system and 80-85 per cent thus keeping the environment safe. Savings are also from land preparation, transplanting costs and labour costs (Anon., 2007) and in turn reducing the total cost of production.

Drip irrigation, also known as trickle irrigation is an irrigation method that applies water slowly to the root zone of plants, through a network of valves, pipes, tubes and emitters. The goal is to optimize water and input usage. Adoption of micro irrigation might help in increasing the irrigated area, productivity of crops, water use efficiency and also achieve more weed control efficiency (83 %) by making non-availability of irrigation water to the weeds (Sivanappan, 2004).

Fertigation is the judicious application of fertilizers through irrigation water, to increase efficient use of water and fertilizers, increase yield, protect environment and sustain irrigated agriculture. Drip and other micro-irrigation systems, which are highly efficient for water application, are ideally-suited for fertigation. Water-soluble fertilizers (WSF) at concentrations required by crops are conveyed *via* the irrigation stream to the wetted volume of soil. Thus the distribution of nutrients in the irrigation water will likely place these nutrients in the desired root zone (Clark *et al*., 1991). In a drip-fertigation system uptake of N, P and K are substantially improved. In this respect per unit of fertilizer and water applied, higher yield and better quality are obtained (Papadopoulos *et al*., 2000).

At present, rice information on the suitability of fertigation levels and planting geometry in aerobic cultivation is meagre. Plant geometry in rice has a direct role on the grain yield, since it is an important yield parameter maintaining inadequate or excess plant population often leads to reduction in yield (Lal *et al*., 1982). So finding out the optimum plant population per unit area under different levels of drip fertigation is of major importance. The present investigation entitled "Standardisation of planting geometry in aerobic rice (*Oryza sativa* L.) under different levels of drip fertigation" was carried out during *Kharif* 2014 at Zonal Agriculture Research Station, University of Agricultural Sciences, Gandhi Krushi Vignana Kendra, Bengaluru with the following objectives:

- To study the effect of planting geometry on growth and yield of aerobic rice under drip fertigation.
- To study the different levels of drip fertigation on growth and yield of aerobic rice.
- To study the soil fertility status and economics of aerobic rice under drip fertigation.

II REVIEW OF LITERATURE

Review of literature pertaining to “Standardisation of planting geometry in aerobic rice (*Oryza sativa L.*) under different levels of drip fertigation” has been presented in this chapter with the following headings.

2.1 Effect of aerobic method of rice cultivation on growth and yield.

2.2 Effect of planting geometry on growth and yield of aerobic rice.

2.3 Effect of drip fertigation.

2.4 Effect of drip fertigation on growth and yield of crops.

2.5 Effect of drip fertigation on soil fertility status.

2.6 Effect of drip fertigation on economics.

2.1 Effect of aerobic method of rice cultivation on growth and yield

Balasubramanian and Krishnarajan (2000) revealed that yields obtained under aerobic rice, the aerobic rice varieties varied from 4.5 to 6.5 t ha^{-1} which is about double of that obtained with traditional upland rain fed varieties and 20-30 per cent lesser than that obtained with lowland varieties grown under flooded conditions.

Bouman *et al.* (2002) reported that aerobic rice is a new concept of growing rice it is high-yielding rice grown in non-puddled, aerobic soils under irrigation and high external inputs. Highest recorded aerobic rice yields were 4.7-6.6 t ha^{-1}. Water inputs in aerobic rice were low only 470 mm-650 mm ha^{-1} with higher water productivity of 64 per cent - 88 per cent higher and lower labour use of 55 per cent .

Ambracio *et al.* (2004) revealed that aerobic rice saved 73 per cent of irrigation water for land preparation and 56 per cent during the crop growth stage. Moreover it could effectively use rainfall during the dry season. The aerobic rice yields were lower by an average of 28 per cent in the dry season and 20 per cent lower in wet season at IRRI, Philippines.

Belder *et al.* (2005) reported that in aerobic rice systems the most promising approach of water saving is in the crop which is established with direct seeding in unpuddled non-flooded fields and managed as an upland crop. In favourable environments grain yield of aerobic rice was 3.89 t ha^{-1} with higher water use efficiency compared to normal method of planting. The alternate wetting and drying resulted in significantly higher grain yield of 5.5 t ha^{-1} with more number of productive tillers i.e. 40 tillers $hill^{-1}$.

In aerobic method of rice cultivation in terms of water saving, wet seeding and transplanted rice, about 92, 42 and 40.6 per cent of water (including rainfall) was used for evapotranspiration or consumptive purpose while remaining 8.0, 58.0 and 59.4 per cent of water left the root zone as seepage and deep percolation flows, respectively. Because of its low water use with reasonable higher yield, aerobic rice has greater scope in areas where water availability is limited (Subramanian *et al.*, 2007).

Rajakumar *et al.* (2009) reported that in achieving higher rice grain yields under irrigated aerobic conditions requires better weed, fertilizer management practices and effective utilization of resources that reduce the cost of cultivation.

Yoichiro *et al*. (2009) studied that Aerobic rice can greatly reduce the water input compared to that of flooded rice cultivation. In aerobic fields, the total amount of water supplied (irrigation plus rainfall) was 800-1300 mm. The average yield under aerobic conditions was similar to or even higher than that achieved with flooded conditions. The average water productivity under aerobic conditions was 0.8– 1.0 kg grain m^{-3} water. The super-high-yielding cultivar Takanari achieved yields greater than 10 t ha^{-1} with no yield penalty under aerobic conditions, high-productivity rice cultivation in aerobic soil is a promising technology for water conservation.

Sridhara *et al.* (2011) revealed that the variety BI-43 has recorded higher grain yield (5.8 t ha^{-1}) compared to other varities like Rasi and BI-27 under aerobic condition.

Gandhi *et al.* (2012) revealed that aerobic rice can be successfully raised with half of the water required as against puddled-transplanted rice in summer and entirely on rainfall in wet season with good rainfall distribution. In aerobic rice 45 to 55 per cent water can be saved in summer season and even higher in *Kharif* season as compared to continuous submerged crop.

Parthasarathi *et al.* (2012) reported that aerobic rice cultivation saved 73 per cent of irrigation water for land preparation and 56 per cent during the crop growth period. Aerobic rice with micro irrigation practices leads sustainable rice production methodology for immediate future to address water scarcity with more benefits and environmental safety in the scenario of global warming by reduced methane emission is an added advantage.

2.2 Effect of planting geometry on growth and yield of aerobic rice

Kanade and Katra (1986) reported that Mashuri variety of rice under transplanting at spacing of 20 cm x 15 cm, 20 cm x 20 cm and 20 cm x 25 cm gave two year average paddy yield of 4760, 4340 and 4120 kg ha^{-1}, respectively which were on par with each other.

Rafiq *et al.* (1998) studied the performance of Basmati 385 at different spacing of 30 cm x 25 cm, 30 cm x 20 cm, 30 cm x 10 cm and 20 cm x 20 cm. The spacing of 20 cm x 20 cm produced higher grain yield (4.88 t ha^{-1}) as compared to other spacing.

Lourduraj (1999) observed that for low tillering rice cultivars, yield declined as spacing increased from15 cm x 15 cm to 25 cm x 25 cm whereas in high tillering cultivars reverse trend was noticed.

Siddiqui *et al.* (1999) revealed that closer (10 cm x 10 cm) recorded significantly higher number of effective tillers (18.45) and grain yield (4.02 t ha^{-1}) over wider spacing (20 cm x 20 cm).

Patel (2000) found that spacing of 20 cm x 10 cm recorded significantly higher grain and straw yields, whereas grain yield was reduced by 8.5 and 20.8 per cent and the straw yield by 9.0 and 21.9 per cent due to adoption of wider spacing of 20 cm x 15 cm and 20 cm x 20 cm. he further reported that the grain yield was significantly higher by 11.9 and 28.18 per cent with 30 days old seedlings than 40 and 50 days old seedlings.

Closer spacing (25 cm x 15 cm) recorded the highest growth attributing characters like leaf area index (6.12), leaf area duration (182.3 days) dry matter accumulation (108.6 g $hill^{-1}$) and crop growth rate (40.2 g m^{-2} day^{-1}). The higher grain yield (4.8 t ha^{-1}) was recorded in closer spacing (25 cm x 15 cm) while better quality was found with wider spacing of 25 cm x 25 cm (Ray *et al*., 2000).

The Rice hybrids like TNRH-10, TNRH-13, and TNRH-18 are grown at a spacing of 20 cm x10 cm or 15 cm with 1, 2 or 3 seedlings $hill^{-1}$ under low-land conditions. The hybrid TNRH-10 gave the highest grain yield (4.32 t ha^{-1}) and harvest index (0.45) (Shrirame *et al.*, 2000).

Singh *et al.* (2001) reported that a closer spacing of 15 cm gave 3.5 per cent more grain yield of rice than the 20 cm row spacing.

Baloch *et al.* (2002) studied to assess the three rice mutant strains of Basmati 370-32, Jajai 77-30 and Sonahri Sugdasi-6 along with their respective mother varieties Basmati 370, Jajai 77, Sonahri Sugdasi and check variety Basmati 385 were evaluated under different plant population (spacings, 20 cm x 20 cm, 22.5 cm x 22.5 cm and 25 cm x 25 cm between plant and rows) for grain yield and yield contributing parameters. As a result, an increase in spacing induced vigorous plant growth, increased the number of panicles $hill^{-1}$ (18 $hill^{-1}$), grain yield per hill (30.12 g $hill^{-1}$), filled grains per panicle (152.3) and 1000 grain weight (21.9 g) and the spacing 22.5 cm x 22.5 cm proved more appropriate because it produced better plant stand, gave more panicle density and higher grain yield (4.92 t ha^{-1}) than other two spacing.

Kewat *et al.* (2002) revealed that transplanting of seedlings at a closer spacing of 20 cm x 10 cm produced significantly higher grain (63 q ha^{-1}) yield than wider spacing of 20 cm x 20 cm and 20 cm x 15 cm but was comparable to 15 cm x 15 cm spacing.

Khan *et al.* (2002) reported that the highest grain yield of rice (7.2 t ha^{-1}) in the spacing of 25 cm x 25 cm (with 160000 plants ha^{-1}), which was statistically different from the 20 cm x 20 cm spacing (with 250000 plants ha^{-1}) producing a yields of 7.1 t ha^{-1}. The lowest yield (5.6 t ha^{-1}) was obtained from the 15 cm x 15 cm spacing.

Makarim *et al.* (2002) a study conducted at West Java of Indonesia revealed that wider spacing (25 cm x 25 cm) registered significantly higher grain yield of 46.80 q ha^{-1} compared to closer spacing of 25 cm x 12.5 cm (42.80 q ha^{-1}). Similarly at East Java, wider spacing of 25 cm x 25 cm recorded significantly higher grain yield (74.10 q ha^{-1}) compared to 20 cm x 20 cm spacing (70.70 q ha^{-1}) and 15 cm x 15 cm spacing (62.80 q ha^{-1}).

Sarker *et al.* (2002) reported from SRI practice which was with 30 cm x 30 cm spacing the higher number of seeds panicle^{-1} (131.4) was obtained out of 178.45 spikelet's panicle^{-1} as compared to 20 cm x 15 cm (126.63) was obtained out of 148.70 spikelet's panicle$^{-1.}$

Verma *et al.* (2002) reported that seedlings planted at 20 cm x 20 cm and 20 cm x 15 cm spacing produced higher number of productive tillers (18.21), grain yield (4.23 t ha^{-1}) and harvest index (0.46) than seedlings planted at 20 cm x 10 cm. Closer spacing (20 cm x 20 cm) gave higher sterility percentage (22.31 %) than wider spacing.

Guilani *et al.* (2003) reported that among different spacing's (15 cm x15 cm, 30 cm x 30 cm and 45 cm x 45 cm), the highest crop yield (7.741 t ha^{-1}) was obtained in 15cm x 15cm crop density. The amounts of biomass produced in 15 cm x15 cm and 45cm x 45cm crop density were 14.97 t ha^{-1} and 10.79 t ha^{-1}.

Hu-Wenhe *et al.* (2006) studied the grain yield of rice at different spacing's like 30 cm x 10 cm, 30 cm x 17 cm and 30 cm x 27 cm and reported that higher number of tillers was with lower plant densities and grain yields were 8.3 t ha^{-1} (30 cm x 10 cm), 9.4 t ha^{-1} (30 cm x 17 cm) and decreased with decreasing plant densities to 8.56 t ha^{-1} (30 cm x 27 cm).

Subramanian *et al*. (2007) the study of plant population in aerobic rice revealed that 100 hills m^{-2} (20 cm x 5 cm) was comparable with 50 hills m^{-2} (20 cm x 10 cm) in terms of grain yield. The plant spacing of 20 cm x 5 cm (100 hills m^{-2}) registered the highest grain yield of 3099 kg ha^{-1}. However, this was comparable with a plant spacing of 20 cm x10 cm which recorded a grain yield of 2834 kg ha^{-1}.

Srivastava and Tripathi (2008) studied rice hybrid 6201 and R 320-300 grown at 20 cm x 15 cm, 15 cm x 10 cm spacing at 1, 2, 3 seedlings hill^{-1}. They observed that R-320-300 grown at 15 cm x 10 cm spacing at 2 seedlings hill^{-1} produced the higher grain yield of 7.59 t ha^{-1}.

Krishna and Biradarpatil (2009) results reveal that wider spacing was found to have significant influence on growth and quality parameters. The wider spacing of 40 cm x 40 cm recorded higher seed yield per ha (3.25 t ha^{-1}).

Lampayan *et al*. (2010) reported that in aerobic rice yields were similar for row spacing's ranging from 25 cm to 35 cm. Although the number of panicles per square meter was significantly higher at 25-cm spacing than at 35-cm spacing, this difference was compensated for by significantly more spikelets per panicle at 35-cm spacing, while spikelet fertility and grain weight were similar for all row spacing's. Lodging and bending resistance of stems were not affected by row spacing.

The narrow row spacing of 20 cm will reduces *Echinocloa colona* and *Echinocloa crusgalli* emergence and yield loss in aerobic rice (Bhagirath *et al.,* 2010).

Parashiva *et al.* (2011) revealed that rice grown with a spacing of 30 cm × 40 cm recorded significantly the highest plant height (90.9 cm), number of tillers per hill (26.5), panicle length (19.6 cm), number of seeds per panicle (200.4), hundred seed weight (2.2 g) as compared to other spacing's . Whereas, rice was grown with a spacing of 30 cm x 15 cm recorded significantly higher seed yield (47.2 q ha^{-1}) as compared to other studied spacing's.

Shashidhar (2011) revealed that at closer planting geometry of 30 cm x 10 cm has recorded higher plant height (102.86 cm), LAI (6.88) and leaf area duration (155.04 days) but higher number of leaves, leaf area, grain and straw yield was obtained in the wider planting geometry of 45 cm x 20 cm (92.12, 3689 cm^2 $hill^{-1}$, 6.12 t ha^{-1} and 7.01 t ha^{-1}, respectively).

The spacing of 30 cm x 30 cm recorded significantly higher root length (24.4 cm), root volume (60.30cc), root number (154.2) root weight (6.5 g) and dry matter accumulation, number of panicles per plant and test weight as compared to other (45 cm x 45 cm) (Sridhara *et al*., 2011).

Hamid *et al*. (2011) conducted experiment to study plant density on yield and yield components of rice variety Hashemi by a factorial format based on randomized complete block design with 3 replications at a paddy field in North of Iran. Factors of Experiment were consisting of three levels of plant spacing (25 cm x 15 cm, 20 cm x 20 cm and 25 cm x 25 cm). Among the different spacing levels the highest grain yield (3415 kg ha^{-1}), Nitrogen uptake (98 Kg ha^{-1}), phosphorous (19.1 kg ha^{-1}) and potassium (93 kg ha^{-1}) was found from 25 cm x 15 cm treatment with and compare to other spacing levels.

The row spacing of 30 cm observed higher weed biomass and less grain yield compared to 15 cm and 10-20-10 cm paired row spacing these two treatments observed similar weed biomass and yield, the critical period of weed control observed is also more in 30cm row spacing (15-64 DAS) in aerobic rice (Bhagirath *et al*., 2011).

Sultana *et al.* (2012) revealed that the crop sown at 25 cm x 15 cm produced the highest total dry matter (123.56 g $hill^{-1}$) and grain yield of 5.69 t ha^{-1} whereas the lowest grain yield of 2.11 t ha^{-1} was found with 20 cm × 2.5 cm spacing. The present study concludes that the highest grain yield of BRRI dhan 45 during *boro* season under aerobic system of cultivation could be achieved by sowing at 25 cm x 15 cm spacing.

Moammad *et al*. (2013), conducted experiment to investigation on effect of planting density on controlling weeds in a rice cultivars with arrangement of planting 10 cm x 10 cm , 10 cm x 20 cm , 10 cm x 30 cm . As a result, the increasing the planting's density the number of productive hull in bushes and total number of small cluster is decreased but added to the grain yield because the number of cluster in m^2 increased and the number of weed and average weight of weeds decreased by increasing the planting density.

Faisul *et al.* (2013) conducted experiment to investigate the influence of different plant spacing's and seedlings per hill on growth characters, yield attributes and yield of newly released transplanted rice variety Shalimar Rice-1. As a result closer spacing (25 cm x 15 cm) recorded higher plant height, tillers m^{-2}, leaf area index, dry matter accumulation and Significantly higher grain yield of 67.1 q ha^{-1} showing a superiority of 8.97 per cent with 25 × 15 cm was observed over that of 25 cm x 25 cm spacing and closer spacing intercepted maximum photosynthetically active radiation (PAR) than wider spacing.

Umair Ashraf *et al.* (2014) revealed that maximum weed suppression was observed in closest plant spacing (15 cm × 15 cm) in case of weedy treatments 20 and 40 days after transplanting (DAT), while widest plant spacing (20 cm × 20 cm) proved effective regarding yield and yield related attributes. Statistically maximum leaf area index (LAI) of 9.06, crop growth rate (CGR) of 3.96 g m^{-2} d^{-1} and leaf area duration (LAD) of 109.28 days, paddy and biological yield (4.14 t ha^{-1} and 15.42 t ha^{-1}), respectively were recorded in widest spacing of 20 cm x 20 cm.

2.3 Effect of drip fertigation

In Mexico in the early 1960's fertigation practice is started when NH_3 and 08N-24P-00K solutions were first injected into open irrigation channels in North West Mexico for wheat and cotton crops. During the middle 1970's, Mexico was one of the leading countries in drip irrigation and fertigation. However, this practice was restricted during the 1980's due to the malfunctioning of some equipment as a result of improper maintenance. At present, an area exceeding 30,000 ha is cultivated under pressurized irrigation, capable of using fertigation. The most important fertigation crops are tomatoes, bell peppers and other vegetable crops, grapes, oranges and other fruit crops.

Fertigation is relatively new but revolutionary concept in applying fertilizer through irrigation. It helps to achieve both fertilizer use efficiency and water use efficiency. By definition, fertigation is the precise application of fertilizers through irrigation water (Bill Segar, 2003). The use of fertigation in trickle irrigation system was reviewed by Haynes (1985). The advantages of the use of fertigation in a trickle irrigation system included reduced labour, increased fertilizer efficiency and the increased flexibility of fertilizer application. Fertigation allows nutrient placement directly into the plant root zone during critical periods of nutrient demand (Mikkelsen, 1989).

The yield response in pea to fertilizer application was higher with fertigation through drip irrigation than conventional method of application (Malik *et al*., 1994).

Bachchav (1995) conducted a case study on fertigation in India by comparing fertigation with NPK over farmer's fertilizer practice with conventional fertilizers in terms of yield, quality and monetary returns. Fertigation at weekly intervals was found more convenient and economically profitable for the farmers.

Jata *et al.* (2013) reported that for minimizing the cost of irrigation and fertilizers, adoption of irrigation and fertigation through drip is essential which will maximize the nutrient uptake, while using minimum amount of water and fertilizer. Fertigation gives advantages such as higher water and fertilizer use efficiency, minimum losses of N due to leaching, supplying nutrients directly to root zone in available forms, control of nutrient concentration in soil solution and saving in application cost. Thus, fertigation becomes prerogative for increasing the yield of most of the crops under drip irrigation.

2.4 Effect of fertigation on growth and yield of crops

2.4.1 Effect of fertigation on growth attributes of aerobic rice

Parthasarathi *et al.* (2012) reported that Laterals spaced at 0.8 m with 1.0 lph drippers performed better in terms of growth parameters such as plant height, tiller density, root biomass, total dry matter accumulation than the conventional method in aerobic rice.

Parthasarathi *et al*. (2013) revealed that the root character of aerobic rice influenced by drip fertigation with different lateral spacing and discharge revealed that laterals spaced at 0.8 m with 1.0 lph drippers + 30 per cent more water on surface drip through fertigation exhibited better performance in terms of root parameters such as root length, mass density, volume and biomass than conventional method.

Satsangi and Yadav (2013) studies on combined application of BGA with urea through fertigation exhibited better response of aerobic rice in almost all growth parameters as compared to application of either urea or BGA alone.

Vanitha and Dass (2013) conducted an experiment to know the root length density, oxidizing power, lion tail roots and yield of rice under drip fertigation with different IW/CPE ratios, revealed that maximum rooting depth (55.8 m $hill^{-1}$) was strongly influenced by fluctuations in water regimes at the flowering stage. For wetter regimes (150 per cent pan evaporation), roots were concentrated at and above the water table interface and had greater horizontal development, whereas in drier regime (100 per cent pan evaporation) roots were concentrated in lower horizons and had more vertical distribution.

Vanitha and Dass (2014) reported that application of 100 per cent recommended dose of fertilizer (150:50:50 NPK kg ha^{-1}) applied with humic acid through drip fertigation recorded maximum root length (58.8 m hill^{-1}), higher chlorophyll content (2.61 mg g^{-1}), leaf area duration (151 days), more filled grain percentage (69.1) in aerobic rice.

2.4.2 Effect of fertigation on yield and yield attributes of aerobic rice

Anbumozhi *et al*. (1998) reported that fertigation was beneficial upto pounding depth of 9 cm water, beyond which yield reduction was observed. However, at zero submergence, fertigation was not beneficial. High values of water productivity were found at 9 cm pounding water depth under different water regimes and due to higher yield as compared to reduced pounding depths in rice.

Vijaykumar (2009) studied that drip fertigation of 100 per cent recommended dose of phosphorous and potassium (50 per cent P and K as basal, remaining NPK as WSF) at 150 per cent pan evaporation registered more number of productive tillers (645 m^{-2}) and resulted in higher grain yield (6769 kg ha^{-1}) in hybrid rice.

Govindan and Grace (2012) reported that drip irrigation at 150 per cent pan evaporation + drip fertigation of 100 per cent recommended dose of fertilizer + azophosmet + humic acid recorded 19 per cent increased yield as compared to drip irrigation at 125 per cent pan evaporation + 100 per cent recommended dose of fertilizer through drip.

Parthasarathi *et al*. (2012) revealed that laterals spaced at 0.8 m with 1.0 lph drippers exhibited better performance in terms of yield and its components such as productive tillers, spikelet numbers, filled grain percentage, harvest index.

Irrigation equivalent to 150 per cent pan evaporation replenishment in conjunction with 120 kg N ha^{-1} registered significantly higher grain yield over other treatment combinations in aerobic rice (Rao *et al*., 2012)

Sundrapandiyan (2012) reported that drip fertigation of recommended dose of fertilizer with biogation in aerobic rice excelled the soil application treatments by accounting significantly higher yield attributes like panicles m^{-2}, 1000 grain weight, and panicle length and produced highest grain yield of 4440 kg ha^{-1}.

Higher grain yield of rice (7.5 to 9.5 t ha^{-1}) under drip fertigation and was found to be significant over conventional irrigation and fertilizer application (3 t ha^{-1}) as reported by Soman (2012).

Parthasarathi *et al.* (2013) opined that lateral spacing at 0.8 m with 1.0 lph drippers + 30 per cent more water on surface drip through fertigation exhibited better performance in terms of yield and its components.

Vanitha and Dass (2013) reported that grain yield of different irrigation regimes were 3786 kg ha^{-1} (100 per cent PE), 5201 kg ha^{-1} (125 per cent PE) and 5030 kg ha^{-1} (150 per cent PE), while under conventional method it was 4865 kg ha^{-1}.

Vanitha and Dass (2014) revealed that application of 100 per cent recommended dose of fertilizer (150:50:50 NPK kg ha^{-1}) applied with humic acid recorded higher grin yield of 5616 kg ha^{-1} than the conventional method.

2.4.3 Effect of fertigation on growth attributes of other crops

Drip fertigation with 80 per cent recommended dose of fertilizer through water soluble fertilizer recorded higher plant height (97.30 cm), number of primary branches (14.0) over soil application (74 cm, 5.8 kg ha^{-1}, respectively) in chilli crop (Veeranna *et al.*, 2000).

Drip fertigation with 100 per cent water soluble fertilizers recorded higher plant height (63.6 cm), more number of leaves (99.77 leaves $hill^{-1}$) which was more than 100 per cent normal fertilizer through furrow irrigation (53.33 cm and 73.33 leaves $hill^{-1}$) in potato (Amarananjundeswara *et al*., 2002).

Total dry matter production (DMP) and leaf area index (LAI) were significantly higher in drip fertigation (165.8 g $plant^{-1}$ and 3.12, respectively) over furrow irrigation and soil application of fertilizers in tomato (Hebbar *et al*., 2004).

Drip fertigation with 125 per cent recommended dose of NPK ha^{-1} recorded significantly higher plant height of cotton at 30, 60 and 90 DAS than surface irrigation and soil application of 100 per cent recommended dose of fertilizer (Shanmugham *et al*., 2007).

Among different combinations, application of irrigation at 80 per cent evapotranspiration through drip and 80 per cent recommended dose of fertilizer recorded higher plant height (45.95 cm) than conventional method (33.45 cm) in capsicum (Gupta *et al.*, 2009).

Application of 150 per cent of recommended dose of nitrogen (25 kg N ha^{-1}) in groundnut through spent wash fertigation had significantly increased plant height (41.32 cm), number of leaves per plant (28.6) and total dry matter (38 g $plant^{-1}$) than the conventional method (Darmlingaiah, 2011).

Application of 100 per cent recommended dose of fertilizer through normal fertilizer recorded higher plant height (165.25 cm), stem girth (8.85 cm) and dry matter accumulation (70.28 g) over no fertilizer with drip irrigation (129.10 cm, 6.77 cm and 52.85 g, respectively) in tomato (Tiwari *et al.*, 2012).

Drip fertigation of water soluble fertilizer at 100 per cent recommended dose of fertilizer (25:75:37.5 kg NPK ha^{-1}) in ground nut recorded higher plant height (42 cm), number of branches per plant (8.00), leaf area (1411.1 cm^2 $plant^{-1}$) and total dry matter (29.48 g $plant^{-1}$) at maturity than the conventional method (Sanju, 2012).

Application of 100 per cent recommended dose of NPK + 100 per cent irrigation levels recorded highest values in all the growth characters of wheat crop (Abdelraouf *et al.*, 2013).

Drip fertigation with 125 per cent recommended dose of fertilizer through water soluble fertilizer recorded higher plant height (200 cm), number of leaves (11.67 $plant^{-1}$), leaf area (3271 cm^2 $plant^{-1}$), leaf area index (2.73) and total dry matter accumulation (426.26 g $plant^{-1}$) over soil application (174.63 cm, 10.47 $plant^{-1}$, 2386 cm^2 $plant^{-1}$, 1.99 and 334.87 g $plant^{-1}$, respectively) (Richa Khanna, 2013).

