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Effect of graded levels of fertilizer nutrients and irrigation methods on nutrient content and uptake of aerobic rice

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Abstract
A study was undertaken to know the effect of graded levels of nutrients and irrigation methods on nutrient content and uptake of aerobic rice at V. C. Farm, Mandya, Karnataka during 2016-17 and 2017-18. The pooled data on grain yield of aerobic rice indicated that drip fertigation with 125 per cent N, P and K of RDF through WSF recorded higher grain yield in pooled analysis (6675 kg ha^{-1}) and similar trend in first and second season which was on par with drip fertigation of RDF with 100 per cent WSF (5969 kg ha^{-1}) in pooled data. The same treatment recorded higher straw yield in pooled analysis (8158 kg ha^{-1}) and similar trend in first and second season. Significantly higher content and uptake of primary and secondary nutrients of aerobic rice during first season, second season and pooled data was registered in the same treatment and was followed by T_6 that received 100 % N, P and K of RDF through WSF.

Keywords: Drip fertigation, aerobic rice, nutrient content, nutrient uptake

Introduction
The traditional or flooding method of rice production system not only results in wastage of water and nutrients, but also causes degradation of environment. The water availability for agriculture is estimated to be 83.3 per cent of total water used today; it is anticipated to shrink up to 71.6 per cent in 2025 and up to 64.6 per cent in 2050 as predicted by Yadav (2002). Scientists are now taking up the challenge to develop rice production systems that cope up with water scarcity. Recent developments demonstrated that rice can also be grown under aerable or non flooded conditions, where in rice can be grown in well-drained, non-puddled and unsaturated soils. Drip irrigation is one novel technique and in addition, simultaneous application of fertilizers (fertigation) opens new possibilities for controlling water and nutrient supply to crops besides maintaining the desired concentration and distribution of nutrients and water in the soil. In drip-fertigation system, uptake of N, P and K are substantially improved as noticed from earlier studies. In this respect, higher yield and better quality produce are obtained per unit of fertilizer and water applied. Hence, keeping these points in view, field experiments were conducted to know the effect of graded levels of fertilizer nutrients and irrigation methods on nutrient content and uptake of aerobic rice.

Material and Methods
Field experiments were conducted during *kharif* 2017 and 2018 at Zonal Agricultural Research Station, V. C. Farm, Mandya situated in Southern Dry Zone (Zone 6), Karnataka. The experimental site, located between 12º 34' N Latitude and 76º 50' E Longitude and at an altitude of 930 m above mean sea level. Composite sample was collected from the experimental site by following quartering technique. Samples were air dried, powdered, sieved and stored in polythene covers for further analysis. The soil was red sandy loam in nature. The results of the soil analysis of the experimental plot along with the methods followed are presented in Table 1.

Table 1: Initial soil properties of the experimental plots

Parameters	Values	Method	Reference
pH (1:2.5 soil: water)	7.30	Potentiometric method	Jackson, 1973 [1]
Electrical conductivity (dS m^{-1})	0.09	Conductometric method	Jackson, 1973 [1]
Available nitrogen (kg ha^{-1})	287.50	Alkaline potassium permanganate method	Subbiah and Asija, 1956 [2]
Available Phosphorus (kg ha^{-1})	19.8	Olsen's extractant method, Colorimetry	Jackson, 1973 [1]
Available potassium (kg ha^{-1})	162.56	Ammonium acetate extractant method, Flame photometry	Jackson, 1973 [1]
Exchangeable calcium [Cmol(p^+) kg^{-1}]	5.27	Ammonium acetate extractant method, Versenate titration method	Jackson, 1973 [1]
Exchangeable magnesium [Cmol(p^+) kg^{-1}]	2.94	Ammonium acetate extractant method, Versenate titration method	Jackson, 1973 [1]
Available Sulphur (mg kg^{-1})	12.24	$CaCl_2$ extractant method, Turbidimetry	Black, 1965

The KRH-4 rice hybrid released by the University of Agricultural Sciences, Bangalore at Zonal Agricultural Research Station, Mandya, derived from CRMS 32A and MSN 36 was used as test crop for the experimental purpose. The crop plants were planted with spacing of 25 cm × 25 cm, seed rate 5 kg ha^{-1} and the recommended dose of FYM applied was 10 t ha^{-1} and RDF as per POP was 125: 62.5: 62.5 kg N, P_2O_5 and K_2O ha^{-1}. The experiment consists of twelve treatments

T_1 - Absolute control with surface irrigation
T_2 - Absolute control with drip irrigation
T_3 - Package of practice with surface irrigation
T_4 - 50 % N, P and K of RDF through water soluble fertilizers
T_5 - 75 % N, P and K of RDF through water soluble fertilizers
T_6- 100 % N, P and K of RDF through water soluble fertilizers
T_7- 125 % N, P and K of RDF through water soluble fertilizers
T_8 - 50 % N, P and K of RDF through conventional fertilizers
T_9 - 75 % N, P and K of RDF through conventional fertilizers
T_{10} - 100 % N, P and K of RDF through conventional fertilizers
T_{11} - 125 % N, P and K of RDF through conventional fertilizers
T_{12} - 100 % N & K of RDF through water soluble fertilizers and 100 % P of RDF through conventional fertilizers

Note: Recommended dose of FYM (10 t ha^{-1}) was applied for all the plots except T_1 andT_2

Nitrogen, phosphorus and potassium for water soluble fertilizer treatments was supplied through drip fertigation in the form of water soluble urea, mono ammonium phosphate (MAP) and muriate of potash (KCl-white coloured), respectively whereas, urea, single super phosphate (SSP) and muriate of potash (KCl-pink coloured), were applied as source of N.P.K. respectively for conventional fertilizer treatments. The treatments received calculated quantities of fertilizers as per the treatment details at the time of sowing. For treatments with recommended dose of fertilizers, 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. For treatments T_4 to T_7 (that received water soluble fertilizers), N, P and K fertilizers were applied through fertigation in equal splits at four days interval starting from 15 days after sowing and stopped at 15 days prior harvest. For treatments T_8 to T_{11} (that received conventional fertilizers), only N and K fertilizers were applied in equal splits at four days interval from 15 days after sowing to 15 days before harvest, whereas P fertilizer was applied directly to soil as basal dose. Treatment T_{12} (that received combination of water soluble and conventional fertilizers) was supplied with N and K fertilizers through drip fertigation and SSP for P as basal dose.

The aerobic rice crop was harvested at physiological maturity stage (135 days after sowing). Plant samples were collected from each treatment separately, dried and powdered by using mixer grinder with stainless steel blade. The powdered samples were stored in airtight containers for further chemical analysis as mentioned in the table 2.

Table 2: Methods adopted for analysis of plant samples

S. No.	Parameter	Method and Reference
1	Total plant nitrogen	Piper (1966) [4]
2	Total plant phosphorus	Yellow phosphovanadoMolybdate complex method, Piper (1966) [4]
3	Total plant potassium	Flame photometry, Jackson (1973) [1]
4	Total plant calcium and magnesium	Complexometric titration method, Piper (1966) [4]

Uptake of nutrients by aerobic rice was calculated using the following formula and expressed in kg ha^{-1}.