2.4.4 Effect of fertigation on yield and yield attributes of other crops

Drip fertigation with 80 per cent recommended dose of fertilizer through water soluble fertilizer recorded higher yield of chilli (1268 kg ha^{-1}) over soil application (875 kg ha^{-1}) at Bangalore (Veeranna *et al*., 2000).

Drip fertigation with 100 per cent water soluble fertilizers recorded higher fresh tuber weight (789.45 g $hill^{-1}$) which was more than 100 per cent normal fertilizer through furrow irrigation (635.89 g $hill^{-1}$) in potato (Amarananjundeswara *et al.*, 2002).

Drip irrigation at 80 per cent pan evaporation along with 50 per cent soil application (basal) and 50 per cent fertigation of recommended dose as the best agronomic options to boost the yield of baby corn in an economical way (Rani, 2006).

Application of 80 per cent recommended dose of nitrogen and potassium through drip fertigation in four splits recorded higher tuber yield (420 q ha^{-1}) and harvest index (66.2) and which was more than conventional furrow irrigation (311q ha^{-1} and 64.5) in potato (Sasani *et al.*, 2006).

Injection pump method had the highest values of all the yield parameter like tallest plants, highest number of spikes m^{-2}, number of spikelet's $spike^{-1}$, heaviest kernel weight and highest values of grain and biological yields than venture method, while control recorded the lowest values for these traits in wheat (Kassem and Al-Suker, 2009).

Scheduling of drip fertigation with 150 per cent of recommended dose of fertilizer applied once in 6 days could be the optimal management practice for getting higher yield in hybrid maize (8,957 kg ha^{-1}) than the conventional method (Sampathkumar and Pandian, 2010).

Maximum grain yield (4891.67 kg ha^{-1}) was obtained from fields provided with fertigation of nitrogen, phosphorus and potassium at the rate of 12.5, 7.87 and 2.62 kg ha^{-1}, respectively at grain development stage followed by 3645.83 kg ha^{-1} grain yield obtained with foliar applied 2 per cent brassica water extract + calcium and boron at

0.125 and 0.0125 kg ha^{1}, respectively at grain development stage in wheat (Jabran *et al.*, 2011).

Higher cob length (22.4 cm), cob girth (14.4 cm), single cob weight (352 g cob^{-1}), number of cobs (1.3 plant^{-1}), marketable green cob yield (11.99 t ha^{-1}) and green fodder yield (26.73 t ha^{-1}) were obtained in drip fertigation with 240 kg N ha^{-1} and it was on par with drip fertigation of 200 and 160 kg N ha^{-1} (Sharana Basava *et al.*, 2012).

Drip fertigation with 100 per cent recommended dose of fertilizer (in which 50 per cent phosphorous and potassium as water soluble fertilizer increased the maize grain yield to the tune of 15.5 per cent as compared to drip fertigation of 100 per cent recommended dose of fertilizer with normal fertilizer (Fanish *et al.*, 2013).

Application of 100:55:120 kg NPK ha^{-1} with 1 kg B, 4 kg Zn and 4 kg Mg through drip irrigation at 2 days interval in tomato recorded higher fruit length (46.18 mm), diameter of fruit (48.37 mm), unit fruit weight (67 g), total yield (38.43 t ha^{-1}) over 100:55:120 kg NPK ha^{-1} through drip irrigation at 3 days interval (Razzaque *et al*., 2012).

2.5 Effect of drip fertigation on soil fertility status.

Gardena *et al*. (2005) reported that micro-irrigation offers a large degree of control, enabling accurate application according to crop water requirements, there by minimize leaching. Furthermore, fertigation allows the controlled placement of nutrients near the plant roots, reducing fertilizer losses through leaching into the groundwater.

Gururaj (2012) revealed that drip irrigation at 1.0 PE up to tillering and 1.5 PE tillering to maturity with soil application of 100 per cent RDF recorded more available nitrogen (342.00 kg ha^{-1}), phosphorous (39.93 kg ha^{-1}) and potassium (262.7 kg ha^{-1}) content of the soil than other levels of treatments in aerobic rice.

Sanju (2012) reported that drip fertigation in groundnut with 100 per cent RDF as WSF recorded higher available nitrogen (278.4 kg ha^{-1}), available phosphorus (65.8 kg ha^{-1}) and available potassium (271.8 kg ha^{-1}) in the soil.

Anitta Fanish and Muthukrishnan (2013) reported that 100 per cent recommended dose of fertilizers as water soluble fertilizers through drip fertigation has increased the soil nutrient status with regard to nitrogen (376.5 kg ha^{-1}), phosphorous (38.2 kg ha^{-1}) and potassium (355.5 kg ha^{-1}) in the surface soil in maize.

Jayakumar *et al.* (2014) reported that drip fertigation with 150 per cent recommended dose of NPK and biofertigation has increased the soil NPK status as compared to 100 per cent recommended dose of NPK applied through drip fertigation in Bt cotton.

Muthu Kumar and Ponnuswami (2014) revealed that the 100per cent WRc through drip irrigation + 100 per cent recommended dose of NPK through inorganic fertilizers showed the highest soil available nitrogen (323.6 kg ha^{-1}), phosphorus (30.45 kg ha^{-1}) and potassium (284.36 kg ha^{-1}) content. The same treatment combination recorded the increased leaf nitrogen, phosphorus and potassium content during vegetative, flowering and harvesting stages of noni (*Morinda citrifolia* L.)

Maximum loss of nitrogen (90.02 to 92.20 and 103.80 to 111.05 kg ha^{-1} in *kharif* and summer, respectively) in 120 per cent recommended dose of nitrogen has compared to the 100 per cent recommended dose of nitrogen was reported in rice (Denesh *et al*., 2006).

The maximum loss of nitrogen in treatment combination of aerobic establishment technique with application of complex 17:17:17 and top dress with urea (29.82 and 49.63 kg ha^{-1} in *Kharif* and summer season, respectively), the loss of phosphorous and potassium varied between 21.71 to 28.24 and 76.71 to 94.79 kg ha^{-1}, respectively among the different treatments (Jayadeva and Prabhakara Shetty, 2010).

2.6 Effect of fertigation on economics

2.6.1 Effect of fertigation on economics of aerobic rice

Vijaykumar (2009) reported that the growth, yield attributes and yield of rice was higher under fertigation of 100 per cent RDF through WSF, net returns and benefit cost ratio were comparatively lower than drip irrigation at 150 per cent PE with drip fertigation of 75 per cent RDF through WSF (₹ 30,860 ha^{-1} and 1.95, respectively) due to higher cost of water soluble fertilizers.

Sundrapandian (2012) revealed that surface drip fertigation of recommended dose of fertilizer with biogation of azophosmet and sea weed extract registered higher gross returns, net returns and benefit cost ratio over surface irrigation with soil application of fertilizer.

2.6.2 Effect of fertigation on economics of wheat

Knowles *et al.* (1996) revealed that maximum *durum* wheat grain yield (2,798 kg $acre^{-1}$), protein content (13.7 per cent), and high income per acre (₹ 25,456) were obtained with the nitrogen fertilizer application. In fact, N fertilization through fertigation at flowering in sandy soil increased *durum* wheat grain yield by 116 kg acre $^{-1}$ as compared to the unfertilized plot.

2.6.3 Effect of fertigation on economics of maize.

Ramah *et al.* (2010) conducted an experiment to know the expenditure incurred from field preparation to harvest was worked out and used for calculating the economics of drip system in maize. The gross income (₹ 3,09,554) was higher in the treatment with 100 per cent WR with 125 per cent RDF whereas, higher benefit cost ratio of 4.07 was recorded by drip irrigation at 100 per cent WR with soil application of RDF. Drip irrigation at 75 per cent WR with 125 per cent RDF recorded higher net profit per mm of water used (₹ 274), which was followed by same irrigation regime with 100 per cent RDF.

Richa Khanna (2013) reported that drip fertigation in maize with 125 per cent recommended dose of fertilizer through normal fertilizer resulted in higher net returns of ₹ 92,734 ha^{-1} and B: C ratio of 3.46 over surface irrigation with soil application of 100 per cent recommended dose of fertilizer through normal fertilizers of ₹ 62,637 ha^{-1} and 2.92, respectively.

2.6.4 Effect of fertigation on economics of other crops

Amarananjundeswara *et al*. (2002) studied that application of 100 per cent normal fertilizer through drip fertigation recorded higher net income of (₹ 36,950 ha^{-1}) and higher benefit cost ratio (2.24) which was more than 100 per cent normal fertilizer through furrow irrigation (₹ 32,583 ha^{-1} and 2.06, respectively) in potato.

Shashidar (2006) reported that higher net returns (₹ 54,450 ha^{-1}) and B:C ratio (3.3:1) was with the 100 per cent recommended dose of normal fertilizer through fertigation over 50 per cent RDF through fertigation (₹ 1,650 ha^{-1} and 2.55, respectively) in chilli.

Prabhakar (2008) revealed that daily sub surface irrigation at 10 cm depth recorded higher gross returns (₹ 5,54,200 ha^{-1}) net return (Rs .4,62,875 ha^{-1}) and B: C ratio (5.07) over surface furrow irrigation with sub surface fertilizer application at 20 cm (₹ 3,40,633 ha^{-1}, ₹ 2,53,308 ha^{-1} and 2.91, respectively) in tomato.

Gupta *et al.* (2009) reported that irrigation at 80 per cent evapotranspiration through drip + 80 per cent recommended dose of fertilizer through fertigation recorded higher net returns (₹ 2,82,026 ha^{-1}) and higher B: C ratio (3:1) over 100 per cent surface irrigation with 100 per cent RDF as soil application (₹ 1,92,000 ha^{-1} and 1.9:1, respectively) in capsicum.

Tahir *et al.* (2009) reported that the highest net returns of sunflower ₹ 59,604 ha^{-1} was obtained with fertigation of nitrogen at the rate of 150 kg ha^{-1} as compared to band placement, with same dosage of nitrogen which recorded net returns of ₹ 48,663 ha^{-1}.

Vijayalakshmi *et al.* (2011) revealed that micro sprinkler irrigation at 100 per cent crop evapotranspiration with fertigation under broad bed and furrow system registered the highest pod yield of 3776 and 3844 kg ha^{-1} in 2002 and 2003, respectively in ground nut.

Patel *et al.*(2012) reported that application of 75 per cent recommended dose of nitrogen and potassium through drip fertigation recorded higher net income of ₹ 39,668 ha^{-1} and higher benefit cost ratio (1.56) which was more than 100 per cent recommended dose of N and K through drip fertigation (₹ 38,971 ha^{-1} and 1.53, respectively) in potato.

Sanju (2012) studied that drip fertigation of water soluble fertilizer at 100 per cent of RDF had recorded higher net returns (₹ 67,970 ha $^{-1}$) and B:C ratio (2.54) in groundnut.

From the above reviews, it can be summarised that cultivation of rice under aerobic condition can save water up to 50 per cent and can increase yield more than 5 tonnes ha^{-1} (30-50 %). The fertigation technique in aerobic rice and other crops can improve the continuous availability of water and nutrient resulting in higher water and nutrient use efficiency. With regard to economics drip fertigation with water soluble fertilizers recorded lower net returns and B:C ratio due to higher cost of water soluble fertilizers, whereas drip fertigation through normal fertilizers recorded higher net returns and B:C ratio.

III MATERIAL AND METHODS

Field experiment on "Standardisation of planting geometry in aerobic rice (*Oryza sativa L*.) under different levels of drip fertigation" was conducted during *Kharif* 2014. The materials used and methodologies adopted during the course of investigation are presented in this chapter.

3.1 Location

The experiment was conducted at Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krushi Vignana Kendra, Bengaluru situated in the Eastern Dry Zone of Karnataka (Zone -5). The experimental site was located between 12º 51' N latitude and 77º 35' E longitude at an altitude of 930 m above mean sea level (MSL).

3.2 Climate

Monthly mean meteorological data was recorded at the observatory, Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krushi Vignana Kendra, Bengaluru for the year 2014. The normal of 38 years (1975-2013) and actual weather parameters for the year 2014 (January 2014 to December 2014) such as total rainfall, temperature (maximum and minimum), sunshine hours, wind speed, relative humidity and pan evaporation are presented in Table 3.1 and Fig.1.

3.2.1 Normal climatic conditions

Gandhi Krishi Vignana Kendra, Bengaluru received an average rainfall of 917.6 mm of which 17.64 per cent (161.9 mm), 54.91 per cent (503.9 mm) and 26.28 per cent (241.2 mm) were received during pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-December) seasons, respectively. The rainfall was bimodal with two peaks, one occur during the month of May (99.5 mm) and the second in September (189.2 mm). The average number of rainy days was about 57 in a year.

December (15.1^0 C) and January (14.1 ^{0}C) the coldest months of the year, while April (34.1 ^{0}C) and May (33.1 ^{0}C) the hottest months. The relative humidity was low (78.2 %) in March and was high from August to September (90 %). The average daily duration of bright sunshine hours was high during February to March (9.3 hours) and low in the month of July and August (4.46 hours). The average daily open pan evaporation reading ranges from 3.84 mm day^{-1} (August) to 6.46 mm day^{-1} (March).

Table 3.1: Monthly meteorological data of normal and actual for the year 2014 at GKVK, Bengaluru

Month	Rainfall (mm)			Temperature (°C)						S.H. (hrs.)			Relative humidity (%)			P.E. day^{-1} (mm)		
				Max			Min											
	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D
January	1.3	0.00	-1.3	27.6	27.6	0	14.1	14.60	0.5	9.05	9.1	0.05	87.9	92	4.1	4.31	4.6	0.29
February	9.3	0.00	-9.3	30.1	29.9	-0.2	15.3	16.30	1	9.43	8.6	-0.83	83.1	87	3.9	5.26	5.5	0.24
March	16.2	10.0	-6.2	33.1	32.2	-0.9	18.2	18.20	0	9.18	8.6	-0.58	78.2	78	-0.2	6.46	6.9	0.44
April	46.2	25.5	-20.7	34.1	34.7	0.6	20.8	21.10	0.3	8.59	8.2	-0.39	80.5	80	-0.5	6.46	6.9	0.44
May	99.5	81.4	-18.1	33.1	33.2	0.1	20.7	21.20	0.5	7.96	8.2	0.24	84.4	86	1.6	5.17	5.9	0.73
June	77.8	92.0	14.2	30.3	30.9	0.6	19.9	20.60	0.7	5.79	7.3	1.51	87.8	88	0.2	5.25	5.2	-0.05
July	102.9	80.8	-22.1	28.4	28.3	-0.1	19.3	19.70	0.4	4.39	4.2	-0.19	90.4	93	2.6	4.44	4.1	-0.34
August	134.0	117.4	-16.6	28.0	28.2	0.2	19.0	19.50	0.5	4.53	3.8	-0.73	90.9	93	2.1	3.84	3.6	-0.24
September	189.2	128.6	-60.6	28.6	28.5	-0.1	19.1	19.40	0.3	5.72	4.5	-1.22	90.3	91	0.7	4.52	3.5	-1.02
October	172.4	428.4	256	28.1	28.1	0	18.5	18.80	0.3	5.86	4.4	-1.46	88.9	94	5.1	4.42	3.3	-1.12
November	56.5	29.4	-27.1	26.9	26.9	0	16.4	16.30	-0.1	6.80	6.8	0	87.4	90	2.6	4.09	3.6	-0.49
December	12.3	1.00	-11.3	26.8	26.6	-0.2	15.1	16.20	1.1	7.61	6.3	-1.31	87.4	90	2.6	4.24	4.0	-0.24
Total	917.60	994.50																

A: Actual for the year 2014 Max: Maximum Min: Minimum R.H: Relative Humidity
N: Normal for previous 37 years (1975-2013) S.H: Sunshine Hours P.E: Pan Evaporation D:Deviation

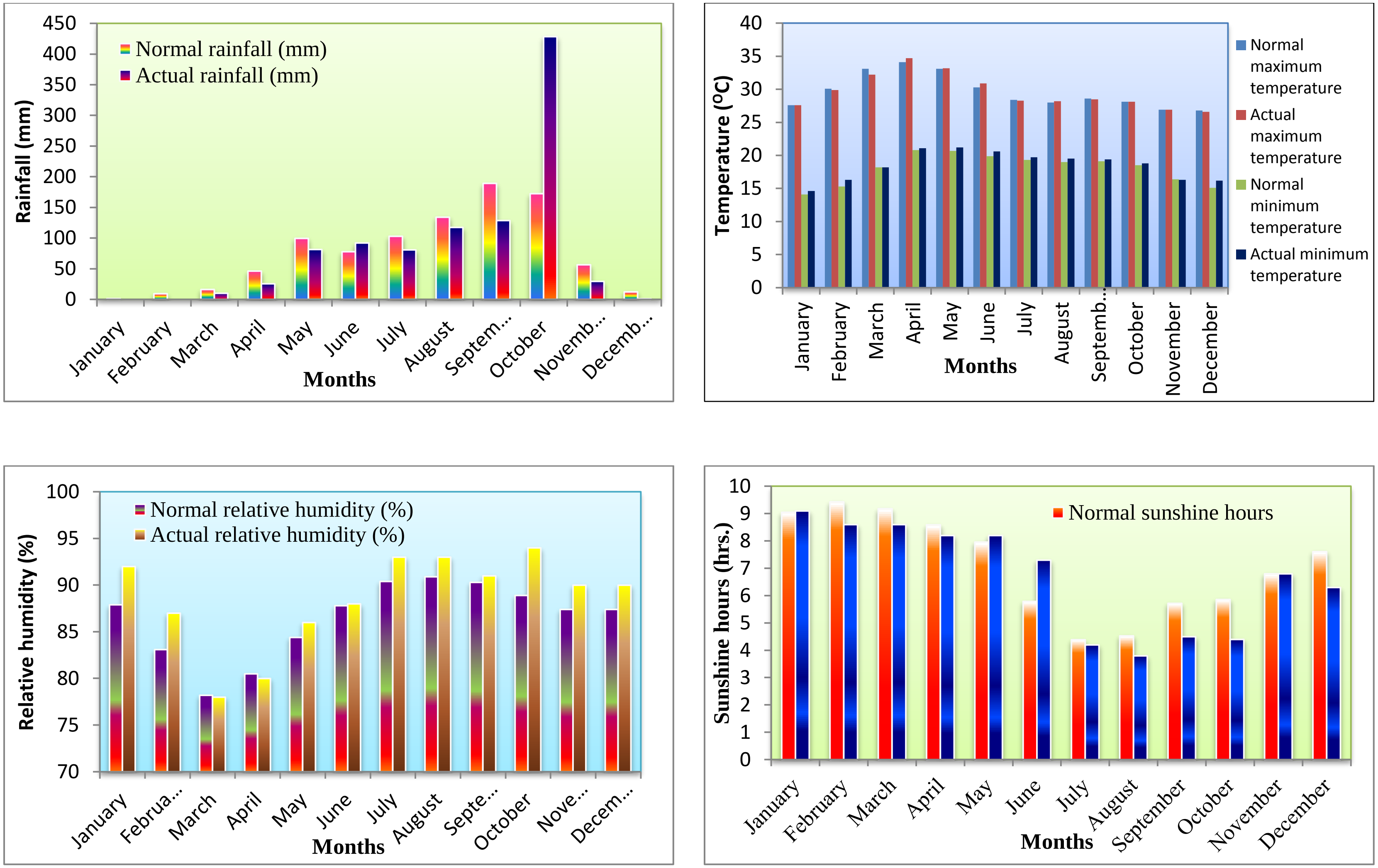

Fig. 1: Monthly meteorological data of normal and actual for the year 2014 at ZARS, UAS, GKVK, Bengaluru

3.2.2 Actual climatic condition during the crop growth period

Actual rainfall during the crop growth period was 704.8 mm, as against 917.6 mm of the normal. The rainfall during the crop growth period was less than the normal in the month of August, September, November and December. The mean maximum temperature during the period of experimentation ranged from 26.6 to 28.5 ^{0}C. While the minimum temperature ranged from 16.2 to 19.5 ^{0}C. The higher relative humidity was 94.00 per cent (October). Similarly higher sunshine hours were 6.8 hours in November (Table 3.1).

3.3 Soil properties of the experimental site

The soil of the experimental site was red sandy clay loam. Composite sample was drawn from the experimental site. Samples were air dried, powdered, sieved soil and stored in plastic cover for further analysis. The results of the soil analysis along with the methods followed are presented in Table 3.2.

3.4 Previous crop in the experimental field

Cowpea crop was grown in the plot during the *summer* season of 2014.

3.5 Experimental details

3.5.1 Crop and variety

The aerobic rice variety BI-33 (Anagha) developed by the University of Agricultural Sciences, Bengaluru was used for the experiment. It is a medium early duration variety comes to maturity in 115-120 days. It is a semi tall plant (100-105 cm) and capable of producing higher grain yield (40-50 q ha^{-1}) and straw yield (50-75 q ha^{-1}). It is tolerant to drought and the grain quality is medium slender (Anon., 2007). However, during the period of investigation BI-33 attained maturity at 135 days.

3.5.2 Spacing, seed rate, manures and fertilizer dose

Spacing	:	As per treatments.
Seed rate	:	5 kg ha^{-1}
FYM	:	10 t ha^{-1}
Fertilizer dose	:	100: 50: 50 N, P_2O_5 and K_2O kg ha^{-1}

3.5.3 Design and layout

The experiment was laid out in a randomized complete block design with factorial concept and replicated thrice. The layout of the experiment is depicted in Fig. 2 and shown in plate 1 and 2.

3.5.4 Plot size

Gross plot size	:	4.5 m × 6.0 m = 27.0 m^2
Net plot size	:	3.5 m × 3.0 m = 10.5 m^2

Table 3.2: Physical and chemical properties of soil in the experimental site

Particulars	Values	Status	Method followed
I. Physical properties			
1. Coarse sand (%)	33.20	-	International pipette method (Piper, 1966)
2. Fine sand (%)	36.40	-	
3. Silt (%)	07.40	-	
4. Clay (%)	23.00	-	
5. Soil textural class	Red Sandy clay loam		
6. Field capacity (%)	18.60	-	Field method
7. Permanent wilting point (%)	6.02	-	Sunflower method (Piper, 1966)
8. Bulk density (Mg m^{-3})	1.45	-	Core sampler (Piper, 1966)
II. Chemical properties			
1. pH (1:2.5)	7.1	Neutral	Potentiometric method (Jackson, 1973)
2. EC (1:2.5) (dSm^{-1})	0.38	Medium	Conductometric method (Jackson, 1973)
3. Organic carbon (%)	0.63	Medium	Wet oxidation method (Walkley and Black, 1934)
4. Available N (kg ha^{-1})	356.3	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
5. Available P_2O_5 (kg ha^{-1})	23.8	Medium	Bray's extractant (Jackson, 1973)
6. Available K_2O (kg ha^{-1})	256.4	Medium	Flame photometry (Jackson, 1973)

LEGEND

Factor-S: Crop geometry

S_1: 25 cm x 10 cm

S_2: 25 cm x 15 cm

S_3: 25 cm x 20 cm

S_4: 25cm x 25 cm

Factor -F: Fertilizer levels through drip fertigation

F_1: 50 per cent of RDF through Drip fertigation.

F_2: 75 per cent of RDF through Drip fertigation.

F_3: 100 per cent of RDF through Drip fertigation.

Interactions (F x S):

T_1: S_1 - 25 cm x 10 cm + (F_1) 50 % of RDF through Drip fertigation.

T_2: S_1 - 25 cm x 10 cm + (F_2) 75 % of RDF through Drip fertigation.

T_3: S_1 - 25 cm x 10 cm + (F_3) 100 % of RDF through Drip fertigation.

T_4 : S_2 - 25 cm x 15 cm + (F_1) 50 % of RDF through Drip fertigation.

T_5 : S_2 - 25 cm x 15 cm + (F_2) 75 % of RDF through Drip fertigation.

T_6 : S_2 - 25 cm x 15 cm + (F_3) 100 % of RDF through Drip fertigation.

T_7 : S_3 - 25 cm x 20 cm + (F_1) 50 % of RDF through Drip fertigation.

T_8 : S_3 - 25 cm x 20 cm + (F_2) 75 % of RDF through Drip fertigation.

T_9 : S_3 - 25 cm x 20 cm + (F_3) 100 % of RDF through Drip fertigation

T_{10}: S_4 - 25 cm x 25 cm + (F_1) 50 % of RDF through Drip fertigation**.**

T_{11}: S_4 - 25 cm x 25 cm + (F_2) 75 % of RDF through Drip fertigation.

T_{12}: S_4 - 25 cm x 25 cm + (F_3) 100 % of RDF through Drip fertigation.

T_{13}: Control i.e., Spacing of 25 cm X 25 cm with surface irrigation and soil application of RDF.

S= Planting geometry. RDF= Recommended dose of fertilizer.

F= Fertilizer

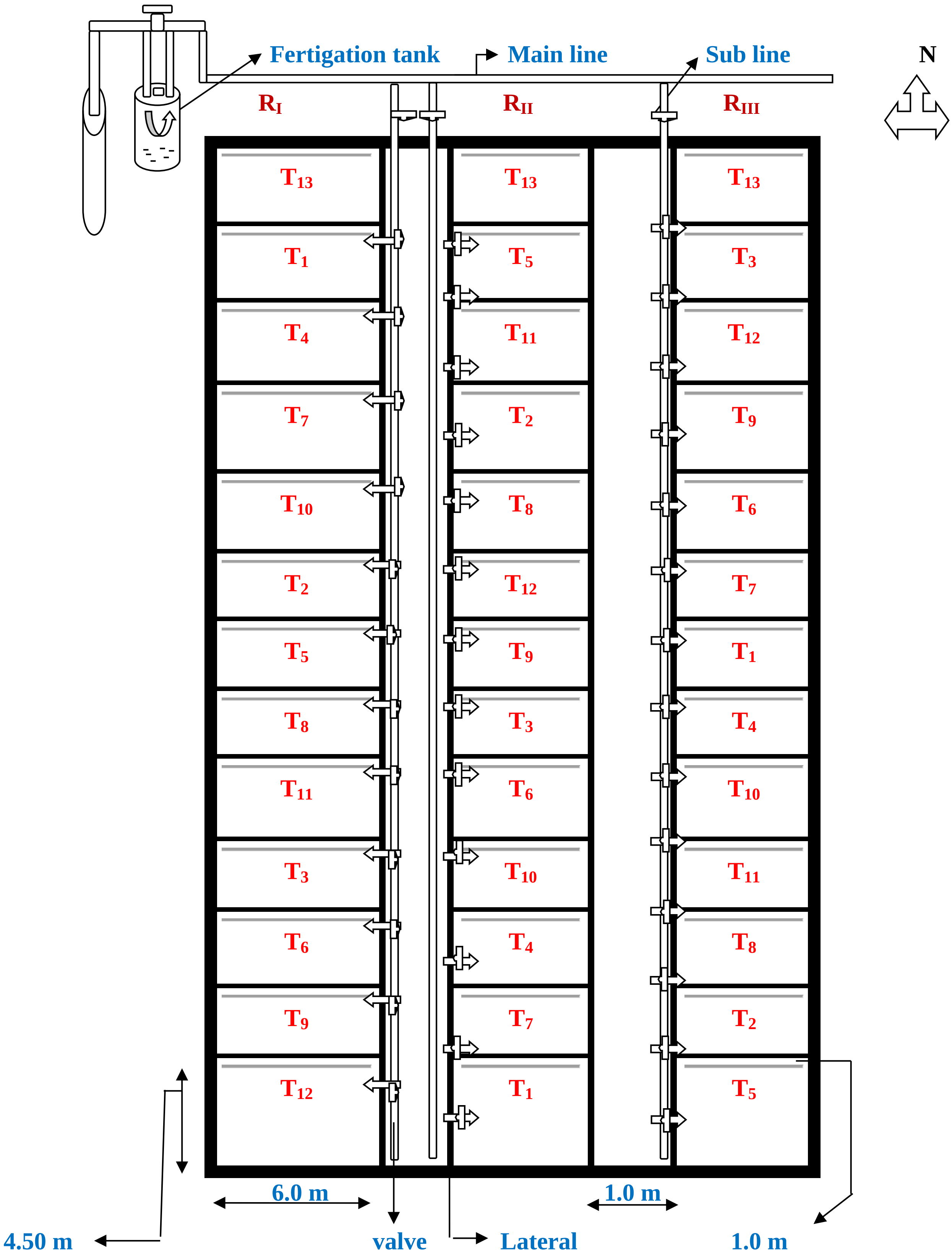

Fig. 2: Plan of layout of experiment

Plate 1: Direct seeding of aerobic rice in experimental plot

Plate 2: General view of the experimental plot with drip irrigation

3.6 Treatment details

Factor-S: Planting geometry

S_1: 25 cm x 10 cm

S_2: 25 cm x 15 cm

S_3: 25 cm x 20 cm

S_4: 25 cm x 25 cm

Factor -F: Fertilizer levels through drip fertigation

F_1: 50 % of RDF through Drip fertigation.

F_2: 75 % of RDF through Drip fertigation.

F_3: 100 % of RDF through Drip fertigation.

Interactions (F x S)

T_1: S_1 - 25 cm x 10 cm + (F_1) 50 % of RDF through Drip fertigation.

T_2: S_1 - 25 cm x 10 cm + (F_2) 75 % of RDF through Drip fertigation.

T_3: S_1 - 25 cm x 10 cm + (F_3) 100 % of RDF through Drip fertigation.

T_4 : S_2 - 25 cm x 15 cm + (F_1) 50 % of RDF through Drip fertigation.

T_5 : S_2 - 25 cm x 15 cm + (F_2) 75 % of RDF through Drip fertigation.

T_6 : S_2 - 25 cm x 15 cm + (F_3) 100 % of RDF through Drip fertigation.

T_7 : S_3 - 25 cm x 20 cm + (F_1) 50 % of RDF through Drip fertigation.

T_8 : S_3 - 25 cm x 20 cm + (F_2) 75 % of RDF through Drip fertigation.

T_9 : S_3 - 25 cm x 20 cm + (F_3) 100 % of RDF through Drip fertigation

T_{10}: S_4 - 25 cm x 25 cm + (F_1) 50 % of RDF through Drip fertigation**.**

T_{11}: S_4 - 25 cm x 25 cm + (F_2) 75 % of RDF through Drip fertigation.

T_{12}: S_4 - 25 cm x 25 cm + (F_3) 100 % of RDF through Drip fertigation.

T_{13}: Control i.e., Spacing of 25 cm x 25 cm with surface irrigation and soil application of RDF.

Note: S= Planting geometry RDF= Recommended dose of fertilizer

F= Fertilizer

3.7 Cultural practices

3.7.1 Land preparation

The experimental plot was ploughed twice and was brought to fine tilth by harrowing for preparation of individual plots.

3.7.2 Sowing

The sowing was taken up on 15th August, 2014 by maintaining spacing as per the treatments using seed rate of five kg ha^{-1}. Immediately after sowing the seeds were covered with soil with the help of wooden plank.

3.7.3 Drip system installation

This system included pump, filter units, fertigation tank, ventury, main line and sub line for each replication and a lateral for each plot. The drip line was passed in between two consecutive rows by skipping one row alternatively, which included 15 emitters in each row at a distance of 40 cm with a total of 135 emitters per plot.

3.7.4 Irrigation

3.7.4.1 Drip irrigation

Irrigation was scheduled each day based on daily Pan Evaporation values during crop period.

3.7.4.2 Surface irrigation

Initially surface irrigation for control plot was given at 5 days interval with a depth of 2 cm and this interval was reduced to 3 days at panicle initiation stage. Further, during advancement of crop, plot was irrigated with a depth of five cm at 3 days interval.

3.7.5 Fertilizer application

FYM was applied before 15 days of sowing to all the treatment plots at the rate of 10 tonnes ha^{-1}. Fertilizers were applied as per the treatment details. The soil application was done as per the recommendation. Out of total nutrients, 50 per cent N and the entire dose of P and K were applied as basal and remaining 50 per cent N in two equal splits at 30 and 60 DAS, respectively (Appendix I). However, drip fertigation through normal fertilizers and were applied in four equal splits at ten days interval which is presented in Appendix II.

3.7.6 After care

Thinning of excessive seedlings leaving two seedlings per hill was done at 15 days after sowing to maintain optimum plant population. Seedlings were spaced at 25 cm between rows and between the plants as per the treatments. Gap filling was also done simultaneously on the same day. Three hand weeding were done manually at 25, 45 and 75 DAS in order to keep the plots weed free. Chlorpyriphos and Tricyclazole were sprayed (at the rate of 2 ml l^{-1} and 1 g l^{-1}, respectively) to overcome minor incidence of stem borer and blast.

3.7.7 Harvesting and threshing

The crop was harvested on 3rd January, 2015 at 141 days after sowing as the ear heads turned brownish colour coupled with straw turned to yellowish colour in more than 90 per cent plants. All border rows were harvested as bulk by leaving net plot area. Later, net plot area was harvested treatment wise. Similarly, the straw from net plot was harvested to ground level separately and dried for a week before recording the weight.

3.8 Collection of experimental data

Observations on growth and yield parameters of aerobic rice at 30, 60, 90, 120 DAS and at harvest were recorded from five randomly selected plants. Destructive sampling was done from the area meant for observation by selecting five plants randomly and cutting these plants at ground level.

The techniques used and the details of observations recorded are described in the following paragraphs.

3.8.1 Growth parameters

3.8.1.1 Plant height (cm)

The plant height (cm) was measured from randomly selected five hills selecting main shoot and recording plant height from ground level to the base of the fully opened leaf at 30, 60, 90,120 DAS and at harvest. After emergence of ear head, the height was taken up to the tip of the ear head on the main shoot. The mean plant height was worked out and expressed in centimeter.

3.8.1.2 Number of tillers (m^{-2})

Number of tillers were recorded from the randomly selected five hills, at 30, 60, 90, 120 DAS and at harvest. They were pooled and average number of tillers $hill^{-1}$ was obtained then that is multiplied with plant population m^{-2} as per the different spacing and it is converted to number of tillers m^{-2}.

3.8.1.3 Number of green leaves (hill^{-1})

Total number of green leaves hill^{-1} was counted from five plants in each treatment which were selected randomly and the mean was computed at 30, 60, 90 and 120 DAS and at harvest.

3.8.1.4 Leaf area (cm^2 hill^{-1})

The leaf area hill^{-1} was recorded at 30, 60, 90 and120 DAS from five randomly selected hills. Leaf area was recorded using "L.I-3100 leaf area meter" designed at LICOR Institute, Lincoln, Nebraska, USA. The average of five hills was considered as the average leaf area hill^{-1}.

3.8.1.5 Leaf area index (LAI)

Leaf area index is the ratio of leaf area to ground area occupied by the crop plant. Leaf area index was worked out using the following formula (Watson *et al.,* 1952).

$$LAI = \frac{\text{Leaf area hill}^{-1}\ (\text{cm}^2)}{\text{Spacing}\ (\text{cm}^2)}$$

3.8.1.6 Leaf area duration (days)

Leaf area duration (LAD) measure the ability to produce leaf area on unit land throughout its life. It was calculated by using the following formula given by Powar *et al*. (1967) and expressed in days.

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

where, LAD- Leaf area duration (days)

LAI_1 and LAI_2 are the leaf area index at time t_1 and t_2, respectively.

3.8.1.7 Crop growth rate (g m^{-2} day^{-1})

Crop growth rate (CGR) was calculated by taking the dry weight increment per hill at different intervals by using following formula.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \text{Land area}$$

Where, CGR- Crop growth rate (g m^{-2} day^{-1})

W_1 and W_2 are the dry weight at the time t_1 and t_2, respectively.

3.8.1.8 Dry matter accumulation and distribution (g m^{-2})

Dry matter accumulation at 30, 60, 90, 120 DAS and at harvest was determined only for the above ground portion of the plant. The sample collected from five hills were partitioned in to different parts like leaves, stem and panicle (depending on the stage of the crop) and later dried in hot air oven at 65^0C till the constant dry weight was attained. The completely dried samples were weighed separately and weight was recorded in grams for each plant part. This primary data was used to estimate the total dry weight hill^{-1} and then that is multiplied with plant population m^{-2} as per the different spacing and it is converted to dry matter g m^{-2}.

3.8.2 Yield parameters

3.8.2.1 Number of productive tillers (m^{-2})

Number of productive tillers hill^{-1} was counted from randomly selected five hills at the time of harvest and average was recorded and then that was multiplied with plant population m^{-2} as per the different spacing and it was converted to number of productive tillers m^{-2}.

3.8.2.2 Panicle length (cm)

From randomly selected five plants, panicle length was measured by meter scale and average was taken.

3.8.2.3 Grains per panicle

Grains from randomly selected panicles were counted manually and average was taken.

3.8.2.4 Per cent chaffyness

Panicles from randomly selected five plants were used for counting the filled and unfilled grains. Per cent chaffyness was calculated by using the formula.

$$\textbf{Per cent chaffyness} = \frac{\text{Number of unfilled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}} \times 100$$

3.8.2.5 Test weight (g)

Thousand grains count was recorded by “NUMIGRAL” seed counter, a seed counting machine, which automatically stops after counting 1000 grains. The weight was recorded in grams.

3.8.2.6 Grain yield (kg ha^{-1})

The harvested plants from net plot were threshed and grains were dried and then weighed. Using net plot yield, the yield in kg ha$^{–1}$ was computed.

From the net plot area, straw was cut at ground level in each treatment and sun dried for 8-10 days, weighed and converted to kg ha^{-1}.

3.8.2.8 Harvest Index (HI)

Harvest index is the proportion of total dry matter that is accumulated in economic yield. It was worked out using the following formula suggested by Donald (1962).

$$\textbf{Harvest index} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

3.8.3 Water use efficiency (kg ha-cm^{-1})

Water use efficiency (WUE) was worked out from the yield of aerobic rice and the amount of water used and expressed in kg ha-cm^{-1}.

$$\text{WUE} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Quantity of total water applied (cm)}}$$

3.9 Chemical analysis

3.9.1 Soil analysis

Soil samples from 0-20 cm depth were collected before sowing and after harvest from each treatment for estimation of available nitrogen, phosphorus and potassium as per the procedure described in Table 3.2.

3.9.2 Plant analysis

Plant samples collected from each treatment were separately dried and powdered by using mixer grinder with stainless steel blade. The powdered samples were stored in airtight containers for further chemical analysis. These samples were used for N, P and K estimation. Nitrogen was estimated with wet digestion and distillation adopting the procedure given by Jackson (1973). Phosphorus in plant samples was estimated upon digestion followed by colorimetric estimation using Spectrophotometer adopting the procedure given by Jackson (1973). Total potassium in plant samples was estimated by Flame photometry following the procedure given by Jackson (1973).

Uptake of nitrogen, phosphorus and potassium were calculated using the following formula and expressed in kg ha^{-1}.

$$\text{Nutrient uptake by grain} = \frac{\text{Nutrient content (\%)} \times \text{Dry weight of grain}}{100}$$

$$\text{Nutrient uptake by straw} = \frac{\text{Nutrient content (\%)} \times \text{Dry weight of straw}}{100}$$

Total nutrient uptake = Uptake by grain + Uptake by straw

3.9.3 Nutrient use efficiency (kg kg^{-1})

Nutrient use efficiency (NUE) was calculated by using following formula and expressed in kg kg^{-1}.

$$\textbf{NUE} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Nutrient applied (kg ha}^{-1}\text{)}}$$

3.10 Economic analysis

The cost of cultivation was computed by considering the present prices of inputs prevailed during their use for different treatments. Similarly, the prevailing market price for rice and straw value was considered for calculating gross return. The per hectare cost of cultivation was deducted from per hectare gross returns to get per hectare net returns. Benefit cost ratio was worked out as follows.

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

3.11 Statistical analysis and interpretation of data

Data recorded on various observations *viz.*, growth, yield and soil parameters were subjected to analysis of variance given by Rangaswamy (2010). The level of significance used in ‘F’ and ‘t’ tests were at $p \leq 0.05$, critical difference values were calculated wherever the ‘F’ test was found to be significant.

IV EXPERIMENTAL RESULTS

The results of the study entitled "Standardisation of planting geometry in aerobic rice (*Oryza sativa L.*) under different levels of drip fertigation" conducted at ZARS, University of Agricultural Sciences, Gandhi Krushi Vignana Kendra, Bengaluru during *Kharif* 2014 are presented in this chapter.

4.1 Growth parameters

The data on growth parameters like plant height (cm), number of leaves (No.hill^{-1}) number of tillers (No. m^{-2}), total dry matter production (g m^{-2}), leaf area (cm^{2} hill^{-1}), leaf area index, leaf area duration (days), crop growth rate (g m^{-2} day^{-1}) at various growth stages are presented in Tables 4.1 to 4.8.

4.1.1 Plant height (cm)

The data on plant height (cm) recorded at 30, 60, 90, 120 DAS and at maturity as influenced by different treatments under study are presented in Table 4.1.

The significant difference among the treatments was noticed at all the crop growth stages except at 30 DAS.

4.1.1.a Plant height (cm) at 60 DAS

The application of fertilizer at different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly more plant height (23.21 cm) followed by 75 per cent RDF through drip fertigation (20.89 cm) however, significantly lower height (19.02 cm) was recorded in 50 per cent RDF (Table 4.1).

Planting geometry significantly influenced the plant height. Significantly higher plant height (22.30 cm) was noticed in 25 cm x 15 cm was on par with 25 cm x 10 cm (20.80 cm), 25 cm x 20 cm (21.71cm) and recorded significantly lower plant height (19.35 cm) in 25 cm x 25 cm.

Significant difference in plant height was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 15 cm with 100 per cent RDF was recorded significantly higher plant height (24.12 cm) and significantly lower plant height was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (17.34 cm).

4.1.1.b Plant height (cm) at 90 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher plant height (50.24 cm) followed by 75 per cent RDF through drip fertigation (44.44 cm) however significantly lower height (41.44 cm) was recorded in 50 per cent RDF.

Table 4.1: Plant height (cm) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Fertilizer levels (F)					
F_1	7.49	19.02	41.41	47.24	51.80
F_2	7.77	20.89	44.44	49.08	52.98
F_3	8.08	23.21	50.24	52.95	57.17
S.Em ±	0.43	0.75	1.19	0.952	1.03
CD at 5 %	NS	2.18	3.47	2.779	3.02
Planting geometry (S)					
S_1	7.75	20.80	45.27	50.06	53.87
S_2	7.96	22.30	47.35	51.42	55.96
S_3	7.64	21.71	45.09	49.42	53.89
S_4	7.79	19.35	43.74	48.12	52.22
S.Em ±	0.49	0.86	1.37	1.10	1.19
CD at 5 %	NS	2.52	4.01	3.21	3.48
Interactions (F x S)					
F_1S_1	7.56	17.91	39.68	46.55	50.60
F_1S_2	7.52	19.91	43.12	48.24	53.27
F_1S_3	7.47	20.76	41.63	48.04	52.53
F_1S_4	7.43	17.51	41.21	46.12	50.80
F_2S_1	7.89	21.39	44.79	48.94	53.40
F_2S_2	7.92	22.88	45.60	50.05	54.67
F_2S_3	7.65	21.47	44.18	48.88	52.20
F_2S_4	7.64	17.84	43.19	48.44	51.67
F_3S_1	7.80	23.11	51.36	54.69	57.60
F_3S_2	8.43	24.12	53.32	55.98	59.93
F_3S_3	7.80	22.90	49.46	51.33	56.93
F_3S_4	7.79	22.71	46.82	49.81	54.20
Control	7.75	17.34	39.59	44.71	48.80
S.Em ±	0.86	1.49	2.38	1.90	2.07
CD at 5 %	NS	4.36	6.95	5.56	6.03
CV (%)	12.76	11.49	8.47	7.16	8.32

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

Planting geometry significantly influenced the plant height. Significantly higher plant height (47.35 cm) was noticed in 25 cm x 15 cm which was on par with 25 cm x 10 cm (45.27 cm), 25 cm x 20 cm (45.09 cm) and recorded significantly lower plant height (43.74 cm) in 25 cm x 25 cm.

Significant difference in plant height was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher plant height (53.32 cm) and significantly lower plant height was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (39.59 cm).

4.1.1.c Plant height (cm) at 120 DAS

The application of fertilizer at different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher plant height (52.95 cm) followed by 75 per cent RDF through drip fertigation (49.08 cm) however significantly lower height (47.24 cm) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the plant height. Significantly higher plant height (51.42 cm) was noticed in 25 cm x 15 cm which was on par with 25 cm x 10 cm (50.06 cm), 25 cm x 20 cm (49.42 cm) and recorded significantly lower plant height (48.12 cm) in 25 cm x 25 cm.

Significant difference in plant height was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher plant height (55.98 cm) and significantly lower plant height was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (44.71 cm).

4.1.1.d Plant height (cm) at maturity

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher plant height (57.17 cm) followed by 75 per cent RDF through drip fertigation (52.98 cm) however significantly lower height (51.80 cm) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the plant height. Significantly higher plant height (55.96 cm) was noticed in 25 cm x 15 cm which was on par with 25 cm x 10 cm (53.87 cm), 25 cm x 20 cm (53.89 cm) and recorded significantly lower plant height (52.22 cm) in 25 cm x 25 cm.

Significant difference in plant height was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher plant height (59.93 cm) and significantly lower plant height was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (48.80 cm).

4.1.2 Number of leaves (hill^{-1})

The data on number of leaves hill^{-1} of rice observed at 30, 60, 90, 120 DAS at maturity as influenced by different treatments under study are presented in Table 4.2.

Significant differences among the treatments were noticed in number of leaves hil^{-1} at all the stages of crop growth except at 30 DAS.

4.1.2.a Number of leaves (hill^{-1}) at 60 DAS

The application of fertilizer at different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher number of leaves (83.14) which was on par with 75 per cent RDF (74.69). Significantly lower number of leaves (67.53) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the number of leaves. Significantly higher number of leaves (83.22) was recorded in 25 cm x 25 cm followed by 25 cm x 20 cm (74.33) and 25 cm x 15 cm (74.19). Significantly less number of leaves (68.74) was recorded in 25 cm x 10 cm.

Significant difference in number of leaves was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF was recorded significantly higher number of leaves (89.33) and significantly lower number of leaves was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (60.00).

4.1.2.b Number of leaves (hill^{-1}) at 90 DAS

The application of fertilizer at different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher number of leaves (133.00) followed by 75 per cent RDF (112.00). However, significantly lower number of leaves (92.56) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the number of leaves. Significantly higher number of leaves (123.19) was noticed in 25 cm x 25 cm which was on par with 25 cm x 15 cm (113.52) and 25 cm x 20 cm (109.70) and significantly lower number of leaves recorded in 25 cm x 10 cm (103.67)

Significant difference in number of leaves was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher number of leaves (149.44) and significantly lower number of leaves was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (79.56).

Table 4.2: Number of leaves (hill^{-1}) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Fertilizer levels (F)					
F_1	13.80	67.53	92.56	65.85	64.26
F_2	14.67	74.69	112.00	77.27	72.12
F_3	15.85	83.14	133.00	87.08	82.71
S.Em ±	0.91	4.17	5.77	3.22	3.38
CD at 5 %	NS	12.16	16.83	9.41	9.87
Planting geometry (S)					
S_1	13.98	68.74	103.67	71.94	68.51
S_2	14.76	74.19	113.52	74.67	71.47
S_3	14.84	74.33	109.70	76.42	71.84
S_4	15.51	83.22	123.19	83.92	80.29
S.Em ±	1.05	4.81	6.66	3.72	3.91
CD at 5 %	NS	14.04	19.44	10.87	11.40
Interactions (F x S)					
F_1S_1	13.40	61.56	81.56	60.83	60.16
F_1S_2	13.20	61.89	89.78	61.08	60.36
F_1S_3	14.07	67.33	96.56	70.17	67.97
F_1S_4	14.53	79.33	102.33	71.33	68.54
F_2S_1	14.13	64.11	102.56	75.92	71.15
F_2S_2	14.67	75.67	108.33	77.17	71.33
F_2S_3	14.73	78.00	119.33	77.25	72.44
F_2S_4	15.13	81.00	117.78	78.75	73.55
F_3S_1	14.60	80.22	118.67	78.83	74.03
F_3S_2	15.80	80.00	124.22	81.92	76.23
F_3S_3	16.13	83.00	139.67	85.92	81.80
F_3S_4	16.87	89.33	149.44	101.67	98.79
Control	13.20	60.00	79.56	58.67	57.44
S.Em ±	1.82	8.33	11.53	6.45	6.76
CD at 5 %	NS	24.32	33.67	18.82	19.74
CV (%)	13.81	14.00	14.76	13.86	12.05

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

4.1.2.c Number of leaves (hill^{-1}) at 120 DAS

The application of fertilizer at different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher number of leaves (87.08) followed by 75 per cent RDF (77.27). Significantly lower number of leaves (65.85) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the number of leaves. Significantly higher number of leaves (83.92) was noticed in 25 cm x 25 cm which was on par with 25 cm x 15 cm (74.67) and 25 cm x 20 cm (76.42) and significantly lower number of leaves recorded in 25 cm x 10 cm (71.94).

Significant difference in number of leaves was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher number of leaves (101.67) which was on par with 25 cm x 20 cm with 100 per cent RDF (85.92) and significantly lower number of leaves was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (58.67).

4.1.2.d Number of leaves (hill^{-1}) at maturity

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher number of leaves (82.71) followed by 75 per cent RDF (64.26). Significantly lower number of leaves (72.12) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the number of leaves. Significantly higher number of leaves (80.29) was noticed in 25 cm x 25 cm which was on par with 25 cm x 15 cm (71.47) and 25 cm x 20 cm (71.84) and significantly lower number of leaves recorded in 25 cm x 10 cm (68.51)

Significant difference in number of leaves was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher number of leaves (98.79) which was on par with 25 cm x 20 cm with 100 per cent RDF (81.20) and significantly lower number of leaves was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation (57.44) and soil application of RDF.

4.1.3 Number of tillers (m^{-2})

The data on number of tillers m^{-2} due to different planting geometry and fertilizer levels under drip fertigation are presented in the Table 4.3.

The results revealed that, there was no significance difference in number of tillers m^{-2} was observed at 30 days after sowing among different treatments.

Table 4.3: Number of tillers (No. m^{-2}) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Fertilizer levels (F)					
F_1	133.68	338.33	348.58	383.29	404.67
F_2	138.43	428.72	455.49	478.48	510.38
F_3	152.32	630.41	655.16	684.15	731.96
S.Em ±	8.30	22.32	17.49	20.96	17.66
CD at 5 %	NS	65.16	51.06	61.19	51.55
Planting geometry (S)					
S_1	141.82	472.26	507.99	523.03	552.71
S_2	147.80	529.59	547.53	554.35	597.58
S_3	144.89	449.96	469.51	513.11	547.57
S_4	131.39	411.48	420.61	469.74	498.15
S.Em ±	9.59	25.78	20.20	24.21	20.39
CD at 5 %	NS	75.24	58.96	70.66	59.53
Interactions (F x S)					
F_1S_1	126.07	304.00	307.20	345.17	380.80
F_1S_2	138.67	366.67	371.40	383.92	418.67
F_1S_3	143.67	349.87	360.53	416.93	417.07
F_1S_4	126.33	332.80	355.20	387.15	402.13
F_2S_1	142.63	451.44	499.43	482.19	506.67
F_2S_2	139.31	494.10	527.87	492.14	579.41
F_2S_3	130.33	386.67	410.67	480.93	492.32
F_2S_4	141.43	382.67	384.00	458.67	463.13
F_3S_1	156.77	661.33	717.33	741.73	770.67
F_3S_2	165.43	728.00	743.33	760.00	794.67
F_3S_3	160.67	613.33	637.33	671.47	733.33
F_3S_4	126.41	518.98	522.63	563.41	629.18
Control	125.17	291.20	297.53	315.90	324.27
S.Em ±	16.61	44.65	34.99	41.93	35.32
CD at 5 %	NS	130.32	102.12	122.39	103.10
CV (%)	10.93	12.77	11.85	13.40	10.62

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

4.1.3.a Number of tillers (m^{-2}) at 60 DAS

The number of tillers m^{-2} was significantly differed due different levels of fertilizer levels under drip fertigation. Among the fertilizer levels 100 per cent RDF through drip fertigation has recorded significantly higher number of tillers (630.41) as compared 50 and 75 per cent RDF through drip fertigation (338.33 and 428.72, respectively).

The number of tillers was significantly higher in planting geometry of 25 cm x 15 cm (529.59) as compared to wider planting geometry of 25 cm x 25 cm (411.48). However, significantly on par tiller were recorded in planting geometry of 25 cm x 20 cm (449.96) and 25 cm x 10 cm (472.26).

The interaction of both planting geometry and fertilizer levels was significantly differed. Among the interaction effect planting geometry of 25 cm x 15 cm with 100 per cent RDF (728.00) has recorded significantly more tillers as compared to all other treatments. However, significantly on par on par tiller were recorded in 25 cm x 10 cm and 25 cm x 20 cm with 100 per cent RDF through drip fertigation (661.33 and 613.33, respectively). Significantly lower number of tillers (291.20) was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.1.3.b Number of tillers (m^{-2}) at 90 DAS

The number of tillers m^{-2} was significantly differed due to different levels of fertilizer levels under drip fertigation. Among the fertilizer levels 100 per cent RDF through drip fertigation has recorded significantly higher number of tillers (655.16) as compared 50 and 75 per cent RDF through drip fertigation (348.58 and 455.49, respectively).

The number of tillers m^{-2} was significantly higher in planting geometry of 25 cm x 15 cm (547.53) as compared to wider planting geometry of 25 cm x 25 cm (420.61). However, significantly on par tiller were recorded in planting geometry of 25 cm x 20 cm (469.51) and 25 cm x 10 cm (507.99).

The interaction of both planting geometry and fertilizer levels was significantly differed. Among the interaction effect planting geometry of 25 cm x 15 cm with 100 per cent RDF (743.33) has recorded significantly more tillers as compared to all other treatments. Which was significantly on par on par tiller were recorded in 25 cm x 10 cm with 100 per cent RDF through drip fertigation (717.33 and 613.33, respectively). Significantly lower number of tillers was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (297.53).

4.1.3.c Number of tillers (m^{-2}) at 120 DAS

The number of tillers m^{-2} was significantly differed due different levels of fertilizer levels under drip fertigation. Among the fertilizer levels 100 per cent RDF through drip fertigation has recorded significantly higher number of tillers (684.15) as compared 50 and 75 per cent RDF through drip fertigation (383.29 and 478.48, respectively).

The number of tillers m^{-2} was significantly higher in planting geometry of 25 cm x 15 cm (554.35) as compared to wider planting geometry of 25 cm x 25 cm (469.74). The planting geometry of 25 cm x 15 cm and 25 cm x 10 cm and 25 cm x 20 cm were found statistically on par with each other (554.35, 523.03 and 523.11, respectively).

The interaction of both planting geometry and fertilizer levels was significantly differed. Among the interaction effect the treatment planting geometry of 25 cm x 15 cm with 100 per cent RDF (760.00) has recorded significantly higher tillers followed by planting geometry of 25 cm x 10 cm with 100 per cent RDF (741.73) and planting geometry of 25 cm x 20 cm with 100 per cent RDF (671.47).Significantly lower tillers was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (315.90).

4.1.3.d Number of tillers (m^{-2}) at maturity

The number of tillers m^{-2} was significantly differed due different levels of fertilizer levels under drip fertigation. Among the fertilizer levels 100 per cent RDF through drip fertigation has recorded significantly higher number of tillers (731.96) as compared 50 and 75 per cent RDF through drip fertigation (404.67 and 510.38, respectively).

The number of tillers m^{-2} was significantly superior at closer planting geometry of 25 cm x 15 cm (597.58) followed by planting geometry of 25 cm x 10 cm and 25 cm x 20 cm (552.71 and 547.57, respectively). Significantly lower numbers of tillers were recorded in planting geometry of 25 cm x 25 cm (498.15).

The interaction of both planting geometry and fertilizer levels was significantly differed. Among the interaction effect the treatment F_3S_2 i.e. 25 cm x 15 cm with 100 per cent RDF (794.67) has recorded significantly superior followed by F_3S_1 i.e. 25 cm x 10 cm with 100 per cent RDF (770.67) and F_3S_3 i.e. 25 cm x 20 cm with 100 per cent RDF (733.33) which were on par each other. Significantly lower yield was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (324.27).

4.1.4 Total dry matter production (g m^{-2})

The data on total dry matter production (g m^{-2}) of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation at different growth stages are presented in Table 4.4.

4.1.4.a Total dry matter production (g m^{-2}) at 30 DAS

Among the fertilizer levels, 100 per cent RDF recorded significantly higher total dry matter production (37.78 g m^{-2}) as compared to 50 and 75 per cent RDF (21.76 and 27.17 g m^{-2}, respectively).

Table 4.4: Total dry matter production (g m^{-2}) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Fertilizer levels (F)					
F_1	21.76	538.7	1383.4	1655.5	1660.8
F_2	27.17	636.3	1617.5	2088.4	2206.5
F_3	37.78	873.9	2302.4	3085.4	3159.0
S.Em ±	1.67	21.1	52.9	34.9	135.0
CD at 5 %	4.88	61.6	154.6	101.9	394.1
Planting geometry (S)					
S_1	28.70	673.3	1764.5	2349.9	2396.8
S_2	34.54	736.6	1910.6	2506.5	2663.6
S_3	26.75	684.8	1776.2	2277.8	2356.4
S_4	25.92	637.3	1619.9	1971.7	2031.5
S.Em ±	1.93	24.3	61.1	40.3	155.9
CD at 5 %	5.63	71.1	178.5	117.7	455.0
Interactions (F x S)					
F_1S_1	19.79	490.0	1294.6	1398.0	1415.1
F_1S_2	24.47	578.6	1512.3	1816.1	1943.8
F_1S_3	21.73	572.5	1423.3	1726.7	1752.0
F_1S_4	21.07	513.8	1303.5	1503.3	1532.1
F_2S_1	28.44	645.5	1637.1	2128.4	2168.2
F_2S_2	30.27	669.8	1673.4	2314.0	2558.8
F_2S_3	25.33	627.5	1619.4	1967.3	2122.2
F_2S_4	24.64	602.4	1540.2	1844.1	1976.7
F_3S_1	37.87	884.4	2361.8	3315.2	3367.1
F_3S_2	48.00	961.3	2546.0	3389.4	3488.3
F_3S_3	33.20	854.4	2285.8	3139.3	3195.1
F_3S_4	32.05	795.7	2016.1	2497.6	2585.7
Control	16.69	451.9	1102.6	1298.9	1365.7
S.Em ±	3.34	42.2	105.9	69.8	270.0
CD at 5 %	9.76	123.2	309.2	203.9	788.2
CV (%)	12.10	10.1	9.8	8.0	13.2

Note: Fertilizer levels **(F)**: F_1: 50 per cent RDF, F_2: 75 per cent RDF, F_3: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S):** S_1: 25 cm x 10 cm, S_2: 25 cm x 15 cm, S_3: 25 cm x 20 cm, S_4: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

Planting geometry of 25 cm x 15 cm recorded significantly higher total dry matter production (34.24 g m^{-2}) over rest of the planting geometries and significantly lower total dry matter production was noticed in planting geometry of 25 cm x 25 cm (25.92 g m^{-2}).

Total dry matter Production differed significantly due to the interaction of planting geometry and fertilizer levels under drip fertigation. Planting geometry of 25 cm x 15 cm with 100 per cent RDF produced significantly higher total dry matter production (48.00 g m^{-2}) followed by planting geometry of 25 cm x 15 cm with 100 per cent RDF (37.87 g m^{-2}). Significantly lower total dry matter production was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (16.69).

4.1.4.b Total dry matter production (g m^{-2}) at 60 DAS

Among the fertilizer levels, 100 per cent RDF recorded significantly higher total dry matter production (873.9 g m^{-2}) as compared to 50 and 75 per cent RDF (538.7 and 636.3 g m^{-2}, respectively).

Planting geometry of 25 cm x 15 cm recorded significantly higher total dry matter production (736.6 g m^{-2}) followed by 25 cm x 10 cm and 25 cm x 20 cm (673.3 and 684.8 g m^{-2}, respectively). Significantly lower total dry matter (637.3 g m^{-2}) was observed in planting geometry of 25 cm x 25 cm.

Total dry matter Production differed significantly due to the interaction of planting geometry and Fertilizer levels under drip fertigation. Planting geometry of 25 cm x 15 cm with 100 per cent RDF produced significantly higher total dry matter production (961.3 g m^{-2}) over all other treatments but which was on par with planting geometry of 25 cm x 10 cm with 100 per cent RDF (884.4 g m^{-2}) and planting geometry of 25 cm x 20 cm with 100 per cent RDF (854.4 g m^{-2}). Significantly lower yield was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (451.9 g m^{-2}).

4.1.4.c Total dry matter production (g m^{-2}) at 90 DAS

Among the fertilizer levels, 100 per cent RDF recorded significantly higher total dry matter production (2302.4 g m^{-2}) as compared to 50 and 75 per cent RDF (1383.4 and 1617.5 g m^{-2}, respectively).

Planting geometry of 25 cm x 15 cm recorded significantly higher total dry matter production (1910.6 g m^{-2}) followed 25 cm x 10 cm and 25 cm x 20 cm (1764.6 and 1776.2 g m^{-2}, respectively). Significantly lower TDM (1619.9 g m^{-2}) were recorded in 25 cm x 25 cm.

Total dry matter Production differed significantly due to the interaction of planting geometry and fertilizer levels under drip fertigation. 25 cm x 15 cm with 100 per cent RDF (F_3S_2) produced significantly higher total dry matter production (2546.0 g m^{-2}) followed by planting geometry of 25 cm x 10 cm with 100 per cent RDF (2361.8 g m^{-2}) and planting geometry of 25 cm x 20 cm with 100 per cent RDF (2285.8 g m^{-2}). Significantly lower yield was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (451.9 g m^{-2}).

4.1.4.d Total dry matter production (g m^{-2}) at 120 DAS

Among the fertilizer levels, 100 per cent RDF recorded significantly higher total dry matter production (3085.4 g m^{-2}) as compared to 50 and 75 per cent RDF (1655.5 and 2088.4 g m^{-2}, respectively).

Planting geometry of 25 cm x 15 cm recorded significantly higher total dry matter production (2506.5 g m^{-2}) as compared to all other planting geometries. The planting geometry of 25 cm x 25 cm was found significantly lower production of total dry matter production (1971.7 g m^{-2}).

Total dry matter Production differed significantly due to the interaction of planting geometry and Fertilizer levels under drip fertigation. Planting geometry of 25 cm x 15 cm with 100 per cent RDF produced significantly higher total dry matter production (3389.4 g m^{-2}) followed by planting geometry of 25 cm x 10 cm with 100 per cent RDF (3315.2 g m^{-2}). Significantly lower yield was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (1298.9 g m^{-2}).

4.1.4.e Total dry matter production (g m^{-2}) at maturity

Among the fertilizer levels, 100 per cent RDF recorded significantly higher total dry matter production (3159.0 g m^{-2}) as compared to 50 and 75 per cent RDF (1660.8 and 2206.5 g m^{-2}, respectively).

Planting geometry of 25 cm x 15 cm recorded significantly higher total dry matter production (2663.6 g m^{-2}) as compared to planting geometry of 25 cm x 25 cm (2031.5 g m^{-2}). The planting geometry of 25 cm x 15 cm and 25 cm x 10 cm and 25 cm x 20 cm were found statistically on par with each other (2663.6, 2316.8 and 2356.4 g m^{-2}, respectively).

Total dry matter Production differed significantly due to the interaction of planting geometry and Fertilizer levels under drip fertigation. Planting geometry of 25 cm x 15 cm with 100 per cent RDF (F_3S_2) produced significantly higher total dry matter production (3488.3 g m^{-2}) followed by planting geometry of 25 cm x 10 cm with 100 per cent RDF (3195.1 g m^{-2}) and planting geometry of 25 cm x 20 cm with 100 per cent RDF (3367.1 g m^{-2}).Significantly lower yield was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (1365.7 g m^{-2}).

4.1.5 Leaf area (cm^2 $hill^{-1}$)

The data on leaf area per hill of rice observed at 30, 60, 90, 120 DAS at maturity as influenced by different treatments under study are presented in Table 4.5.

Significant differences among the treatments were noticed in leaf area per hill at all the stages of crop growth.

4.1.5.a Leaf area (cm^2 $hill^{-1}$) at 30 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area (62.22 cm^2) followed by 75 per cent RDF (46.88 cm^2) and significantly lower leaf area (36.56 cm^2) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area. Significantly higher leaf area (54.60 cm^2) was noticed in 25 cm x 25 cm and recorded significantly lower leaf area (42.41 cm^2) in 25 cm x 10 cm which was on par with 25 cm x 15 cm (48.71 cm^2) and 25 cm x 20 cm (48.93 cm^2).

Significant difference in leaf area was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 x 25 cm with 100 per cent RDF has recorded significantly higher leaf area (68.07 cm^2) followed by 25 cm x 20 cm and 25 cm x 15 cm with 100 per cent RDF (64.67 cm^2 and 62.00 cm^2). Significantly lower leaf area was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (30.67 cm^2).

4.1.5.b Leaf area (cm^2 $hill^{-1}$) at 60 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area (938.2 cm^2) which was on par with 75 per cent RDF (829.9 cm^2) and significantly lower leaf area (750.7 cm^2) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area. Significantly higher leaf area (911.9 cm^2) was noticed in 25 cm x 25 cm followed by 25 cm x 15 cm (836.6 cm^2) and 25 cm x 20 cm (831.4 cm^2). Significantly lower leaf area recorded in 25 cm x 10 cm (778.3 cm^2).

Significant difference in leaf area was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher leaf area (1014.4 cm^2) and significantly lower leaf area was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (700.3 cm^2).

4.1.5.c Leaf area (cm^2 hill^{-1}) at 90 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area (3196.8 cm^2) and significantly lower leaf area (2219.7 cm^2) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area. Significantly higher leaf area (2957.3) was noticed in 25 cm x 25 cm which was on par with 25 cm x 15 cm (2650.4 cm^2) and 25 cm x 20 cm (2719.1 cm^2). Significantly lower leaf area recorded in 25 cm x 10 cm (2466.6 cm^2)

Significant difference in leaf area was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher leaf area (3554.2 cm^2) and significantly lower leaf area (1744.8 cm^2) was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.1.5.d Leaf area (cm^2 hill^{-1}) at 120 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area (2138.9 cm^2) and significantly lower leaf area (1620.0 cm^2) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area. Significantly higher leaf area (2059.9 cm^2) was noticed in 25 cm x 25 cm which was on par with 25 cm x 15 cm (1879.8 cm^2), 25 cm x 20 cm (1836.8 cm^2) and significantly lower leaf area recorded in 25 cm x 10 cm (1755.1 cm^2).

Significant difference in leaf area was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher leaf area (2501.0 cm^2) which was on par with 25 cm x 20 cm with 100 per cent RDF (2113.5 cm^2). Significantly lower leaf area was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (1486.5 cm^2).

4.1.5.e Leaf area (cm^2 hill^{-1}) at maturity

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area (2046.6 cm^2) and significantly lower leaf area (1618.7 cm^2) was recorded in 50 per cent RDF.

Table 4.5: Leaf area (cm^2 $hill^{-1}$) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At Maturity
Fertigation level (F)					
F_1	36.56	750.7	2219.7	1620.0	1618.7
F_2	46.88	829.9	2678.5	1889.8	1787.3
F_3	62.22	938.2	3196.8	2138.9	2046.6
S.Em ±	3.48	39.1	140.9	79.6	92.6
CD at 5 %	10.17	114.3	411.3	232.5	270.3
Planting geometry (S)					
S_1	42.4	778.3	2466.6	1755.1	1731.4
S_2	48.2	836.6	2650.4	1879.8	1760.9
S_3	48.9	831.4	2719.1	1836.8	1770.2
S_4	54.6	911.9	2957.3	2059.9	2007.8
S.Em ±	4.0	45.2	162.7	91.9	92.6
CD at 5 %	11.7	132.0	475.0	268.4	270.3
Interactions (F X S)					
F_1S_1	33.73	702.9	1956.5	1496.5	1514.7
F_1S_2	34.42	706.0	2117.3	1502.6	1567.5
F_1S_3	39.00	771.1	2332.7	1726.1	1672.8
F_1S_4	39.07	802.7	2472.3	1754.8	1720.0
F_2S_1	38.67	778.5	2424.7	1836.8	1750.9
F_2S_2	43.80	849.7	2617.3	1898.3	1755.3
F_2S_3	48.40	861.9	2826.7	1900.3	1782.7
F_2S_4	56.67	871.0	2845.5	1923.9	1860.4
F_3S_1	54.13	867.0	2857.8	1925.9	1875.9
F_3S_2	62.00	905.8	3001.2	2015.1	1854.6
F_3S_3	64.67	954.5	3374.3	2113.5	2013.1
F_3S_4	68.07	1014.4	3554.2	2501.0	2442.9
Control	30.67	700.3	1744.8	1486.5	1496.3
S.Em ±	6.96	78.3	281.8	159.3	160.4
CD at 5 %	20.34	228.6	822.7	465.0	468.2
CV (%)	13.61	12.1	11.1	13.7	14.3

Note: Fertilizer levels **(F)**: F_1: 50 per cent RDF, F_2: 75 per cent RDF, F_3: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S):** S_1: 25 cm x 10 cm, S_2: 25 cm x 15 cm, S_3: 25 cm x 20 cm, S_4: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

Planting geometry significantly influenced the leaf area. Significantly higher leaf area (2007.8 cm^2) was noticed in 25 cm x 25 cm which was on par with 25 cm x 15 cm (1760.9 cm^2) and 25 cm x 20 cm (1770.2 cm^2) and significantly lower leaf area recorded in 25 cm x 10 cm (1731.4 cm^2).

Significant difference in leaf area was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher leaf area (2442.9 cm^2) which was on par with 25 cm x 20 cm with 100 per cent RDF (2013.1 cm^2) and significantly lower leaf area was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (1496.3 cm^2).

4.1.6 Leaf area index

The data on leaf area index of rice observed at 30, 60, 90, 120 DAS at maturity as influenced by different treatments under study are presented in Table 4.6.

Significant differences among the treatments were noticed in leaf area index at all the stages of crop growth.

4.1.6.a Leaf area index at 30 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area index (0.16) and significantly lower leaf area index (0.10) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area index. Significantly higher leaf area index (0.21) was noticed in 25 cm x 10 cm and recorded significantly lower leaf area index (0.07) in 25 cm x 25 cm.

Significant difference in leaf area index was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 x 10 cm with 100 per cent RDF has recorded significantly higher leaf area index (0.27) and significantly lower leaf area index was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (0.05).

4.1.6.b Leaf area index at 60 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area index (2.47) and significantly lower leaf area index (2.05) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area index. Significantly higher leaf area index (3.49) was noticed in 25 cm x 10 cm and significantly lower leaf area index recorded in 25 cm x 25 cm (1.30).

Significant difference in leaf area index was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 10 cm with 100 per cent RDF has recorded significantly higher leaf area index (4.17) and significantly lower leaf area index was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (1.12).

4.1.6.c Leaf area index at 90 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area index (4.50) and significantly lower leaf area index (6.22) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area index. Significantly higher leaf area index (6.55) was noticed in 25 cm x 10 cm and significantly lower leaf area index recorded in 25 cm x 25 cm (4.73).

Significant difference in leaf area index was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 10 cm with 100 per cent RDF has recorded significantly higher leaf area index (6.83) and significantly lower leaf area index (2.79) was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.1.6.d Leaf area index at 120 DAS

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area index (5.33) and significantly lower leaf area index (4.35) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the leaf area index. Significantly higher leaf area index (6.01) was noticed in 25 cm x 10 cm and significantly lower leaf area index recorded in 25 cm x 25 cm (3.30).

Significant difference in leaf area index was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 10 cm with 100 per cent RDF has recorded significantly higher leaf area index (6.70) and significantly lower leaf area index was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (2.38).

Table 4.6: Leaf area index (LAI) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At Maturity
Fertilizer level (F)					
F_1	0.10	2.05	4.50	4.35	4.36
F_2	0.13	2.15	5.22	4.82	4.56
F_3	0.16	2.47	6.22	5.33	5.10
S.Em ±	0.01	0.11	0.31	0.17	0.19
CD at 5 %	0.03	0.31	0.89	0.48	0.54
Planting geometry (S)					
S_1	0.21	3.49	6.55	6.01	5.88
S_2	0.14	2.32	6.42	4.81	4.60
S_3	0.10	1.77	6.05	4.21	4.02
S_4	0.07	1.30	4.73	3.30	3.21
S.Em ±	0.01	0.12	0.35	0.19	0.21
CD at 5 %	0.03	0.36	1.03	0.56	0.63
Interactions (F X S)					
F_1S_1	0.13	2.81	6.16	5.99	5.59
F_1S_2	0.10	2.19	5.65	4.01	4.18
F_1S_3	0.10	2.06	5.22	4.60	4.46
F_1S_4	0.06	1.13	3.96	2.81	2.75
F_2S_1	0.23	3.48	6.70	6.03	5.89
F_2S_2	0.13	2.23	5.98	5.06	4.68
F_2S_3	0.08	1.56	5.65	3.80	3.57
F_2S_4	0.07	1.33	4.55	3.08	2.98
F_3S_1	0.27	4.17	6.83	6.70	6.50
F_3S_2	0.17	2.55	6.40	6.02	4.95
F_3S_3	0.11	1.70	5.75	4.23	4.03
F_3S_4	0.10	1.45	5.69	4.00	3.91
Control	0.05	1.12	2.79	2.38	2.39
S.Em ±	0.02	0.22	0.61	0.33	0.37
CD at 5 %	0.05	0.63	1.79	0.97	1.09
CV (%)	10.41	9.82	10.59	12.12	9.56

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

4.1.6.e Leaf area index at maturity

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher leaf area index (5.10) and significantly lower leaf area index (4.36) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the number of leaves. Significantly higher leaf area index (6.86) was noticed in 25 cm x 10 cm and significantly lower leaf area index recorded in 25 cm x 25 cm (3.21).

Significant difference in leaf area index was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher leaf area index (6.50) and significantly lower leaf area index was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (2.39).

4.1.7 Leaf area duration (days)

The data on LAD as influenced by planting geometry and fertilizer levels in drip fertigated aerobic rice between 30-60, 60-90, 90-120 DAS and 120 DAS-maturity are presented in Table 4.7.

The trend in observation on leaf area duration was similar to that of leaf area index. Among the different fertilizer level treatments in drip fertigation with 100 per cent RDF recorded significantly highest leaf area duration (39.44, 129.19, 168.35 and 152.59 days at 30-60, 60-90, 90-120 DAS and 120 DAS-maturity, respectively) and significantly lower leaf area duration was recorded in 50 per cent RDF (32.21, 108.15, 142.70, and 129.21 days at 30-60, 60-90, 90-120 DAS and 120 DAS-maturity, respectively).

Planting geometry significantly influenced the leaf area duration. Significantly higher leaf area duration (55.59, 144.02, 185.22, and 184.35 days at 30-60, 60-90, 90-120 DAS and 120 DAS-maturity, respectively) was noticed in 25 cm x 10 cm and significantly lower leaf area duration (20.68, 90.54, 120.41 and 97.63 days at 30-60, 60-90, 90-120 DAS and 120 DAS-maturity, respectively) recorded in 25 cm x 25 cm.

Significant difference in leaf area duration was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 10 cm with 100 per cent RDF has recorded significantly higher leaf area duration (66.61, 164.76, 202.79 and 213.11 at 30-60, 60-90, 90-120 DAS and 120 DAS-maturity, respectively) and significantly lower leaf area duration (17.54, 58.69, 77.55 and 71.59 at 30-60, 60-90, 90-120 DAS and 120 DAS-maturity, respectively) was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF.

Table 4.7: Leaf area duration (LAD days) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatment	30- 60 DAS	60- 90 DAS	90- 120 DAS	120 DAS- at maturity
Fertilizer level (F)				
F_1	32.21	108.15	142.70	129.21
F_2	34.16	114.34	149.40	135.18
F_3	39.44	129.19	168.35	152.59
S.Em ±	1.61	4.27	4.62	3.94
CD at 5 %	4.70	12.47	13.48	11.51
Planting geometry (S)				
S_1	55.49	144.02	185.22	184.35
S_2	36.89	124.67	162.03	141.25
S_3	28.02	109.69	146.27	123.42
S_4	20.68	90.54	120.41	97.63
S.Em ±	1.86	4.93	5.33	4.55
CD at 5 %	5.43	14.40	15.57	13.29
Interactions (F X S)				
F_1S_1	44.20	129.57	177.18	174.68
F_1S_2	34.47	117.60	144.80	122.81
F_1S_3	32.41	109.16	147.36	135.96
F_1S_4	17.77	76.28	101.45	83.40
F_2S_1	55.66	137.75	175.70	165.27
F_2S_2	35.41	123.17	165.63	146.15
F_2S_3	24.52	108.16	141.81	110.49
F_2S_4	21.04	88.29	114.47	90.83
F_3S_1	66.61	164.76	202.79	213.11
F_3S_2	40.77	133.23	175.65	154.79
F_3S_3	27.14	111.74	149.64	123.80
F_3S_4	23.23	107.04	145.32	118.66
Control	17.54	58.69	77.55	71.59
S.Em ±	3.22	8.55	9.24	7.88
CD at 5 %	9.40	24.94	26.96	23.01
CV (%)	11.19	12.12	10.00	9.57

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

4.1.8 Crop growth rate (g m^{-2} day^{-1})

Data on crop growth rate (CGR) as influenced by planting geometry and fertilizer levels of drip fertigated aerobic rice are presented in Table 4.8.

The crop growth rate increased progressively from 30-60 DAS to 60-90 DAS and then gradually decreased between 90-120 DAS and 120 DAS- till maturity in all the treatments. But non-significant results were observed in 120 DAS- maturity.

The application of fertilizer at different levels through drip fertigation showed the significant differences in crop growth rate. The 100 per cent RDF through drip fertigation recorded significantly higher crop growth (27.87, 47.62 and 26.10 g m^{-2} day^{-1} at 30-60, 60-90, 90-120 DAS, respectively) and significantly lower crop growth rate (17.23, 28.16, and 7.58 at 30-60, 60-90, 90-120 DAS, respectively) was recorded in 50 per cent RDF. Between 90-120 DAS the data due to treatment effect were non-significant, however higher crop growth rate was observed in 100 per cent RDF (5.50 g m^{-2} day^{-1}), planting geometry of 25 cm x 15 cm (4.28 g m^{-2} day^{-1}) and among interaction 25 cm x 15 cm with 100 per cent RDF (8.16 g m^{-2} day^{-1}).

Planting geometry significantly influenced the crop growth rate. Significantly higher crop growth rate (23.41, 39.13 and 21.09 g m^{-2} day^{-1} at 30-60, 60-90, 90-120 DAS, respectively) was noticed in 25 cm x 15 cm and significantly lower crop growth rate recorded in 25 cm x 25 cm (20.38, 32.76, and 10.94 g m^{-2} day^{-1} at 30-60, 60-90, 90-120 DAS, respectively).

Significant difference in crop growth rate was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher crop growth rate (30.44, 52.82 and 31.78 g m^{-2} day^{-1} at 30-60, 60-90, 90-120 DAS) and significantly lower crop growth rate (14.51 and 21.69 at 30-60 and 60-90, respectively) was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF. But in 90-120 DAS significantly lower crop growth rate (5.47 g m^{-2} day^{-1}) was observed in 25 cm x 10 cm with 50 per cent RDF.

4.2 Yield parameters of aerobic rice

The data on yield parameters *viz.*, productive tillers hill^{-1}, grain yield g hill^{-1}, panicle length (cm), panicle weight (g), 1000 grain weight (g), total number of grains panicle^{-1}, filled grains panicle^{-1}, chaffy grains panicle^{-1}, per cent chaffyness, grain yield, straw yield and harvest index as influenced by different treatments are presented in Tables 4.9 to 4.11.

Table 4.8: Crop growth rate (g m^{-2} day^{-1}) of aerobic rice at different growth stages as influenced by planting geometry and fertilizer levels under drip fertigation

Treatment	30- 60 DAS	60- 90 DAS	90- 120 DAS	120- at maturity
Fertilizer level (F)				
F_1	17.23	28.16	7.58	1.03
F_2	20.31	32.71	14.86	2.35
F_3	27.87	47.62	26.10	5.50
S.Em ±	0.70	1.86	2.31	1.54
CD at 5 %	2.06	5.43	6.76	NS
Planting geometry (S)				
S_1	21.49	36.37	15.99	2.10
S_2	23.41	39.13	21.09	4.28
S_3	21.94	36.38	16.72	2.32
S_4	20.38	32.76	10.94	3.15
S.Em ±	0.81	2.15	2.67	1.12
CD at 5 %	2.37	6.26	7.80	NS
Interactions (F X S)				
F_1S_1	15.67	26.82	5.47	0.55
F_1S_2	18.47	31.12	10.13	1.73
F_1S_3	18.36	28.36	10.11	0.84
F_1S_4	16.42	26.32	6.63	0.99
F_2S_1	20.57	33.05	16.38	1.33
F_2S_2	21.32	33.45	21.35	2.93
F_2S_3	20.07	33.06	11.60	1.86
F_2S_4	19.26	31.26	10.13	3.30
F_3S_1	28.22	49.25	28.12	4.42
F_3S_2	30.44	52.82	31.78	8.16
F_3S_3	27.37	47.72	28.45	4.26
F_3S_4	25.46	40.68	16.05	5.16
Control	14.51	21.69	6.54	2.28
S.Em ±	1.41	3.72	4.63	2.70
CD at 5 %	4.11	10.85	13.51	NS
CV (%)	10.60	12.95	13.92	10.41

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

4.2.1 Number of Productive tillers (m^{-2})

The data on number of productive tillers $m^{-2}$of aerobic rice as influence by planting geometry and fertilizer levels through drip fertigation are presented in the table 4.9.

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher number of productive tillers (601.73) and significantly lower number of productive tillers (330.55) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the number of productive tillers. Significantly higher number of productive tillers (516.61) was noticed in 25 cm x 15 cm and significantly lower number of productive tillers recorded in 25 cm x 25 cm (394.13).

Significant difference in number of productive tillers was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher number of productive tillers (719.47) and significantly lower number of productive tillers was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (248.8).

4.2.2 Grain yield (g $hill^{-1}$)

The data on grain yield (g $hill^{-1}$**)** of aerobic rice as influence by planting geometry and fertilizer levels through drip fertigation are presented in the table 4.9.

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher grain yield (31.72 g $hill^{-1}$) and significantly lower grain yield (15.66 g $hill^{-1}$) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the grain yield. Significantly higher grain yield (27.12 g $hill^{-1}$) was noticed in 25 cm x 25 cm and significantly lower grain yield recorded in 25 cm x 10 cm (20.94 g $hill^{-1}$).

Significant difference in grain yield per plant was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher grain yield (34.75 g $hill^{-1}$) and significantly lower grain yield was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (10.25 g $hill^{-1}$).

4.2.3 Panicle length (cm)

The data on panicle length (cm) of aerobic rice as influence by planting geometry and fertilizer levels through are presented in the table 4.9.

Table 4.9: Yield parameters of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation at harvest

Treatments	No. of Productive Tillers (no. m^{-2})	Grain yield (g $hill^{-1}$)	Panicle length (cm)	panicle weight (g)	1000-grain weight
Fertilizer levels (F)					
F_1	330.55	15.66	18.84	2.39	20.63
F_2	424.69	24.54	19.17	2.71	21.18
F_3	601.73	31.72	19.81	3.03	23.11
S.Em ±	12.45	1.31	0.09	0.019	0.08
CD at 5 %	36.35	3.82	0.28	0.055	0.233
Planting geometry (S)					
S_1	447.70	20.94	19.13	2.59	21.24
S_2	516.61	23.07	19.24	2.73	21.63
S_3	450.84	24.77	19.25	2.67	21.68
S_4	394.13	27.12	19.46	2.84	22.01
S.Em±	14.38	1.51	0.11	0.022	0.092
CD at 5 %	41.97	4.41	0.32	0.063	0.269
Interactions (F x S)					
F_1S_1	283.84	11.63	18.75	2.32	20.50
F_1S_2	377.67	14.99	18.78	2.37	20.53
F_1S_3	342.93	16.85	18.90	2.39	20.77
F_1S_4	317.76	19.16	18.94	2.48	20.73
F_2S_1	432.6	22.01	19.00	2.51	21.00
F_2S_2	452.69	23.87	19.16	2.68	21.17
F_2S_3	411.73	24.83	19.21	2.77	21.23
F_2S_4	401.73	27.44	19.30	2.88	21.30
F_3S_1	626.67	29.16	19.63	2.90	22.20
F_3S_2	719.47	30.35	19.70	2.94	23.10
F_3S_3	597.87	32.63	19.79	3.10	23.17
F_3S_4	462.91	34.75	20.13	3.17	23.98
Control	248.8	10.25	18.6	2.29	19.60
S.Em±	24.91	2.61	0.19	0.037	0.159
CD at 5 %	72.70	7.63	0.55	0.109	0.465
CV (%)	9.11	11.25	4.26	4.36	5.45

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher panicle length (19.81 cm) and significantly lower panicle length (18.84 cm) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the panicle length. Significantly higher panicle length (27.12 cm) was noticed in 25 cm x 25 cm which was on par with 25 cm x 15 cm (23.07 cm), 25 cm x 20 cm (24.77 cm) and significantly lower panicle length (19.14 cm) recorded in 25 cm x 10 cm.

Significant difference in panicle length was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher panicle length (20.13 cm) and significantly lower panicle length was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (18.6 cm).

4.2.4 Panicle weight (g)

The data on panicle weight (g) of aerobic rice as influence by planting geometry and fertilizer levels through drip fertigation are presented in the table 4.9.

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher panicle weight (3.03 g) and significantly lower panicle weight (2.39 g) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the panicle weight. Significantly higher panicle weight (2.84 g) was noticed in 25 cm x 25 cm and significantly lower panicle weight (2.59 g) recorded in 25 cm x 10 cm.

Significant difference in panicle weight was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher panicle weight (3.17 g) and significantly lower panicle weight was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (2.29 g).

4.2.5 Test weight (g)

The data on test weight (g) of aerobic rice as influence by planting geometry and fertilizer levels through drip fertigation are presented in the table 4.9.

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher test weight (23.11 g) and significantly lower test weight (20.63 g) was recorded in 50 per cent RDF.

Planting geometry significantly influenced test weight. Significantly higher test weight (22.01 g) was noticed in 25 cm x 25 cm and significantly lower test weight (21.24 g) recorded in 25 cm x 10 cm.

Significant difference in test weight was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher test weight (23.98 g) and significantly lower panicle weight was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application RDF (19.6 g).

4.2.6 Total grains panicle^{-1}

The data on total grains panicle^{-1} of aerobic rice as not significantly influenced by planting geometry and fertilizer levels through drip fertigation. There is no significant influence of planting geometry and fertilizer levels through drip fertigation.

4.2.7 Filled grains panicle^{-1}

The data on filled grains panicle^{-1} of aerobic rice as influenced by planting geometry and fertilizer levels through drip fertigation are presented in the table 4.10.

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher filled grains (124.4) and significantly lower filled grains (109.47) were recorded in 50 per cent RDF.

Planting geometry significantly influenced the filled grains. Significantly higher filled grains (120.76) were noticed in 25 cm x 25 cm and significantly lower filled grains (115.42) recorded in 25 cm x 10 cm.

Significant difference in filled grains was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher filled grains (129.40) and significantly lower filled grains was observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF (104.00).

4.2.8 Chaffy grains panicle^{-1}

The data on chaffy grains panicle^{-1} of aerobic rice as influenced by planting geometry and fertilizer levels through drip fertigation are presented in the table 4.10.

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 50 per cent RDF through drip fertigation recorded significantly higher chaffy grains (32.42) and significantly lower chaffy grains (18.68) were recorded in 100 per cent RDF.

Planting geometry significantly influenced the chaffy grains panicle^{-1}. Significantly higher chaffy grains (27.82) were noticed in 25 cm x 10 cm and significantly lower chaffy grains (22.18) recorded in 25 cm x 25 cm.

Significant difference in chaffy grains was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with surface irrigation has recorded significantly higher chaffy grains (42.33) and significantly lower chaffy grains was observed in planting geometry of 25 cm x 25 cm with 100 per cent RDF (17.27).

4.2.9 Per cent chaffyness (%)

The data on per cent chaffyness of aerobic rice as influenced by planting geometry and fertilizer levels through drip fertigation are presented in the table 4.10.

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly lower chaffyness per cent (13.07 %) and significantly lower chaffyness per cent (22.77 %) were recorded in 50 per cent RDF.

Planting geometry significantly influenced the chaffyness. Significantly higher chaffyness per cent (19.28 %) were noticed in 25 cm x 10 cm and significantly lower chaffyness per cent (15.28 %) recorded in 25 cm x 25 cm.

Significant difference in chaffyness per cent was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF has recorded significantly higher chaffyness per cent (28.93 %) and significantly lower chaffy grains was observed in planting geometry of 25 cm x 25 cm with 100 per cent RDF (11.76 %).

4.2.10 Grain yield (kg ha^{-1})

The data on grain yield of aerobic rice as influenced by planting geometry and fertilizer levels through drip fertigation are presented in Table 4.11. The application of fertilizer in different levels through drip fertigation showed significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher grain yield (6115 kg ha^{-1}) and recorded significantly lower grain yield in 50 per cent RDF (4823 kg ha^{-1}) .Which was on par with the 75 per cent RDF through drip fertigation (5538 kg ha^{-1}).

Planting geometry significantly influenced the grain yield. Significantly higher grain yield (5954 kg ha^{-1}) was noticed in 25 cm x 15 cm followed by 25 cm x 20 cm (5428 kg ha^{-1}) and significantly lower yield (5168 kg ha^{-1}) was observed in 25 cm x 25 cm spacing.

Table 4.10: Grain parameters of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation at harvest

Treatment	Total grains (panicle^{-1})	Filled grains (panicle^{-1})	Chaffy grains (panicle^{-1})	Per cent chaffyness
Fertilizer levels (F)				
F_1	141.22	109.47	32.42	22.77
F_2	142.23	118.15	24.50	17.18
F_3	142.75	124.4	18.68	13.07
S.Em±	0.73	0.46	0.53	0.30
CD at 5 %	NS	1.33	1.54	0.87
Planting geometry (S)				
S_1	142.53	115.42	27.82	19.28
S_2	140.73	116.04	26.11	18.99
S_3	142.07	117.13	23.69	16.83
S_4	142.93	120.76	22.18	15.58
S.Em±	0.84	0.53	0.61	0.35
CD at 5 %	NS	1.54	1.77	1.01
Interactions (F x S)				
F_1S_1	142.33	104.13	40.87	28.15
F_1S_2	144.80	110.13	34.67	23.94
F_1S_3	138.53	110.87	27.67	19.95
F_1S_4	139.20	112.73	26.47	19.02
F_2S_1	140.53	114.60	25.93	18.46
F_2S_2	143.47	118.67	24.80	17.28
F_2S_3	142.00	119.20	24.47	17.01
F_2S_4	142.93	120.13	22.80	15.95
F_3S_1	142.27	121.53	20.73	14.58
F_3S_2	140.20	121.60	18.60	13.26
F_3S_3	141.87	125.07	18.13	12.66
F_3S_4	146.67	129.40	17.27	11.76
Control	142.67	104.00	42.33	28.93
S.Em±	1.46	0.91	1.05	0.60
CD at 5 %	4.25	2.66	3.07	1.74
CV (%)	5.92	4.97	6.34	8.15

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

Significant difference in grain yield was observed due to interaction of planting geometry and fertilizer levels, planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation recorded significantly higher grain yield (6762 kg ha^{-1}) which was on par with 25 cm x 10 cm with 100 per cent RDF (6105 kg ha^{-1}), 25 cm x 20 cm with 100 per cent RDF (5994 kg ha^{-1}) and 25 cm x 25 cm with 100 per cent RDF (5759 kg ha^{-1}). Significantly lower yield (4028 kg ha^{-1}) was observed in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF which was on par with 25 cm x 10 cm with 50 per cent RDF (4487 kg ha^{-1}).

4.2.11 Straw yield (kg ha^{-1})

The data on straw yield of aerobic rice as influence by planting geometry and fertilizer levels through drip fertigation are presented in Table 4.11. The application of fertilizer in different levels through drip fertigation showed significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher straw yield (8792 kg ha^{-1}) and recorded significantly lower straw yield in 50 per cent RDF (6927 kg ha^{-1}).Which was on par with the 75 per cent RDF through drip fertigation (7811 kg ha^{-1}).

Planting geometry significantly influenced the straw yield. Significantly higher straw yield (8297 kg ha^{-1}) was noticed in 25 cm x 15 cm followed by 25 cm x 20 cm (7863 kg ha^{-1}) and significantly lower yield (7463 kg ha^{-1}) was observed in 25 cm x 25 cm spacing.

Significant difference in straw yield was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation has recorded significantly higher straw yield (9186 kg ha^{-1}) which is on par with 25 cm x 10 cm with 100 per cent RDF (8914 kg ha^{-1}), 25 cm x 20 cm with 100 per cent RDF (8671 kg ha^{-1}) and 25 cm x 25 cm with 100 per cent RDF (8389 kg ha^{-1}). Significantly lower yield (6356 kg ha^{-1}) was observed in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF which was on par with 25 cm x 10 cm with 50 per cent RDF (6475 kg ha^{-1}).

4.2.12 Harvest Index

The data pertaining to harvest index of aerobic rice as influenced by planting geometry and drip fertigation are presented in Table 4.11. The results revealed that, there was no significance in harvest index among different treatments.

Table 4.11: Grain and straw yield (kg ha^{-1}) of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation at harvest

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Fertilizer level (F)			
F_1	4823	6927	0.412
F_2	5538	7811	0.413
F_3	6155	8792	0.414
S.Em ±	226	243	0.013
CD at 5 %	661	708	NS
Planting geometry (S)			
S_1	5416	7750	0.409
S_2	5954	8297	0.420
S_3	5482	7863	0.411
S_4	5168	7463	0.411
S.Em ±	261	280	0.015
CD at 5 %	762	817	NS
Interactions (F X S)			
F_1S_1	4487	6475	0.409
F_1S_2	5349	7370	0.424
F_1S_3	4966	7268	0.404
F_1S_4	4489	6596	0.409
F_2S_1	5656	7861	0.413
F_2S_2	5753	8336	0.410
F_2S_3	5487	7651	0.422
F_2S_4	5254	7394	0.416
F_3S_1	6105	8914	0.406
F_3S_2	6762	9186	0.426
F_3S_3	5994	8671	0.407
F_3S_4	5759	8398	0.408
Control	4028	6356	0.388
S.Em ±	452	485	0.026
CD at 5 %	1321	1416	NS
CV (%)	12.42	10.03	9.92

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

4.3 Available nutrient status of soil after harvest

The data on soil fertility status of drip fertigated aerobic rice as influence by planting geometry and fertilizer levels are presented in the table 4.12.

4.3.1 Available nitrogen (kg ha^{-1})

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher available nitrogen (307.79 kg ha^{-1}) and significantly lower available nitrogen (279.99 kg ha^{-1}) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the available nitrogen. Significantly higher available nitrogen (299.96 kg ha^{-1}) was noticed in 25 cm x 25 cm and significantly lower available nitrogen (288.96 kg ha^{-1}) recorded in 25 cm x 10 cm.

Significant difference in available nitrogen was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher available nitrogen (315.19 kg ha^{-1}) and significantly lower available nitrogen (274.51 kg ha^{-1}) was observed in 25 cm x 10 cm with 50 per cent RDF.

4.3.2 Available Phosphorous (kg ha^{-1})

The application of fertilizer in different levels through drip fertigation showed the significant differences. The 100 per cent RDF through drip fertigation recorded significantly higher available phosphorous (36.13 kg ha^{-1}) and significantly lower available Phosphorous (26.16 kg ha^{-1}) was recorded in 50 per cent RDF.

Planting geometry significantly influenced the available phosphorous. Significantly higher available Phosphorous (34.04 kg ha^{-1}) was noticed in 25 cm x 25 cm and significantly lower available phosphorous (28.39 kg ha^{-1}) was recorded in 25 cm x 10 cm.

Table 4.12: Soil nutrient (kg ha^{-1}) status of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatment	N	$P_2 0_5$	$K_2 0$
Fertilizer levels (F)			
F_1	279.99	26.16	217.13
F_2	294.40	33.05	225.77
F_3	307.79	36.13	234.43
S.Em±	0.72	0.75	1.25
CD at 5 %	2.12	2.18	3.63
Planting geometry (S)			
S_1	288.96	28.39	217.02
S_2	291.87	31.36	223.71
S_3	295.75	33.32	228.78
S_4	299.66	34.04	233.61
S.Em±	0.84	0.86	1.44
CD at 5 %	2.44	2.52	4.20
Interactions (F X S)			
F_1S_1	274.51	21.26	206.42
F_1S_2	278.31	25.70	216.42
F_1S_3	281.29	28.34	220.30
F_1S_4	285.83	29.34	225.39
F_2S_1	290.96	30.22	218.16
F_2S_2	293.55	32.17	223.41
F_2S_3	295.14	34.52	228.54
F_2S_4	297.95	35.27	232.98
F_3S_1	301.41	33.69	226.47
F_3S_2	303.73	36.22	231.30
F_3S_3	310.80	37.11	237.52
F_3S_4	315.19	37.51	242.45
Control	306.29	38.20	239.54
S.Em±	1.45	1.49	2.49
CD at 5 %	4.23	4.36	7.27
CV (%)	8.75	7.40	9.75

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

Significant difference in available phosphorous was observed due to interaction of planting geometry and fertilizer levels. Planting geometry of 25 cm x 25 cm with 100 per cent RDF recorded significantly higher available phosphorous (37.51 kg ha^{-1}) and significantly lower available phosphorous (21.26 kg ha^{-1}) was observed in 25 cm x 10 cm with 50 per cent RDF.

4.3.3 Available Potassium (kg ha^{-1})

The fertilizer application in different levels through the drip fertigation has significant differences. Among the different levels of fertilizers 100 per cent RDF recorded significantly higher available potassium (234.43 kg ha^{-1}) and significantly lower available potassium (217.13 kg ha^{-1}) was recorded in 50 per cent RDF.

Among the different planting geometries, 25 cm x 25 cm planting geometry has recorded significantly higher available potassium in soil (233.61 kg ha^{-1}) and significantly lower available potassium (217.02 kg ha^{-1}) was recorded in 25 cm x 10 cm.

The interaction of planting geometry and fertilizer levels has the significant differences on available potassium in soil. Planting geometry of 25 cm x 25 cm with 100 per cent RDF through drip fertigation has recorded significantly higher available potassium (242.45 kg ha^{-1}) and significantly lower available potassium (206.42 kg ha^{1}) was noticed in 25 cm x 10 cm with 50 per cent RDF.

4.4 Nutrient uptake (kg ha^{-1})

The data on nutrient uptake as influenced by planting geometry and fertilizer levels in drip fertigation in aerobic rice at harvest are presented in Table 4.13 to 4.15. In general, planting geometry of 25 cm x 1 5 cm with 100 per cent RDF has recorded higher nutrient uptake.

4.4.1 Nitrogen uptake by grain (kg ha^{-1})

The different levels of application of fertilizers through drip fertigation had significant influence on nitrogen uptake by grain (Table 4.13). The 100 per cent RDF has recorded significantly higher (73.86 kg ha^{-1}) nitrogen uptake by grain and significantly lower (39.07 kg ha^{-1}) nitrogen uptake by grain was observed in 50 per cent RDF through drip fertigation.

Planting geometry under drip fertigation significantly influenced grain nitrogen uptake. Planting geometry of 25 cm x 15 cm was recorded significantly higher grain nitrogen uptake (61.29 kg ha^{-1}) which was on par with 25 cm x 10 cm (55.01 kg ha^{-1}) and 25 cm x 20 cm (55.31 kg ha^{-1}). Significantly lower nitrogen uptake (52.32 kg ha^{-1}) by grain was recorded in planting geometry of 25 cm x 25 cm.

Table 4.13: Nitrogen uptake (kg ha^{-1}) by aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Grain	Straw	Total
Fertilizer levels (F)			
F_1	39.07	38.10	77.17
F_2	54.27	47.65	101.92
F_3	73.86	62.43	136.29
S.Em±	2.34	1.54	2.71
CD at 5 %	6.83	4.50	7.92
Planting geometry (S)			
S_1	55.01	48.95	103.97
S_2	61.29	52.80	112.49
S_3	55.31	49.41	104.72
S_4	52.32	47.01	99.33
S.Em±	2.70	1.78	3.13
CD at 5 %	7.89	5.19	9.15
Interactions (F x S)			
F_1S_1	36.34	35.61	71.95
F_1S_2	43.33	40.53	83.86
F_1S_3	40.23	39.98	80.21
F_1S_4	36.37	36.28	72.65
F_2S_1	55.44	47.95	103.39
F_2S_2	56.38	50.85	107.23
F_2S_3	53.78	46.67	100.45
F_2S_4	51.50	45.11	96.61
F_3S_1	73.26	63.29	136.56
F_3S_2	81.15	65.22	146.37
F_3S_3	71.94	61.57	133.50
F_3S_4	69.11	59.63	128.74
Control	30.61	31.78	62.39
S.Em±	4.68	3.08	5.43
CD at 5 %	13.66	8.99	15.85
CV (%)	12.30	10.25	8.52

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

Interaction of both planting geometry and fertilizer levels under drip fertigation significantly influenced nitrogen uptake by grain. Among the interactions 25 cm x 15 cm with 100 per cent RDF recorded significantly higher (81.15 kg ha^{-1}) nitrogen uptake by grain and significantly lower (30.61 kg ha^{-1}) grain nitrogen uptake was noticed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.4.2 Nitrogen uptake by straw (kg ha^{-1})

The different levels of application of fertilizers through drip fertigation significantly influenced nitrogen uptake by straw (Table 4.13). The 100 per cent RDF recorded significantly higher (62.43 kg ha^{-1}) nitrogen uptake by straw and significantly lower (38.10 kg ha^{-1}) nitrogen uptake by straw was observed in 50 per cent RDF through drip fertigation.

Planting geometry under drip fertigation significantly influenced straw nitrogen uptake. Planting geometry of 25 cm x 15 cm recorded significantly higher straw nitrogen uptake (52.80 kg ha^{-1}) which was on par with 25 cm x 10 cm (48.95 kg ha^{-1}) and 25 cm x 20 cm (49.41 kg ha^{-1}). Significantly lower nitrogen uptake (47.01 kg ha^{-1}) by straw was recorded in planting geometry of 25 cm x 25 cm.

Interaction of both planting geometry and fertilizer levels under drip fertigation has significant influence on nitrogen uptake by straw. Among the interactions 25 cm x 15 cm with 100 per cent RDF was recorded significantly higher (65.22 kg ha^{-1}) nitrogen uptake by straw and significantly lower (31.78 kg ha^{-1}) straw nitrogen uptake was noticed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.4.3 Total nitrogen uptake (kg ha^{-1})

The different levels of application of fertilizers through drip fertigation significantly influenced total nitrogen uptake (Table 4.13). The 100 per cent RDF recorded significantly higher (136.29 kg ha^{-1}) total nitrogen uptake and significantly lower (77.71 kg ha^{-1}) total nitrogen uptake was observed in 50 per cent RDF through drip fertigation.

Planting geometry under drip fertigation had significant influence on total nitrogen uptake. Planting geometry of 25 cm x 15 cm was recorded significantly higher total nitrogen uptake (112.49 kg ha^{-1}) which was on par with 25 cm x 10 cm (103.97 kg ha-$^{`1}$) and 25 cm x 20 cm (104.72 kg ha^{-1}).Significantly lower nitrogen uptake (99.30 kg ha^{-1}) was recorded in planting geometry of 25 cm x 25 cm.

Interaction of both planting geometry and fertilizer levels under drip fertigation has significant influence on total nitrogen uptake. Among the interactions 25 cm x 15 cm with 100 per cent RDF was recorded significantly higher (146.37 kg ha^{-1}) total nitrogen uptake and significantly lower (62.39 kg ha^{-1}) total nitrogen uptake was noticed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.4.4 Phosphorous uptake by grain (kg ha^{-1})

The levels of fertilizers under drip fertigation had the significant influence on phosphorous uptake by grain (Table 4.14). 100 per cent RDF recorded significantly higher (19.70 kg ha^{-1}) phosphorous uptake by grain and significantly lower (8.20 kg ha^{-1}) phosphorous uptake by grain was recorded in 50 per cent RDF.

Planting geometry has influenced the phosphorous uptake by grain. Planting geometry of 25 cm x 15 cm recorded significantly higher phosphorous uptake by grain (15.54 kg ha^{-1}) and significantly lower phosphorous uptake by grains (13.77 kg ha^{-1}) was noticed in 25 cm x 25 cm.

Fertilizer levels and planting geometry interactions had significant influence on phosphorous uptake by grain. The planting geometry of 25 cm x 15 cm with 100 per cent RDF recorded significantly higher phosphorous uptake by grain (21.64 kg ha^{-1}) and significantly lower (6.44 kg ha^{-1}) phosphorous uptake by grain was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.4.5 Phosphorous uptake by straw (kg ha^{-1})

The levels of fertilizers under drip fertigation had the significant influence on phosphorous uptake by straw (Table 4.14). 100 per cent RDF recorded significantly higher (17.59 kg ha^{-1}) phosphorous uptake by straw and significantly lower (6.23 kg ha^{-1}) phosphorous uptake by straw was recorded in 50per cent RDF.

Planting geometry had influenced the phosphorous uptake by straw. Planting geometry of 25 cm x 15 cm was recorded significantly higher phosphorous uptake by straw (12.73 kg ha^{-1}) and significantly lower nutrient uptake by grains (11.55 kg ha^{-1}) was noticed in 25 cm x 25 cm.

Fertilizer levels and planting geometry interactions had significant influence on phosphorous uptake by straw. The planting geometry of 25 cm x 15 cm with 100 per cent RDF recorded significantly higher phosphorous uptake by straw (18.37 kg ha^{-1}) and significantly lower (5.08 kg ha^{-1}) phosphorous uptake by straw was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application RDF.

4.4.6 Total phosphorous uptake (kg ha^{-1})

The levels of fertilizers under drip fertigation had the significant influence on phosphorous uptake. 100 per cent RDF recorded significantly higher (37.28 kg ha^{-1}) total phosphorous uptake and significantly lower (14.43 kg ha^{-1}) phosphorous uptake by straw was recorded in 50 per cent RDF.

Planting geometry had influenced the total phosphorous uptake. Planting geometry of 25 cm x 15 cm was recorded significantly higher total phosphorous uptake (27.86 kg ha^{-1}) which was on par with and significantly lower phosphorous uptake (24.10 kg ha^{-1}) was noticed in planting geometry of 25 cm x 25 cm which was on par with 25 cm x 20 cm (25.31 kg ha^{-1}).

Table 4.14: Phosphorous uptake (kg ha^{-1}) by aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Grain	Straw	Total
Fertilizer levels (F)			
F_1	8.20	6.23	14.43
F_2	13.85	10.94	24.78
F_3	19.70	17.59	37.28
S.Em±	0.60	0.39	0.68
CD at 5 %	1.76	1.13	1.98
Planting geometry (S)			
S_1	13.77	11.55	25.32
S_2	15.54	12.73	27.86
S_3	13.78	11.53	25.31
S_4	13.07	11.03	24.10
S.Em±	0.70	0.45	0.78
CD at 5 %	2.04	1.30	2.29
Interactions (F x S)			
F_1S_1	7.63	5.83	13.45
F_1S_2	9.09	6.63	15.73
F_1S_3	8.44	6.54	14.99
F_1S_4	7.63	5.94	13.57
F_2S_1	14.14	11.01	25.15
F_2S_2	14.38	11.67	26.05
F_2S_3	13.72	10.71	24.43
F_2S_4	13.14	10.35	23.49
F_3S_1	19.54	17.83	37.37
F_3S_2	21.64	18.37	40.01
F_3S_3	19.18	17.34	36.53
F_3S_4	18.43	16.80	35.23
Control	6.44	5.08	11.53
S.Em±	1.21	0.77	1.36
CD at 5 %	3.53	2.26	3.96
CV (%)	14.4	11.15	8.87

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

Fertilizer levels and planting geometry interactions had a significant influence on total phosphorous uptake. The planting geometry of 25 cm x 15 cm with 100 per cent RDF recorded significantly higher total phosphorous uptake (40.01 kg ha^{-1}) which was on par with 25 cm x 10 cm with 100 per cent RDF (37.37 kg ha^{-1}), 25 cm x 20 cm with 100 per cent RDF (36.53 kg ha^{-1}) and significantly lower (11.53 kg ha^{-1}) total phosphorous uptake was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.4.7 Potassium uptake by grain (kg ha^{-1})

The levels of fertilizers under drip fertigation had the significant influence on potassium uptake by grain (Table 4.15). 100 per cent RDF recorded significantly higher (68.50 kg ha^{-1}) potassium uptake by grain and significantly lower (38.10 kg ha^{-1}) potassium uptake by grain was recorded in 50 per cent RDF.

Planting geometry was influenced the potassium uptake by grain. Planting geometry of 25 cm x 15 cm recorded significantly higher potassium uptake by grain (57.73 kg ha^{-1}) which was on par with 25 cm x 10 cm (52.32 kg ha^{-1}), 25 cm x 20 cm (52.64 kg ha^{-1}) and significantly lower potassium uptake by grain (49.77 kg ha^{-1}) was noticed in 25 cm x 25 cm.

Fertilizer levels and planting geometry interactions had significant influence on potassium uptake by grain. The planting geometry of 25 cm x 15 cm with 100 per cent RDF recorded significantly higher potassium uptake by grain (75.06 kg ha^{-1}) and significantly lower (28.50 kg ha^{-1}) potassium uptake by grain was recorded in control i.e. 25 cm x 25 cm with surface irrigation.

4.4.8 Potassium uptake by straw (kg ha^{-1})

The levels of fertilizers under drip fertigation have the significant influence on potassium uptake by straw (Table 4.15). 100 per cent RDF recorded significantly higher (60.99 kg ha^{-1}) potassium uptake by straw and significantly lower (36.02 kg ha^{-1}) potassium uptake by straw was recorded in 50 per cent RDF.

Planting geometry was influenced the potassium uptake by straw. Planting geometry of 25 cm x 15 cm was recorded significantly higher potassium uptake by straw (51.02 kg ha^{-1}) and significantly lower nutrient uptake by straw (45.05 kg ha^{-1}) was noticed in 25 cm x 25 cm.

Fertilizer levels and planting geometry interactions had significant influence on potassium uptake by straw. The planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher potassium uptake by straw (63.39 kg ha^{-1}) and significantly lower (29.87 kg ha^{-1}) potassium uptake by straw was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.4.9 Total potassium uptake (kg ha^{-1})

The levels of fertilizers under drip fertigation had significant influence on total potassium uptake. 100 per cent RDF recorded significantly higher (128.99 kg ha^{-1}) total

Table 4.15: Potassium uptake (kg ha^{-1}) by drip fertigated aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Grain	Straw	Total
Fertilizer levels (F)			
F_1	38.10	36.02	74.12
F_2	52.61	45.30	97.92
F_3	68.32	60.66	128.99
S.Em±	2.23	1.48	2.58
CD at 5 %	6.50	4.31	7.53
Planting geometry (S)			
S_1	52.32	46.92	99.24
S_2	57.73	51.02	107.34
S_3	52.64	47.33	99.97
S_4	49.77	45.05	94.82
S.Em±	2.57	1.71	2.98
CD at 5 %	7.50	4.98	8.70
Interactions (F x S)			
F_1S_1	35.44	33.67	69.11
F_1S_2	42.26	38.32	80.58
F_1S_3	39.24	37.80	77.03
F_1S_4	35.47	34.30	69.77
F_2S_1	53.74	45.60	99.34
F_2S_2	54.66	48.35	103.01
F_2S_3	52.13	44.38	96.51
F_2S_4	49.92	42.89	92.81
F_3S_1	67.77	61.51	129.28
F_3S_2	75.06	63.39	138.45
F_3S_3	66.54	59.83	126.37
F_3S_4	63.93	57.95	121.88
Control	28.20	29.87	58.07
S.Em±	4.45	2.95	5.16
CD at 5 %	13.00	8.62	15.07
CV (%)	13.92	10.27	8.50

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

potassium uptake and significantly lower (74.12 kg ha^{-1}) potassium uptake by straw was recorded in 50 per cent RDF.

Planting geometry had influenced the total potassium uptake. Planting geometry of 25 cm x 15 cm recorded significantly higher total potassium uptake (107.34 kg ha^{-1}) and significantly lower total potassium uptake (94.82 kg ha^{-1}) was noticed in 25 cm x 25 cm which was on par with 25 cm x 20 cm (99.97 kg ha^{-1}).

Fertilizer levels and planting geometry interactions significantly influenced total potassium uptake. The planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher total potassium uptake (138.45 kg ha^{-1}) which was on par with 25 cm x 10 cm with 100 per cent RDF (129.28 kg ha^{-1}), 25 cm x 20 cm with 100 per cent RDF (126.37 kg ha^{-1}) and significantly lower (58.07 kg ha^{-1}) total potassium uptake was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.5 Nutrient use efficiency (kg grain yield/kg nutrients)

The data pertaining to nutrient use efficiency as influenced by planting geometry and fertilizer levels under drip fertigation are presented in the table 4.16.

4.5.1 Nitrogen use efficiency (kg grain yield/kg N)

The levels of fertilizers under drip fertigation significantly influenced on Nitrogen use efficiency. The 50 per cent RDF recorded significantly higher (96.46 kg kg^{-1}) nitrogen use efficiency and significantly lower (61.55 kg kg^{-1}) nutrient use efficiency was recorded in 100 per cent RDF.

Planting geometry has influenced the nitrogen use efficiency. Planting geometry of 25 cm x 15 cm recorded significantly higher nitrogen use efficiency (83.77 kg kg^{-1}) and significantly lower nitrogen use efficiency (72.48 kg kg^{-1}) was noticed in 25 cm x 25 cm which was on par with 25 cm x 20 cm (77.98 kg kg^{-1}).

Fertilizer levels and planting geometry interactions had a significant influence on nitrogen use efficiency. The planting geometry of 25 cm x 15 cm with 50 per cent RDF recorded significantly higher nitrogen use efficiency (106.98 kg kg^{-1}) and significantly lower (40.28 kg kg^{-1}) nitrogen use efficiency was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.5.2 Phosphorous use efficiency (kg grain yield/kg P)

The levels of fertilizers under drip fertigation significantly influenced on phosphorous use efficiency. The 50 per cent RDF recorded significantly higher (192.92 kg kg^{-1}) phosphorous use efficiency and significantly lower (123.11 kg kg^{-1}) phosphorous use efficiency was recorded in 100 per cent RDF.

Planting geometry has influenced the phosphorous use efficiency. Planting geometries, 25 cm x 15 cm recorded significantly higher phosphorous use efficiency

Table 4.16: Nutrient use efficiency (kg kg^{-1}) of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Nitrogen use efficiency	Phosphorus use efficiency	Potassium use efficiency
Fertilizer levels (F)			
F_1	96.46	192.92	192.92
F_2	73.84	147.68	147.68
F_3	61.55	123.11	123.11
S.Em ±	2.96	5.93	5.93
CD at 5%	8.65	17.30	17.30
Planting geometry (S)			
S_1	75.4	150.81	150.81
S_2	83.77	167.54	167.54
S_3	77.48	154.97	154.97
S_4	72.48	144.97	144.97
S.Em ±	3.42	6.84	6.84
CD at 5%	9.99	19.97	19.97
Interactions (F x S)			
F_1S_1	89.73	179.47	179.47
F_1S_2	106.98	213.97	213.97
F_1S_3	99.34	198.68	198.68
F_1S_4	89.79	179.59	179.59
F_2S_1	75.43	150.85	150.85
F_2S_2	76.71	153.42	153.42
F_2S_3	73.16	146.33	146.33
F_2S_4	70.06	140.13	140.13
F_3S_1	61.05	122.11	122.11
F_3S_2	67.62	135.25	135.25
F_3S_3	59.95	119.89	119.89
F_3S_4	57.59	115.18	115.18
Control	40.28	80.56	80.56
S.Em ±	5.93	11.85	11.85
CD at 5%	17.3	34.59	34.59
CV (%)	12.72	12.72	12.72

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NS-** Non-significant.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).

(167.54 kg kg^{-1}) and significantly lower phosphorous use efficiency (144 kg kg^{-1}) was noticed in 25 cm x 25 cm which was on par with 25 cm x 10 cm (150.81 kg kg^{-1}).

Fertilizer levels and planting geometry interactions had significant influence on phosphorous use efficiency. The planting geometry of 25 cm x 15 cm with 50 per cent RDF has recorded significantly higher (213.97 kg kg^{-1}) phosphorous use efficiency and significantly lower (80.56 kg kg^{-1}) phosphorous use efficiency was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.5.3 Potassium use efficiency (kg grain yield/kg K)

The levels of fertilizers under drip fertigation had the significant influence on potassium use efficiency. The 50 per cent RDF recorded significantly higher (192.92 kg kg^{-1}) phosphorous use efficiency and significantly lower (123.11 kg kg^{-1}) potassium use efficiency was recorded in 100 per cent RDF.

Planting geometry has influenced the potassium use efficiency. Planting geometry of 25 cm x 15 cm was recorded significantly higher potassium use efficiency (167.54 kg kg^{-1}) and significantly lower potassium use efficiency (144 kg kg^{-1}) was noticed in 25 cm x 25 cm which was on par with 25 cm x 10 cm (150.81 kg kg^{-1}).

Fertilizer levels and planting geometry interactions significantly influenced potassium use efficiency. The planting geometry of 25 cm x 15 cm with 50 per cent RDF recorded significantly higher (213.97 kg kg^{-1}) potassium use efficiency and significantly lower (80.56 kg kg^{-1}) potassium use efficiency was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.6 Water used (cm) and water use efficiency (kg ha-cm^{-1})

4.6.1 Irrigation water used (mm)

The data on irrigation water used in drip fertigated aerobic rice as influenced by planting geometry, fertilizer levels and surface irrigation treatments are presented in Table 4.17.

Irrigation water applied was found to be higher with surface irrigation (858.00 mm) followed by all treatments with different planting geometry and fertilizer levels under drip fertigation (492.15 mm).

4.6.2 Water used [Irrigation water (mm) + Effective rainfall (mm)]

The data on total water used in drip fertigated aerobic rice as influenced by planting geometry, fertilizer levels and surface irrigation treatments are presented in Table 4.17.

Total water used was highest in surface irrigation method (1104.68 mm) when compared with different planting geometry and fertilizer levels with drip fertigation (738.83 mm).

Table 4.17: Water used (mm) and water use efficiency (kg ha-cm^{-1}) of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Irrigation water used [I_R (mm)]	Total water used [$I_R + E_R$ (mm)]	WUE
Fertilizer levels (F)			
F_1	492.15	738.83	65.33
F_2	492.15	738.83	75.01
F_3	492.15	738.83	83.37
S.Em ±	NA	NA	3.03
CD at 5 %	NA	NA	8.86
Planting geometry (S)			
S_1	492.15	738.83	73.36
S_2	492.15	738.83	80.66
S_3	492.15	738.83	74.26
S_4	492.15	738.83	70.00
S.Em ±	NA	NA	3.50
CD at 5 %	NA	NA	10.23
Interactions (F x S)			
F_1S_1	492.15	738.83	60.77
F_1S_2	492.15	738.83	72.45
F_1S_3	492.15	738.83	67.28
F_1S_4	492.15	738.83	60.81
F_2S_1	492.15	738.83	76.62
F_2S_2	492.15	738.83	77.93
F_2S_3	492.15	738.83	74.32
F_2S_4	492.15	738.83	71.17
F_3S_1	492.15	738.83	82.69
F_3S_2	492.15	738.83	91.59
F_3S_3	492.15	738.83	81.20
F_3S_4	492.15	738.83	78.00
Control	858.00	1104.68	36.61
S.Em ±	NA	NA	6.07
CD at 5 %	NA	NA	17.72
CV (%)	NA	NA	11.43

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **NA**- Not analysed.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).
I_R- Irrigation water. **E_R**- Effective rainfall.

4.6.3 Water use efficiency (kg ha-cm^{-1})

The data on water use efficiency in drip fertigated aerobic rice as influenced by planting geometry, fertilizer levels and surface irrigation treatments are presented in Table 4.17.

The levels of fertilizers under drip fertigation have the significant influence on water use efficiency. The 100 per cent RDF recorded significantly higher (83.37 kg ha-cm^{-1}) phosphorous use efficiency and significantly lower (65.33 kg ha-cm^{-1}) water use efficiency was recorded in 50 per cent RDF.

Planting geometry has influenced the water use efficiency. Planting geometry of 25 cm x 15 cm recorded significantly higher water use efficiency (80.66 kg ha- cm^{-1}) and significantly lower water use efficiency (70.00 kg ha-cm^{-1}) was noticed in 25 cm x 25 cm which was on par with 25 cm x 10 cm (73.36 kg ha-cm^{-1}).

Fertilizer levels and planting geometry interactions significantly influenced on water use efficiency. The planting geometry of 25 cm x 15 cm with 100 per cent RDF recorded significantly higher (91.59 kg ha-cm^{-1}) water use efficiency and significantly lower (36.61 kg ha-cm^{-1}) water use efficiency was recorded in control i.e. 25 cm x 25 cm with surface irrigation and soil application of RDF.

4.7 Nutrient balance

The data corresponding to initial nutrient status of soil, addition of nutrients through fertilizers, removal of nutrients by crop, expected balance, actual balance and net loss or gain (kg ha^{-1}) are furnished in Tables 4.18, 4.19 and 4.20.

4.7.1 Nitrogen balance (kg ha^{-1})

The initial status of available nitrogen in soil before sowing of crop was 292.4 kg ha^{-1} in *Kharif* season 2014 (Table 4.18). Planting geometry of 25 cm x 15 cm with 100 per cent of RDF through drip fertigation recorded higher removal of nitrogen (146.37 kg ha^{-1}) as compared to other treatments.

The maximum loss of nitrogen was noticed in treatment where soil application of RDF with surface irrigation (87.62 kg ha^{-1}).

4.7.2 Phosphorus balance (kg ha^{-1})

The initial status of available phosphorus in soil before sowing of crop was 23.8 kg ha^{-1} in *Kharif* season 2014 (Table 4.19). Planting geometry of 25 cm x 15 cm with 100 per cent of RDF through drip fertigation recorded higher removal of phosphorous (40.01 kg ha^{-1}) as compared to other treatments.

The maximum loss of phosphorus was noticed in treatment where soil application of RDF through surface irrigation. (24.07 kg ha^{-1}).

Table 4.18: Nitrogen balance (kg ha^{-1}) in the soil of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Initial status (a)	Addition through fertilizer (b)	Total N status (c)	Uptake of N by crop (kg ha^{-1}) (d)	Expected balance (c-d=e)	Actual balance (f)	Net loss (-) or gain (+) (f-e)
T_1: S_1 - 25 cm x10 cm + (F_1) 50 % of RDF through Drip fertigation.	356.3	50	406.3	71.95	334.35	274.51	-59.84
T_2: S_1 - 25 cm x 10 cm + (F_2) 75 % of RDF through Drip fertigation.	356.3	75	431.3	103.39	327.91	290.96	-36.95
T_3: S_1 - 25 cm x 10 cm + (F_3) 100 % of RDF through Drip fertigation.	356.3	100	456.3	136.56	319.74	301.41	-18.33
T_4 : S_2 - 25 cm x 15 cm + (F_1) 50 % of RDF through Drip fertigation.	356.3	50	406.3	83.86	322.44	278.31	-44.13
T_5 : S_2 - 25 cm x 15 cm + (F_2) 75 % of RDF through Drip fertigation.	356.3	75	431.3	107.23	324.07	293.55	-30.52
T_6 : S_2 - 25 cm x 15 cm + (F_3) 100 % of RDF through Drip fertigation.	356.3	100	456.3	146.37	309.93	303.73	-6.20
T_7 : S_3 - 25 cm x 20 cm + (F_1) 50 % of RDF through Drip fertigation.	356.3	50	406.3	80.21	326.09	281.29	-44.80
T_8 : S_3 - 25 cm x 20 cm + (F_2) 75 % of RDF through Drip fertigation.	356.3	75	431.3	100.45	330.85	295.14	-35.71
T_9 : S_3 - 25 cm x 20 cm + (F_3) 100 % of RDF through Drip fertigation	356.3	100	456.3	133.5	322.8	310.80	-12.00
T_{10}: S_4 - 25 cm x 25 cm + (F_1) 50 % of RDF through Drip fertigation**.**	356.3	50	406.3	72.65	333.65	285.83	-47.82
T_{11}: S_4 - 25 cm x 25 cm + (F_2) 75 % of RDF through Drip fertigation.	356.3	75	431.3	96.61	334.69	297.95	-36.74
T_{12}: S_4 - 25 cm x 25 cm + (F_3) 100 % of RDF through Drip fertigation.	356.3	100	456.3	128.41	327.89	315.19	-12.70
T_{13}: Control i.e., Spacing of 25 cm X 25 cm with surface irrigation.	356.3	100	456.3	62.39	393.91	306.29	-87.62

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF. **RDF**: Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).
Planting geometry **(S): S_1**: 25 cm x 10 cm **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm

Table 4.19: Phosphorous balance (kg ha^{-1}) in the soil of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Initial status (a)	Addition through fertilizer (b)	Total P_2O_5 (c)	Uptake of P_20_5 by crop (kg ha^{-1}) (d)	Expected balance (c-d=e)	Actual balance (f)	Net loss (-) or gain (+) (f-e)
T_1: S_1 - 25 cm x 10 cm + (F_1) 50 % of RDF through Drip fertigation.	23.8	25	48.8	13.45	35.345	21.26	-14.08
T_2: S_1 - 25 cm x 10 cm + (F_2) 75 % of RDF through Drip fertigation.	23.8	37.5	61.3	25.14	36.152	30.22	-5.93
T_3: S_1 - 25 cm x 10 cm + (F_3) 100 % of RDF through Drip fertigation.	23.8	50	73.8	37.36	36.434	33.69	-2.75
T_4 : S_2 - 25 cm x 15 cm + (F_1) 50 % of RDF through Drip fertigation.	23.8	25	48.8	15.72	33.074	25.70	-7.38
T_5 : S_2 - 25 cm x 15 cm + (F_2) 75 % of RDF through Drip fertigation.	23.8	37.5	61.3	26.05	35.246	32.17	-3.08
T_6 : S_2 - 25 cm x 15 cm + (F_3) 100 % of RDF through Drip fertigation.	23.8	50	73.8	40.01	33.788	36.22	2.44
T_7 : S_3 - 25 cm x 20 cm + (F_1) 50 % of RDF through Drip fertigation.	23.8	25	48.8	14.98	33.815	28.34	-5.47
T_8 : S_3 - 25 cm x 20 cm + (F_2) 75 % of RDF through Drip fertigation.	23.8	37.5	61.3	24.43	36.870	34.52	-2.35
T_9 : S_3 - 25 cm x 20 cm + (F_3) 100 % of RDF through Drip fertigation	23.8	50	73.8	36.52	37.275	34.11	-3.17
T_{10}: S_4 - 25 cm x 25 cm + (F_1) 50 % of RDF through Drip fertigation**.**	23.8	25	48.8	13.56	35.231	29.34	-5.89
T_{11}: S_4 - 25 cm x 25 cm + (F_2) 75 % of RDF through Drip fertigation.	23.8	37.5	61.3	23.49	37.810	35.27	-2.54
T_{12}: S_4 - 25 cm x 25 cm + (F_3) 100 % of RDF through Drip fertigation.	23.8	50	73.8	35.22	38.573	37.51	-1.07
T_{13}: Control i.e., Spacing of 25 cm X 25 cm with surface irrigation.	23.8	50	73.8	11.53	62.270	38.20	-24.07

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF. **RDF**: Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).
Planting geometry **(S): S_1**: 25 cm x 10 cm **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm

4.7.3 Potassium balance (kg ha^{-1})

The initial status of available potassium in soil before sowing of crop was 209.16 kg ha^{-1} in *Kharif* season 2014 (Table 20). Planting geometry of 25 cm x 15 cm with 100 per cent of RDF through drip fertigation recorded higher removal of potassium (138.44 kg ha^{-1}) as compared to other treatment combinations.

The net gain of potassium ranged from 13.76 to 57.93 kg ha^{-1} among the different drip fertigation treatments. The maximum loss of potassium was noticed in the soil application of RDF through surface irrigation (8.79 kg ha^{-1}).

4.8 Economics

The data on economics of drip fertigated aerobic rice as influenced by planting geometry and fertilizer levels treatments under study are presented in Table 4.21.

The treatments with 100 per cent RDF through drip fertigation with normal fertilizer under different planting geometries i.e. 25 cm x 10 cm, 25 cm x 15 cm, 25 cm x 20 cm and 25 cm x 25 cm has registered higher cost of cultivation (₹ 46293, 46163, 46106 and 46068 ha^{-1}, respectively), followed by drip fertigation with 75 per cent RDF under different planting geometries i.e. 25 cm x 10 cm, 25 cm x 15 cm, 25 cm x 20 cm and 25 cm x 25 cm (₹ 45291, 45161, 45104 and 45066 ha^{-1}, respectively) and lower cost of cultivation was observed in drip fertigation with 50 per cent RDF under different planting geometries i.e. 25 cm x 10 cm, 25 cm x 15 cm ,25 cm x 20 cm and 25 cm x 25 cm (₹ 44288, 44158, 44101 and 44063 ha^{-1}, respectively). However, the cost of cultivation was found least under 25 cm x 25 cm with surface irrigation and soil application of RDF (₹ 36468 ha^{-1}).

Gross returns were ultimately the result of grain yield and straw yield of different treatments. Planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation has higher gross returns (₹ 121977) fallowed by 25 cm x 10 cm with 100 per cent RDF (₹ 111057) However, least gross returns were obtained in 25 cm x 25 cm with surface irrigation with soil application of RDF (₹ 73983 ha^{-1}).

Application of 100 per cent RDF with planting geometry of 25 cm x 15 cm in which had given higher net returns of ₹ 75814 ha^{-1} followed by 100 per cent RDF with planting geometry of 25 cm x 10 cm (₹ 64764 ha^{-1}) and 100 per cent RDF with planting geometry of 25 cm x 20 cm (₹ 62815 ha^{-1}). Generally the treatments with 100 per cent RDF through drip fertigation recorded higher net returns as compared to treatments with 75 per cent and 50 per cent RDF through drip fertigation. However, least net returns were obtained in planting geometry of 25 cm x 25 cm with surface irrigation with soil application of RDF (₹ 37515 ha^{-1}).

The treatment planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation recorded higher B:C ratio of 2.64, followed by planting geometry of 25 cm x 10 cm with 100 per cent RDF (2.40) and 25 cm x 20 cm with 100 per cent RDF (2.36). Generally the treatments with 100 per cent RDF had given higher B:C ratio as compared to other treatments and planting geometry of 25 cm x 15 cm has recorded higher B:C ratio compare to other planting geometries under different levels of fertilizers. However, least B:C ratio was obtained in planting geometry of 25 cm x 10 cm with 50 per cent of RDF through drip fertigation (1.84).

Table 4.20: Potassium balance (kg ha^{-1}) in the soil of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Initial status (a)	Addition through fertilizer (b)	Total $K_2$0 (c)	Uptake of K20 by crop (kg ha^{-1}) (d)	Expected balance (c-d=e)	Actual balance (f)	Net loss (-) or gain (+) (f-e)
T_1: S_1 - 25 cm x 10 cm + (F_1) 50 % of RDF through Drip fertigation.	256.4	25	281.4	69.11	212.28	206.42	-5.87
T_2: S_1 - 25 cm x 10 cm + (F_2) 75 % of RDF through Drip fertigation.	256.4	37.5	293.9	99.33	194.56	218.16	23.60
T_3: S_1 - 25 cm x 10 cm + (F_3) 100 % of RDF through Drip fertigation.	256.4	50	306.4	129.27	177.12	226.47	49.34
T_4 : S_2 - 25 cm x 15 cm + (F_1) 50 % of RDF through Drip fertigation.	256.4	25	281.4	80.58	200.82	216.42	15.60
T_5 : S_2 - 25 cm x 15 cm + (F_2) 75 % of RDF through Drip fertigation.	256.4	37.5	293.9	103.00	190.89	223.41	32.52
T_6 : S_2 - 25 cm x 15 cm + (F_3) 100 % of RDF through Drip fertigation.	256.4	50	306.4	138.44	167.95	231.30	63.35
T_7 : S_3 - 25 cm x 20 cm + (F_1) 50 % of RDF through Drip fertigation.	256.4	25	281.4	77.03	204.36	220.30	15.93
T_8 : S_3 - 25 cm x 20 cm + (F_2) 75 % of RDF through Drip fertigation.	256.4	37.5	293.9	96.50	197.39	228.54	31.15
T_9 : S_3 - 25 cm x 20 cm + (F_3) 100 % of RDF through Drip fertigation	256.4	50	306.4	126.37	180.02	237.52	57.49
T_{10}: S_4 - 25 cm x 25 cm + (F_1) 50 % of RDF through Drip fertigation.	256.4	25	281.4	69.77	211.63	225.39	13.76
T_{11}: S_4 - 25 cm x 25 cm + (F_2) 75 % of RDF through Drip fertigation.	256.4	37.5	293.9	92.81	201.08	232.98	31.89
T_{12}: S_4 - 25 cm x 25 cm + (F_3) 100 % of RDF through Drip fertigation.	256.4	50	306.4	121.87	184.52	242.45	57.93
T_{13}: Control i.e., Spacing of 25 cm X 25 cm with surface irrigation.	256.4	50	306.4	58.07	248.32	239.54	-8.79

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF. **RDF**: Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).
Planting geometry **(S): S_1**: 25 cm x 10 cm **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm

Table 4.21: Economics of aerobic rice as influenced by planting geometry and fertilizer levels under drip fertigation

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1: S_1 - 25 cm x 10 cm + (F_1) 50 % of RDF through Drip fertigation.	44288	81499	37211	1.84
T_2: S_1 - 25 cm x 10 cm + (F_2) 75 % of RDF through Drip fertigation.	45291	102304	57013	2.26
T_3: S_1 - 25 cm x 10 cm + (F_3) 100 % of RDF through Drip fertigation.	46293	111057	64764	2.40
T_4 : S_2 - 25 cm x 15 cm + (F_1) 50 % of RDF through Drip fertigation.	44158	96641	52483	2.19
T_5 : S_2 - 25 cm x 15 cm + (F_2) 75 % of RDF through Drip fertigation.	45161	104556	59395	2.32
T_6 : S_2 - 25 cm x 15 cm + (F_3) 100 % of RDF through Drip fertigation.	46163	121977	75814	2.64
T_7 : S_3 - 25 cm x 20 cm + (F_1) 50 % of RDF through Drip fertigation.	44101	90374	46273	2.05
T_8 : S_3 - 25 cm x 20 cm + (F_2) 75 % of RDF through Drip fertigation.	45104	99274	54170	2.20
T_9 : S_3 - 25 cm x 20 cm + (F_3) 100 % of RDF through Drip fertigation	46106	108921	62815	2.36
T_{10}: S_4 - 25 cm x 25 cm + (F_1) 50 % of RDF through Drip fertigation**.**	44063	81729	37666	1.85
T_{11}: S_4 - 25 cm x 25 cm + (F_2) 75 % of RDF through Drip fertigation.	45066	95169	50103	2.11
T_{12}: S_4 - 25 cm x 25 cm + (F_3) 100 % of RDF through Drip fertigation.	46068	104743	58675	2.27
T_{13}: Control i.e., Spacing of 25 cm x 25 cm with surface irrigation.	36468	73983	37515	2.03

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF. **RDF**: Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}).
Planting geometry **(S): S_1**: 25 cm x 10 cm **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm. **B:C-** Benefit cost ratio.

V DISCUSSION

Aerobic rice cultivation under drip fertigation technique provides an opportunity to save the resources like water and nutrients. Lack of suitable fertilizer levels and optimum planting geometry resulted in low productivity of aerobic rice. Hence, an investigation on "Standardisation of planting geometry in aerobic rice (*Oryza sativa L.*) under different levels of drip fertigation**"** was conducted during *Kharif* 2014 at Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krushi Vignana Kendra, Bengaluru. The results of the investigation are discussed in detail in this chapter along with causes of variation among different planting geometries and fertilizer levels practices are also discussed.

5.1 Crop and weather

Environment is the foster parent of plants. The fluctuations in weather conditions are a true reflection on the expected yield.

Total amount of rainfall received at the University of Agricultural Science, Gandhi Krishi Vignan Kendra, Bengaluru was 917.60 mm during 2014. The rainfall received during the crop growth period was 704.8 mm. The mean maximum temperature during the period of experimentation ranged from 26.6 to 28.5 °C. While the mean minimum temperature ranged from 16.2 to 19.5 ^{o}C. The actual mean sunshine hours and pan evaporation were considerably lower during the entire crop growth period. However, this situation hardly had any impact on growth and yield of aerobic rice.

5.2 Effect of planting geometry on growth and yield of aerobic rice under drip fertigation

5.2.1 Effect of planting geometry on growth of aerobic rice under drip fertigation

The crop plants depend largely on temperature, solar radiation, moisture and soil fertility for their growth and development. Among various agronomic factors limiting yield, planting pattern is considered of great importance. Increase in yield can be ensured by maintaining appropriate plant population through different planting patterns (Ather Nadeem *et al*., 2004). The optimum plant density depends on different factors viz, plant characteristics, growth period duration, planting time and methods, soil fertility, plant size, available moisture, sunshine, planting pattern and situation of weeds.

The height of the plant differed significantly between different spacing at all stages of crop. The planting geometry of 25 cm x 15 cm has recorded higher plant height (55.96 cm at maturity). This might be due to competition of individual plant for space and nutrients there by instead of horizontal spread, plant has shown more vertical growth under high population level. Similar results were also observed by Shashidhar (2011).

Number of leaves and leaf area (cm^{-2} $hill^{-1}$) was significantly influenced by planting geometry under drip fertigation at 60 days onwards. Significantly higher number of leaves and leaf area (cm^2 $hill^{-1}$) was observed in wider planting geometry of 25 cm x 25 cm as compared to closer planting geometry of 25 cm x 10 cm this may be due to effective utilisation of moisture, nutrients and solar radiation due to less competition among the plants, similar observations are also noticed by Shashidhar (2011). Baloch *et al.* (2002) found that wider spacing had linearly increasing effect on the performance of individual plants. The plants grown with wider spacing have more area of land around them to draw the nutrition and had more solar radiation to absorb for better photosynthetic process and hence performed better as individual plants.

The pre requisite for getting higher yields in any crop is higher total dry matter production and it's partitioning into various plant parts coupled with maximum translocation of photosynthates to the sink. Total dry matter accumulation is the sum of dry matter accumulation in individual plant parts which depends on the moisture, nutrients and availability of sun light. The planting geometry of 25 cm x 15 cm has shown significantly maximum dry matter (2663.69 g m^{-2}) at harvest over planting geometry of 25 cm x 25 cm this may be due to increase in plant population. These growth attributing parameters were on par with 25 cm x 10 cm planting geometry (Fig.3). Higher dry matter accumulation was a consequence of increased plant height, number of tillers per meter square. In most of the periodical observations these growth attributing parameters were significantly superior at planting geometry of 25 cm x 15 cm as compared to rest of the planting geometry treatments. These results are in conformity with the findings of Sultana (2012) and Faisul *et al*. (2013) who, reported that higher dry matter accumulation through increased shoots, associated with longer leaf area duration.

Leaf area index and Leaf area duration was significantly higher at closer spacing of 25 cm x 10 cm (6.88 at 90 DAS and 185.22 days at 90 DAS) as compared to wider spacing of 25 cm x 25 cm (4.73 at 90 DAS, 120.41days at 90 DAS). This was due to increased leaf area (Yoshida 1982). This might gave further reduced the production and translocation of photosynthates towards sink and resulted in lower grain yield per hill with closer spacing of 25 cm x 10 cm. These results are in accordance with the findings of Ray *et al.* (2000) and Shrirame *et al.* (2000).

Number of tillers per meter square was more in rectangular planting (25 cm x 15 cm) as compared to square planting (25 cm x 25 cm) (Fig.4). This was due to no-set back in growth and drying up of the soil up to crack development which might have helped better air circulation and in particular more oxygen supply. The direct supply of oxygen provides more energy to the growing roots, which would resulted in massive growth of roots. Because of dense deep and active root system which comes in contact with more surface area of soil by which more amount of moisture and nutrients were supplied for the growth of the plant (tillers). This might have lead to the production of more panicles per meter square. Competition for light and air optimum among the tillers at rectangular spacing, reduced mortality of tillers and increased population per unit area resulted into an increased panicles per meter square. These results were in conformity with findings of Lourduraj (1999).

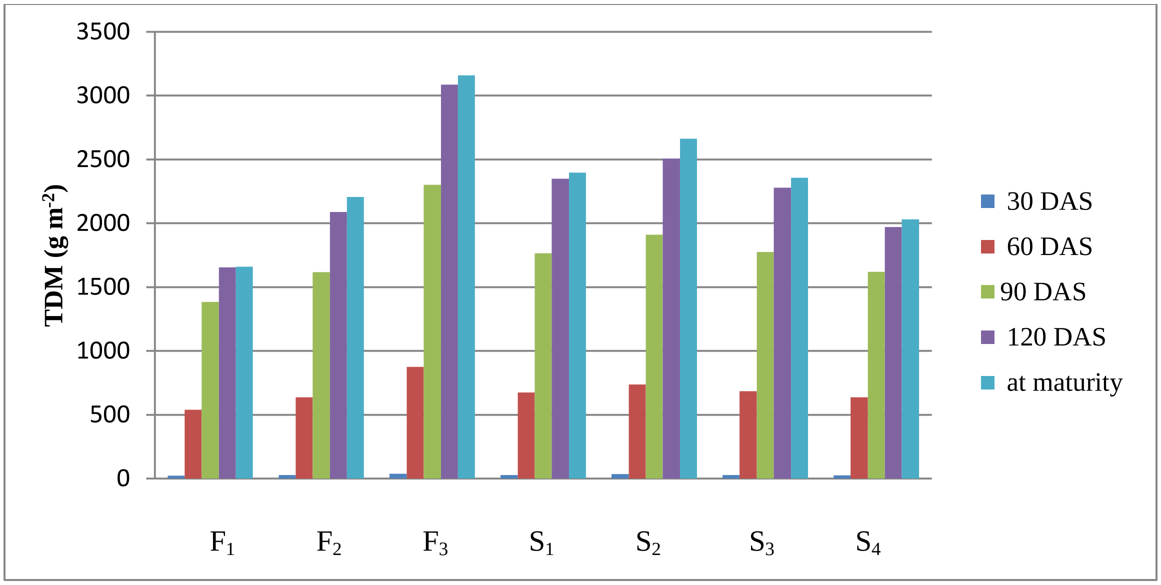

Fig. 3: Total dry matter production (g m^{-2}) of aerobic rice at different growth stages as influenced by planting geometry and levels of drip fertigation

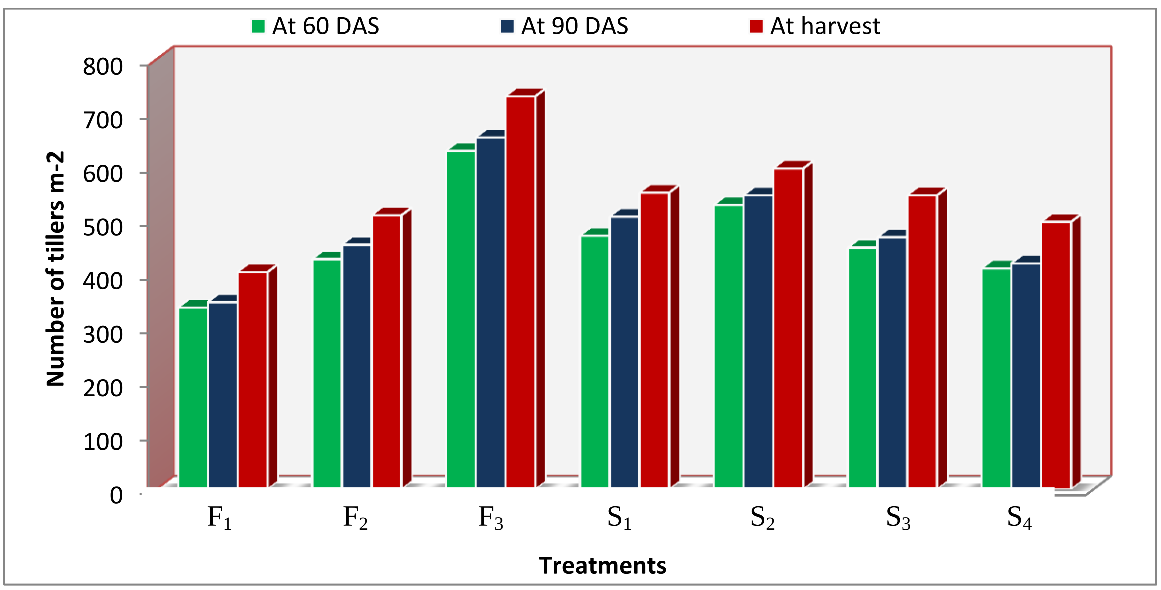

Fig. 4: Number of tillers (m^{-2}) of aerobic rice at different growth stages as influenced by planting geometry and levels of drip fertigation

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
DAS- Days after sowing. **RDF**- Recommended dose of fertilizers (100:50:50 kg NPK ha^{-1})
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25cm

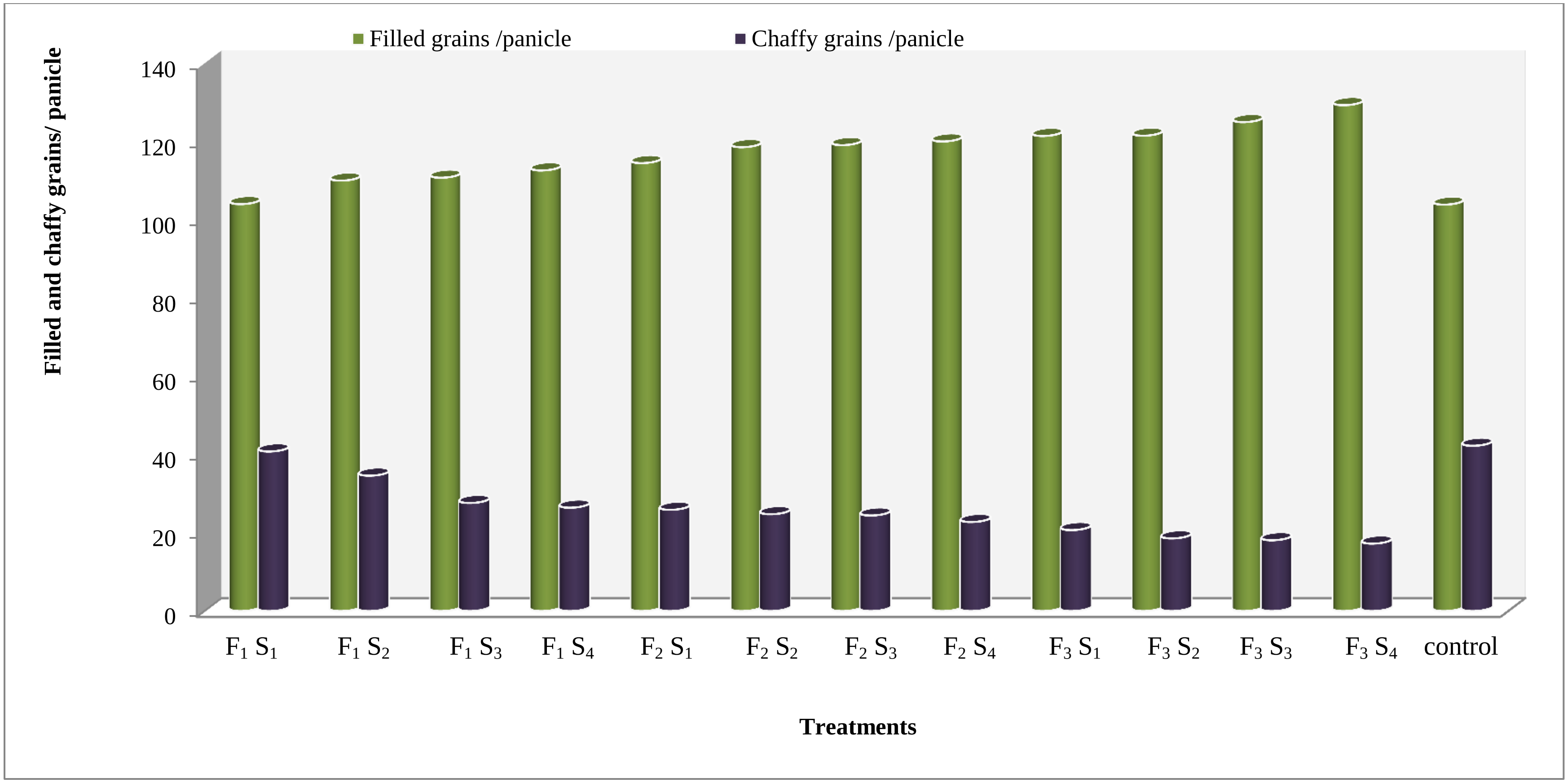

Fig. 5: Grain parameters of aerobic rice as influenced by planting geometry and fertilizer levels of drip fertigation

Note: Fertilizer levels **(F)**: $\mathbf{F_1}$: 50 per cent RDF, $\mathbf{F_2}$: 75 per cent RDF, $\mathbf{F_3}$: 100 per cent RDF.
Planting geometry **(S):** $\mathbf{S_1}$: 25 cm x 10 cm, $\mathbf{S_2}$: 25 cm x 15 cm, $\mathbf{S_3}$: 25 cm x 20 cm, $\mathbf{S_4}$: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 NPK kg ha^{-1}).

5.2.2 Effect of planting geometry on yield and nutrient uptake of aerobic rice under drip fertigation

Economic yield is expressed as a function of number of grains per panicle, grain weight per panicle, 1000 grain weight, and number of panicles meter square. Planting geometry of 25 cm x 15 cm has recorded significantly higher grain yield (5954 kg ha^{-1}) as compare to 25 cm x 25 cm (5168 kg ha^{-1}). The higher grain yield with rectangular planting geometry might be due to number of panicles per meter square (516.61), Total dry matter per meter square, number of tillers per meter square followed by 25 cm x 25 cm. Planting geometry of 25 cm x 15 cm will accommodate more number of plants per unit area than 25 cm x 25 cm and provide optimum space for light interception, nutrient absorption and weed suppression. Hence the higher yield is observed in case of planting geometry of 25 cm x 15 cm. These results are in accordance with the findings of Ray *et al*. (2000) and Sultana *et al.* (2012).

The grain yield is dependent on photosynthetic source, which could build up a sound source in terms of plant height and number of tillers and hold the leaves for longer period and to increase total dry mater and later leading to higher grain yield.

Yield parameters differed significantly in different planting geometry. The plant spacing of 25 cm x 25 cm recorded higher total grains per panicle, filled grains per panicle, less chaffy grains per panicle as compared to 25 cm x 15 cm and 25 cm x 10 cm spacing's. This was because of efficient utilization of growth resources, less intra plant competition coupled with higher availability of nutrients. Similar findings were opined by Baloch *et al*. (2002) and Umair Ashraf *et al*. (2014). The wider spacing adopted appears to be an advantageous factor for better development of panicles, hence more total grains per panicle, filled grains per panicle and lesser chaffy grains. However, the plant geometry 25 cm x 15 cm shown maximum number of tillers and higher total dry matter.

The straw and grain yields were significantly higher in 25 cm x 15 cm (Fig. 6). This might be due to cumulative influence of higher plant population, more leaf area index, more of light interception and higher number of effective tillers per meter square and higher total dry matter per meter square, resulting in increased grain and straw yield. Similar results were in accordance with Sultana *et al.* (2012).

Significantly higher nutrient uptake of Nitrogen, phosphorus and potassium was recorded with rectangular planting geometry of 25 cm x 15 cm as compared to square planting geometry of 25 cm x 25 cm. Higher nutrient uptake by rice plants due to well-developed root system. Better air circulation in the soil and better circulation of oxygen to the better root growth due to pass up of wheel hoe. This might have helped to absorb more nutrients and moisture for plant growth, resulting into higher dry matter production with higher nutrient uptake. Similar observations was also made by Hamid *et al*. (2011).

5.3 Effect of Fertilizer levels on growth and yield of aerobic rice under drip Fertigation

5.3.1 Effect of Fertilizer levels on growth of aerobic rice under drip fertigation

The growth components of aerobic rice were significantly influenced by drip fertigation and planting geometry. They were significantly superior with fertigation treatments as compared to nutrients applied with surface irrigation, because of required and frequent supply of moisture and nutrients to the effective root zone of the crop.

The highest plant height was observed in 100 per cent RDF through drip fertigation than other treatments. This may be attributed to availability of nutrients in root zone of plants, where plants were able to utilize all the nutrients. Significantly lower yield was observed in 50 per cent RDF. This is because of adequate supply of nutrients to the plants and it will meet the nutrient demand of the crop. Vijaykumar (2009); Abdelraouf *et al.* (2013) and Richa Khanna (2013), also recorded increased plant height under drip fertigation.

The treatment of 100 per cent RDF through drip fertigation recorded more number of leaves, tillers, leaf area, leaf area index and leaf area duration at all the growth stages. The superior growth parameters observed with 100 per cent RDF through drip fertigation can be linked to higher uptake of water and nutrients due to application through drip which improved the uptake of water and nutrients by the crop, in term resulted in higher vegetative growth. The results are in agreements with the findings of Vanitha and Dass (2013) and Richa Khanna (2013).

Application of 100 per cent RDF through drip fertigation recorded higher dry matter production during entire crop growth period as compared to other treatments (Fig 3). The increased dry matter accumulation in these treatments may be due to production of more number of tillers and leaves because of higher uptake of moisture and nutrients due to frequent fertigation. These results are in conformity with the results obtained by Vijaykumar (2009), Anitta Fanish and Muthhu Krishna (2013) and Richa Khanna (2013).

5.3.2 Effect of fertilizer levels on yield and yield components of aerobic rice under levels drip fertigation

The yield and yield components of aerobic rice were differed significantly due to fertigation levels.

Significantly higher grain yield was recorded in 100 per cent RDF through drip fertigation (Fig 6). Higher grain yield higher number of productive tillers (601.73 m^{-2}), panicle length (19.81 cm), thousand seed weight (23.11 g) and total number of filled grains per panicle (124.4) with lower per cent chaffyness (13.07 %) than other treatments. The higher number of productive tillers was due to continuous availability of water and nutrients that resulted in higher uptake of nutrients and higher dry matter under drip

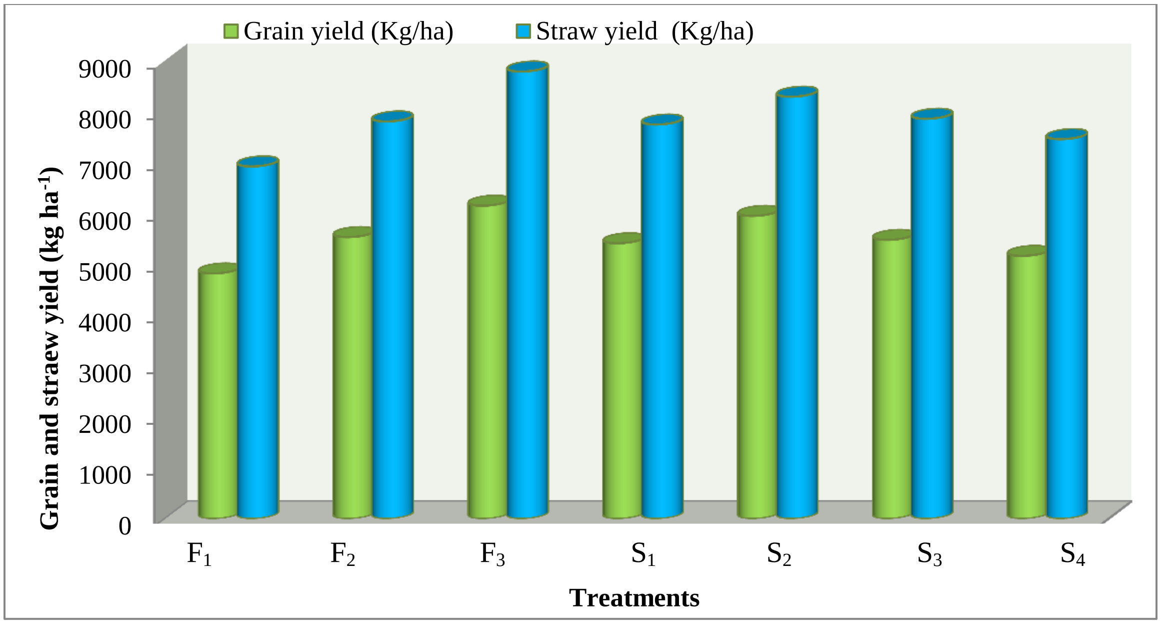

Fig. 6: Grain and straw yield (kg ha^{-1}) of aerobic rice as influenced by planting geometry and levels of drip fertigation

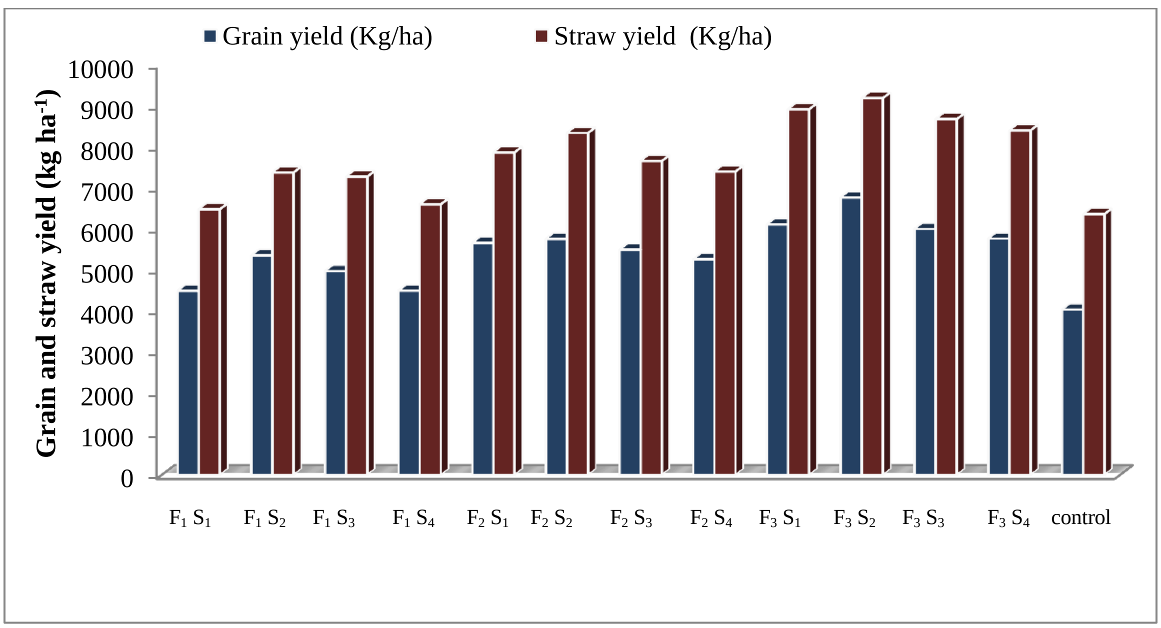

Fig. 7: Interaction effect of planting geometry and fertilizer levels on grain yield (kg ha^{-1}) of aerobic rice under drip fertigation

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25 cm.
RDF- Recommended dose of fertilizers (100:50:50 NPK kg ha^{-1}).

fertigation. These findings are in conformity with the findings of Vijaykumar (2009) and Soman (2012).

Significantly higher straw yield (Fig.6) was recorded in 100 per cent RDF through drip fertigation (8792 kg ha^{-1}) than in surface irrigation with RDF (6356 kg ha^{-1}). Higher straw yield is attributed to higher leaf area resulting in higher dry matter production. Lower straw yield in surface irrigation with soil application per cent RDF might be due to relatively lesser leaf area resulted in higher crop growth. Similar findings were reported by Sundrapandiyan (2012) and Richa khanna (2013).

5.3.3 Effect of drip fertigation on nutrient uptake, nutrient use efficiency, nutrient budgeting and water use efficiency of aerobic rice

5.3.3.1 Effect on nutrient uptake and Nutrient use efficiency

The drip fertigation treatments recorded significantly higher N, P and K uptake over surface irrigation. Among different fertigation treatments, 100 per cent RDF through drip fertigation registered higher nutrient uptake (136.29, 37.28 and 128.99 N, P and K kg ha^{-1}, respectively). This may be due to the application of higher rate of nutrients and due to higher dry matter production and yield. This increase in uptake per plant was due to better availability of nutrients and water in root zone as a result of frequent fertigation schedule which in turn promoted better root activity as indicated by increased root volume. Nutrient uptake was higher due to reduced leaching of nutrients in drip fertigation as compared to soil application of fertilizer with surface irrigation. These results are in conformity with the findings of Hebbar *et al*. (2004) and Gururaj (2012).

In addition, drip fertigation treatments in general registered higher nutrient use efficiency as compared to surface irrigation with direct soil application of nutrients. Among the different drip fertigation treatments, 50 per cent RDF through drip fertigation recorded significantly higher N, P and K use efficiency (96.46, 192.92 and 192.92 kg kg^{-1}, of NPK respectively) as compared to other treatments. This is attributed by better availability of moisture and nutrients throughout the crop growth stages in drip fertigation. These findings are in conformity with the findings of Gururaj (2012) in aerobic rice.

5.3.3.2 Effect on nutrient budgeting

The maximum loss of nitrogen was noticed in soil application of 100 per cent RDF through surface irrigation (87.62 kg ha^{-1}). The loss of nitrogen might be due to leaching, volatilization and denitrification. The loss of phosphorous was also maximum in surface irrigation (24.07 kg ha^{-1}) and it was due to fixation of phosphorous in the soil. The gain of potassium varied between 44.77 to 68.74 kg ha^{-1} in different treatments. This might be due to the fact that crop could not completely utilise the available potassium and mineralisation of potassium containing minerals. The results are in line with findings of Denesh *et al.* (2006) and Jayadeva and Prabhakara Setty (2010).

5.3.3.3 Effect on water use efficiency

Surface irrigation with soil application of 100 per cent RDF recorded higher water use (1104.68 mm) as compared to drip fertigation treatments (7138.83 mm).

However, 100 per cent RDF through drip fertigation resulted in maximum water use efficiency (83.37 kg ha-cm^{-1}), indicating highest grain yield per unit quantity of water applied. This may be attributed to higher yield levels due to higher uptake of nutrients by crop as a result of timely and frequent supplementation of water and nutrient to root zone. Whereas, in surface irrigation with soil application of RDF recorded lower water use efficiency (36.61 kg ha-cm^{-1}) which might be due lesser dry matter production. These results are in accordance with findings of Vijaykumar (2009), Anitta Fanish and Muthu Krishna (2013), Sundrapandiyan (2012) and Fanish *et al*. (2013).

5.3 Interaction effect of planting geometry and fertilizer levels on growth and yield of aerobic rice under drip fertigation

5.3.1 Interaction effect on growth of drip fertigated aerobic rice

The planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation has recorded significant higher plant height at harvest (59.93 cm). This might be due to competition for light and higher availability of nutrients in root zone of plants, where plants were able to utilize all the nutrients.

The planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation recorded more number tillers per meter square, total dry matter per meter square and crop growth rate at all the growth stages (Fig. 3 and 4). This is due to more number of plant population with less competition for available resources and higher uptake of water and nutrients due to application through drip which improved the uptake of water and nutrients by the crop, which resulted in higher vegetative growth.

The planting geometry of 25 cm x 25 cm with 100 per cent RDF through drip fertigation recorded higher number of leaves, leaf area (cm^{-2} hill^{-1}) at all the growth stages. This is may be because of higher uptake of moisture and nutrients when applied through drip and due to effective utilisation of moisture, nutrients and solar radiation due to less competition among the plants.

Leaf area index and Leaf area duration was significantly higher at closer planting geometry of 25 cm x 10 cm with 100 Per cent RDF under drip fertigation. This was mainly due to increased uptake of nutrients, applied nearby crop roots.

5.3.2 Interaction effect on yield of aerobic rice under drip fertigation

Planting geometry and fertilizer levels through drip fertigation caused the variation in yield parameters. The planting geometry of 25 cm x 25 cm with 100 Per cent RDF recorded higher filled grains per panicle, less chaffy grains per panicle and less per cent of chaffyness, panicle length, panicle weight, test weight and also grain yield (g hill^{-1}) compared to control i.e. 25 cm x 25 cm with 100 per cent RDF through surface application (Fig. 5). This was mainly due to better translocation of photosynthates from source to sink by efficient utilisation of nutrients, solar radiation and also avoided nutrient losses from crop root zone.

Planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation has recorded significantly higher grain yield (6762 kg ha^{-1}) and straw yield (9186 kg ha^{-1}) as compare to control i.e. 25 cm x 25 cm with surface irrigation (4028 kg ha^{-1} and 6356 kg ha^{-1}, respectively) (Fig.7) . The higher grain yield with rectangular planting geometry might be due to higher yield parameters such as number of panicles per meter square (719.47), total dry matter per meter square, number of tillers per meter square. This may be due to more plant population with less competition for the nutrients and moisture when applied through drip fertigation.

5.4 Interaction effect of planting geometry and fertilizer levels on soil nutrient status of aerobic rice under drip fertigation

The soil fertility status under drip fertigation was affected by planting geometry and fertilizer levels. The planting geometry of 25 cm x 25 cm with 100 per cent RDF through drip fertigation has recorded higher available nitrogen (315.19 kg ha^{-1}), phosphorous (37.51 kg ha^{-1}), potassium (242.45 kg ha^{-1}) (Fig. 8 and 9). This might be due to higher application of fertilizers and lesser uptake of nutrients by crop and less leaching loss due to application of nutrients directly in to root zone under drip fertigation. The results are in agreement with findings of Gururaj (2012) and Sanju (2012).

5.5 Economics of drip fertigation in aerobic rice

The economics of aerobic rice varied with respect to gross returns, net returns and B:C ratio in relation to varying levels of inputs used.

Drip fertigation with varied levels of fertilizer and planting geometry registered difference in gross returns, net returns and B:C ratio as compared to surface irrigation and soil application of RDF. Among different planting geometry and fertilizer level treatments under drip fertigation, planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation recorded higher gross returns of ₹ 1,21,977 per hectare, followed by 25 cm x 10 cm with 100 per cent RDF through drip fertigation (₹ 111057 ha^{-1}) (Fig. 10). This is mainly because these treatments were out yielded in grain and straw as compared to rest of the treatments.

Meanwhile, higher net returns (₹ 75,814 ha^{-1}) and B:C ratio (2.64) were recorded in planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation with normal fertilizer which is comparable with 100 per cent RDF with planting geometry of 25 cm x 10 cm (₹ 64,764 ha^{-1} and 2.40, respectively). The least net returns and B:C ratio was observed in planting geometry of 25 cm x 10 cm with 50 per cent

RDF (₹ 37211 and 1.84, respectively). This could be due to increased yield and better market price.

Practical utility of the investigation

- ✓ The planting geometry of 25 cm x 15 cm can be followed for aerobic rice cultivation under drip fertigation for getting higher yields.

- ✓ For obtain higher grain and straw yield application of 100 per cent RDF (100:50:50 N, P_2O_5, K_20 kg ha^{-1}) through drip fertigation is useful.

- ✓ B:C ratio was highest with 100 per cent RDF with planting geometry of 25 cm x 15 cm which may be followed for aerobic rice cultivation under drip fertigation for obtaining higher returns.

Future line of work

- ✓ Need to develop optimum spacing particularly for newly released varieties or hybrids for aerobic condition under drip fertigation.

- ✓ Comparative studies on solubility, availability and release pattern of nutrients of normal fertilizers and water soluble fertilizers in relation to crop yield are required.

- ✓ Appropriate irrigation and nutrient scheduling and their interaction effect under drip fertigation needs further investigation.

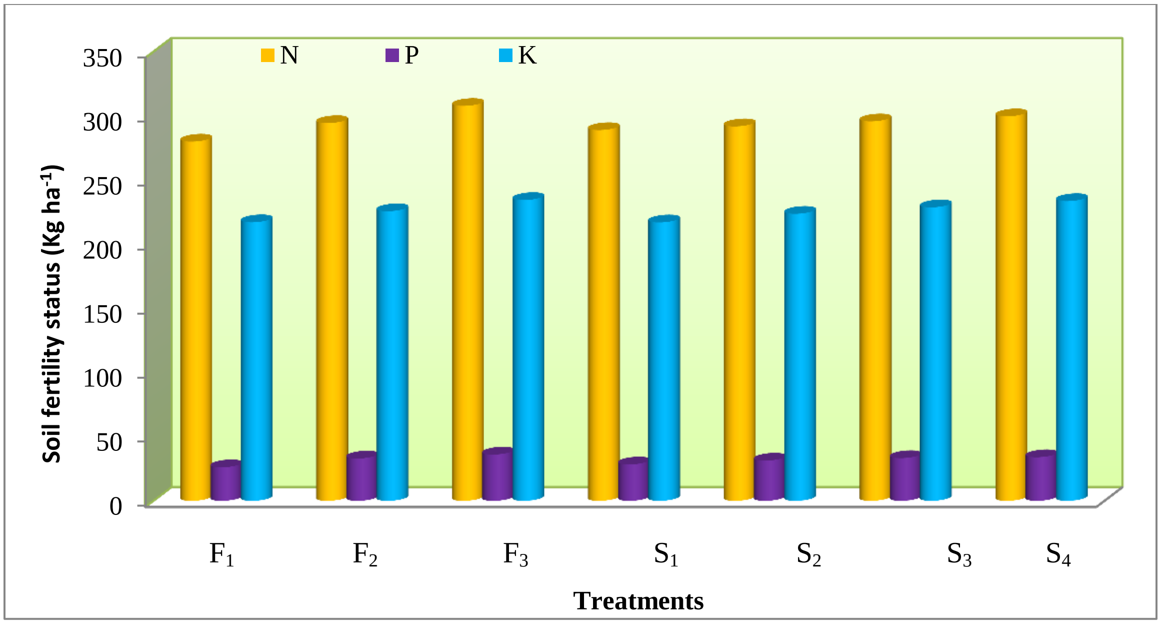

Fig. 8: Soil nutrient (kg ha^{-1}) status of aerobic rice as influenced by planting geometry and levels of drip fertigation

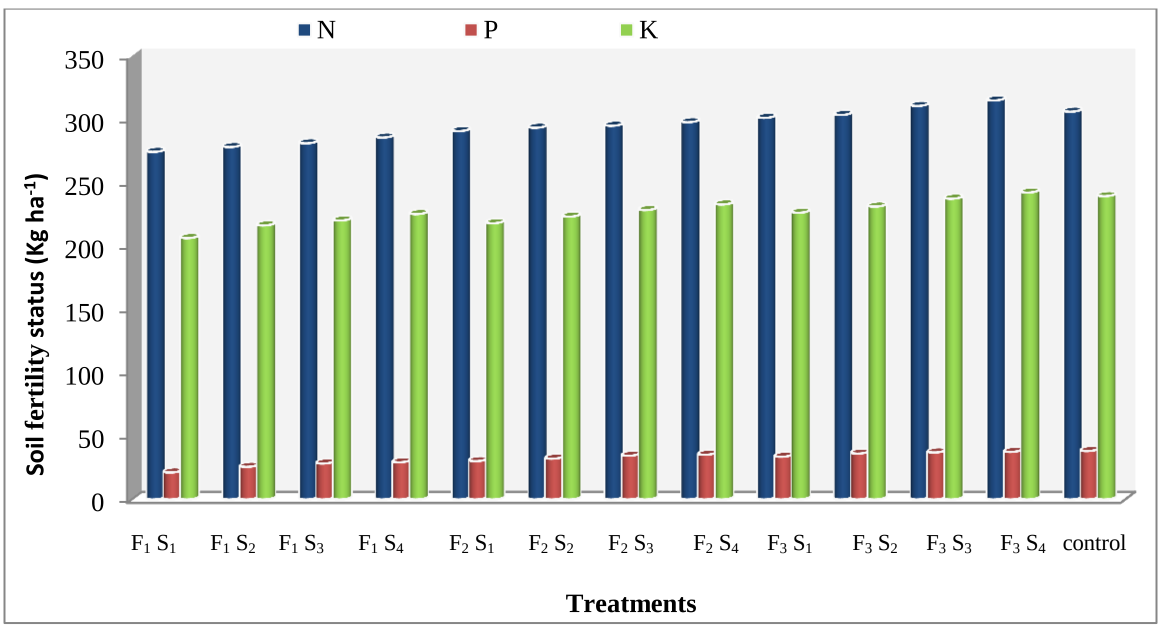

Fig. 9: Interaction effect of planting geometry and fertilizer levels on Soil fertility (kg ha^{-1}) status of aerobic rice under drip fertigation

Note: Fertilizer levels **(F)**: **F_1**: 50 per cent RDF, **F_2**: 75 per cent RDF, **F_3**: 100 per cent RDF.
Planting geometry **(S): S_1**: 25 cm x 10 cm, **S_2**: 25 cm x 15 cm, **S_3**: 25 cm x 20 cm, **S_4**: 25 cm x 25cm.
RDF- Recommended dose of fertilizers (100:50:50 NPK kg ha^{-1}).

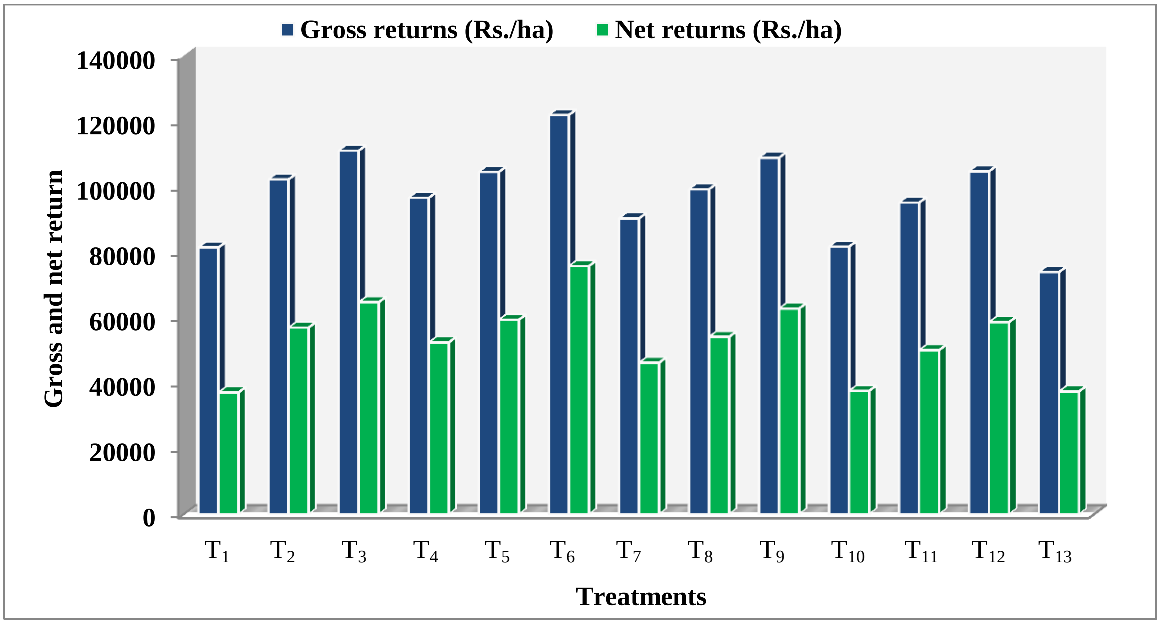

Fig. 10: Economics of aerobic rice as influenced by planting geometry and levels of drip fertigation

T_1 : S_1 - 25 cm x 10 cm + (F_1) 50 % of RDF through Drip fertigation.

T_2 : S_1 - 25 cm x 10 cm + (F_2) 75 % of RDF through Drip fertigation.

T_3 : S_1 - 25 cm x 10 cm + (F_3) 100 % of RDF through Drip fertigation.

T_4 : S_2 - 25 cm x 15 cm + (F_1) 50 % of RDF through Drip fertigation.

T_5 : S_2 - 25 cm x 15 cm + (F_2) 75 % of RDF through Drip fertigation.

T_6 : S_2 - 25 cm x 15 cm + (F_3) 100 % of RDF through Drip fertigation.

T_7 : S_3 - 25 cm x 20 cm + (F_1) 50 % of RDF through Drip fertigation.

T_8 : S_3 - 25 cm x 20 cm + (F_2) 75 % of RDF through Drip fertigation.

T_9 : S_3 - 25 cm x 20 cm + (F_3) 100 % of RDF through Drip fertigation

T_{10}: S_4 - 25 cm x 25 cm + (F_1) 50 % of RDF through Drip fertigation**.**

T_{11}: S_4 - 25 cm x 25 cm + (F_2) 75 % of RDF through Drip fertigation.

T_{12}: S_4 - 25 cm x 25 cm + (F_3) 100 % of RDF through Drip fertigation.

T_{13}: Control i.e., Spacing of 25 cm X 25 cm with surface irrigation and soil application RDF

Note: **RDF**- Recommended dose of fertilizers (100:50:50 NPK kg ha^{-1}).

VI SUMMARY

A field experiment on "Standardisation of planting geometry in aerobic rice (*Oryza sativa L.*) under different levels of drip fertigation" was carried out during *Kharif* 2014 in Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krushi Vignana Kendra, Bengaluru. This was aimed to find out the optimum planting geometry and suitability of drip fertigation levels under aerobic system of rice cultivation and to optimize for higher production.

The experiment was laid out in a factorial concept of randomized complete block design with 13 treatments which were replicated thrice. The treatments constitutes 50 per cent of RDF through Drip fertigation (F_1), 75 per cent of RDF through Drip fertigation (F_2), 100 per cent of RDF through Drip fertigation (F_3) and four planting geometry 25 cm x 10 cm, 25 cm x 15 cm, 25 cm x 20 cm and 25 cm x 25 cm, with a control i.e., planting geometry of 25 cm X 25 cm with surface irrigation and soil application of RDF. Observation on growth, yield and yield components were recorded at different growth stages of the crop. The salient findings of the study are summarized as follows.

- The height of the plants differed significantly between fertilizers levels at all stages of crop growth except at 30 DAS under drip fertigation. Among the levels of drip fertigation 100 per cent RDF recorded significantly higher plant height as compared to 50 per cent RDF. The planting geometry of 25 cm x 15 cm has recorded significantly higher plant height at all the stages of crop growth. Interaction of planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation has recorded higher plant height at all the stages of crop growth.

- Application of 100 per cent RDF through drip fertigation has recorded higher number of leaves and leaf area (82.71 and 2046.66 cm^2 $hill^{-1}$ at maturity, respectively). Planting geometry of 25 cm x 25 cm has recorded higher number of leaves and leaf area (80.29 and 2007.85 cm^2 $hill^{-1}$ at maturity, respectively). Significantly higher number of leaves and leaf area (98.79 and 2442.99 cm^2 $hill^{-1}$ at maturity, respectively) was observed in interaction of planting geometry of 25 cm x 25 cm with 100 per cent RDF and significantly lower number of leaves and leaf area (57.44 and 1496.35 cm^2 $hill^{-1}$ at maturity, respectively) observed in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation.

- The number of tillers (m^{-2}), total dry matter (g m^{-2}) and crop growth rate (g m^{-2} day^{-1}) has significantly influenced by fertilizer levels and planting geometry at all stages of crop growth. Application of 100 per cent RDF through drip fertigation has recorded higher number of tillers (731.96 m^{-2} at maturity), total dry matter (3159 g m^{-2} at maturity) and crop growth rate (26.10 g m^{-2} day^{-1} at 90-120 DAS). Planting geometry of 25 cm x15 cm has recorded higher number of tillers (597.58 m^{-2} at maturity), total dry matter (2663.69 g m^{-2} at maturity) and crop growth rate (21.09 g m^{-2} day^{-1} at 90-120 DAS). Significantly higher number of tillers (794.67 m^{-2} at maturity), total dry matter (3488.32 g m^{-2} at maturity) and crop growth rate

(31.78 g m^{-2} day^{-1} at 90-120 DAS) was observed in interaction of planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation.

- The LAI and LAD were significantly higher (6.50 and 213.11 days at maturity, respectively) in planting geometry of 25 cm x 10 cm with 100 per cent RDF through drip fertigation and significantly lower LAI and LAD was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation (2.39 and 71.59 days at maturity, respectively).

- Significantly higher productive tillers were observed in 100 per cent RDF through drip fertigation (601.73 m^{-2}). Planting geometry of 25 cm x 15 cm (516.61 m^{-2}) has recorded higher productive tillers m^{-2}. Interaction of planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation has recorded significantly higher productive tillers (719.47 m^{-2}).

- The higher yield components such as grain yield (34.75 g hill^{-1}) panicle length (27.12 cm), panicle weight (3.17 g), thousand grain weight (23.98 g) and total number of filled grains panicle^{-1} (129.40) with lower per cent chaffyness (11.76 %) were observed under planting geometry of 25 cm x 25 cm with 100 per cent RDF through drip fertigation. The 100 per cent RDF through drip fertigation recorded significantly higher grain yield (6115 kg ha^{-1}) and significantly lower grain yield was recorded in 50 per cent RDF (4823 kg ha^{-1}) was on par with the 75 per cent RDF through drip fertigation (5538 kg ha^{-1}).

- Application of 100 per cent RDF through drip fertigation recorded significantly higher grain and straw yield (6115 and 8792 kg ha^{-1}) .Planting geometry significantly influences the grain and straw yield, significantly higher grain and straw yield (5954 and 8297 kg ha^{-1}) was noticed in 25 cm x 15 cm and significantly lower grain and straw yield (5168 and 7463 kg ha^{-1}) observed in 25 cm x 25 cm spacing. Planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation recorded significantly higher grain and straw yield of aerobic rice (6762 and 9186 kg ha^{-1}, respectively). The increase in grain yield was 63 per cent over surface irrigation with soil application of 100 per cent RDF.

- Planting geometry of 25 cm x 25 cm with 100 per cent RDF has recorded significantly higher available nitrogen, phosphorous and potassium (315.19, 37.51 and 242.45 kg ha^{-1}, respectively), significantly lower available nitrogen, phosphorous and potassium (274.51, 21.26 and 206.42 kg ha^{-1}, respectively) was observed in 25 cm x 10 cm with 50 per cent RDF.

- Planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher nitrogen, phosphorous and potassium uptake (146.37, 40.01 and 138.45 kg ha^{-1}, respectively).

- The levels of fertilizers under drip fertigation had the significant influence on water use efficiency. Application of 100 per cent RDF recorded significantly

Plate 3: The planting geometry of 25 cm x 15 cm with 100 % RDF through drip fertigation

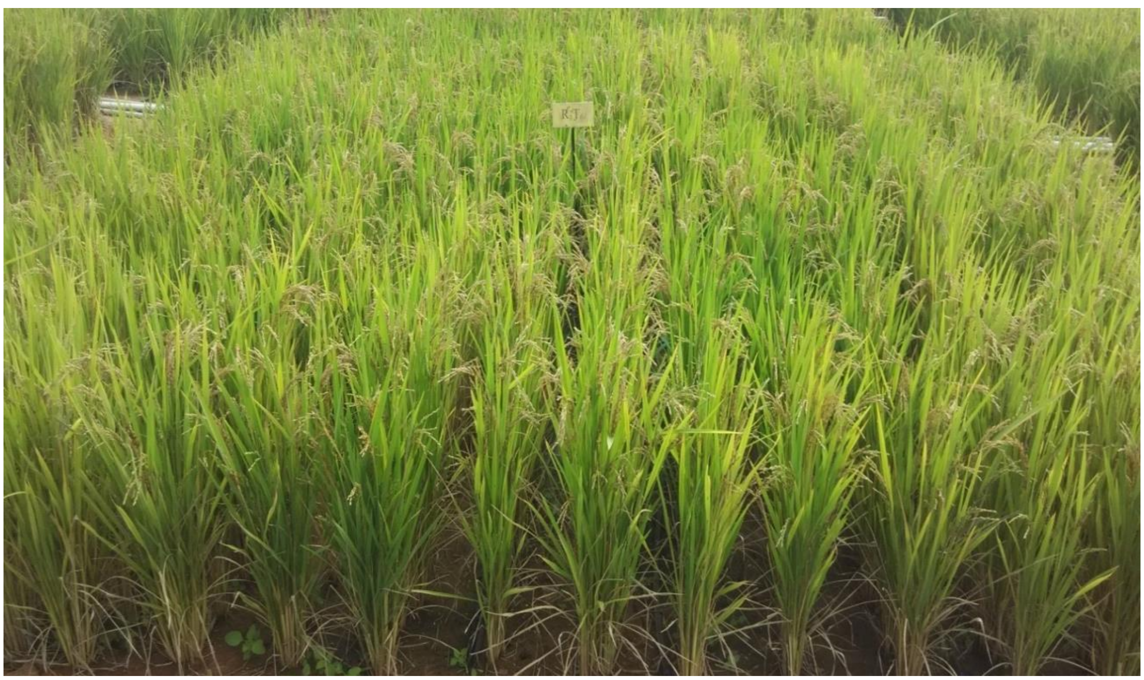

Plate 4: The planting geometry of 25 cm x 25 cm with soil application of 100 %RDF

higher (83.37 kg ha-cm^{-1}) water use efficiency and significantly lower (65.33 kg ha-cm^{-1}) water use efficiency was recorded in 50 per cent RDF. Among planting geometries, 25 cm x 15 cm was recorded significantly higher water use efficiency (80.66 kg ha-cm^{-1}) and significantly lower water use efficiency (70.00 kg ha-cm^{-1}) was noticed in 25 cm x 25 cm which was on par with 25 cm x 10 cm (73.36 kg ha-cm^{-1}). Fertilizer levels and planting geometry interactions has a significant influence on water use efficiency. Planting geometry of 25 cm x 15 cm with 100 per cent RDF has recorded significantly higher (91.59 kg ha-cm^{-1}) water use efficiency and significantly lower water use efficiency (36.61 kg ha-cm^{-1}) was recorded in control i.e. 25 cm x 25 cm with surface irrigation.

- The planting geometry of 25 cm x 15 cm with 100 per cent RDF through drip fertigation recorded higher gross, net returns and B:C ratio (₹ 121977, ₹ 75814 ha^{-1} and 2.64, respectively) and lowest was recorded in control i.e. planting geometry of 25 cm x 25 cm with surface irrigation with soil application of RDF (₹ 73983, ₹ 37515 ha^{-1} and 2.03)

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APPENDIX I

Fertilizer schedule for soil application of RDF – 100:50:50 kg NPK ha^{-1}

Sl. No.	Stage of crop	Nutrients (kg ha^{-1})			Source of fertilizers (kg ha^{-1})			Fertilizer applied per plot for each split (g per 27 m^2)		
		N	P	K	Urea	SSP	MOP	Urea	SSP	MOP
1	Basal	50	50	50	108.5	312.5	83.0	298	844	225
2	30 DAS	25	-	-	54.25	-	-	150	-	-
3	60 DAS	25	-	-	54.25	-	-	150	-	-
Total		100	50	50	217.0	312.5	83.0	598	844	225

Note: N content in Urea- 46 %

P_2O_5 content in SSP- 16 %

K_2O content in MOP- 60 %

APPENDIX II

Drip fertigation schedule for treatments with normal fertilizers (4 equal splits)

Level/ dose	Nutrients (kg ha^{-1})			Source of fertilizers (kg ha^{-1})			Total fertilizers applied per plot (g per 27 m^2)			Fertilizer applied per plot for each split (g per 27 m^2)		
	N	P	K	Urea	DAP	MOP	Urea	DAP	MOP	Urea	DAP	MOP
100 % RDF	100	50.0	50.0	174.86	108.69	83.00	470	292.9	222.7	117.5	73.2	29.37
75 % RDF	75	37.5	37.5	130.92	81.51	62.25	352.5	219.6	167.0	88.1	54.9	41.7
50 % RDF	50	25.0	25.0	87.33	54.35	41.50	235	146.4	111.3	58.7	36.6	27.8

Note: Urea contains 46 % N.
DAP contains 18 % N and 46 % P_2O_5.
MOP contains 60 % K_2O.

APPENDIX III

Cost of Inputs and Prices of Output

Sl. No.	Particulars	Unit	Cost unit^{-1} (₹)	Units used ha^{-1}	Cost ha^{-1} (₹)
1	**Land preparation**				
	Disc plough and harrowing	Hour	350	18	6300
2	**Labour**	Man day (8 hrs.)	160		
	a) FYM spreading			5	800
	b) Sowing (dibbling of seeds)			18	2880
	c) Surface irrigation			25	4000
	d) Drip irrigation			18	2880
	e) Fertilizer application			8	960
	f) Weeding			28	4480
	g) Plant protection chemicals			10	1600
	h) Harvesting			18	3200
	i) Threshing, winnowing, cleaning and bagging			16	2880
3	**Inputs**				
	a) Seeds	kg	26	*	*
	b) FYM	Tonne	500	10	5000
	c) Fertilizers				
	• Urea	kg	5.3	*	*
	• DAP	kg	25	*	*
	• MOP	kg	16.72	*	*
	d) Plant protection chemicals				
	• Chloropyriphos	Ltr.	320	2.4	768
	• Tricyclazole	G	400	2.6	1040
4	**Drip fertigation unit including filter (life span of 10 years)**	-	-	-	13600
5	**Grain**	Quintal	1600	*	*
6	**Straw**	Tonne	1500	*	*

Note: * units and cost varies according to treatment

IV APPENDIX

B: C ratio	Benefit cost ratio
C.D	Critical difference
cm	Centimeter
DAP	Di- ammonium phosphate
DAS	Days after sowing
ds m^{-1}	Deci siemen per meter
g	Grams
K, K_2O	Potassium
kg ha^{-1}	Kilograms per hectare
lph	Litres per hour
m^{-2}	Per meter square
Mg m^{-3}	Mega gram per meter cube
mm	Milli meter
MOP	Murate of potash
N	Nitrogen
NS	Non significant
P, P_2O_5	Phosphorus
P=0.05	At 5 per cent probability
q ha^{-1}	Quintals per hectare
RDF	Recommended dose of fertilizers
S.Em	Standard error mean
t ha^{-1}	Tonnes per hectare
TDM	Total dry matter
Viz	Namely
WSF	Water soluble fertilizers
ZARS	Zonal Agricultural Research Station
%	Per cent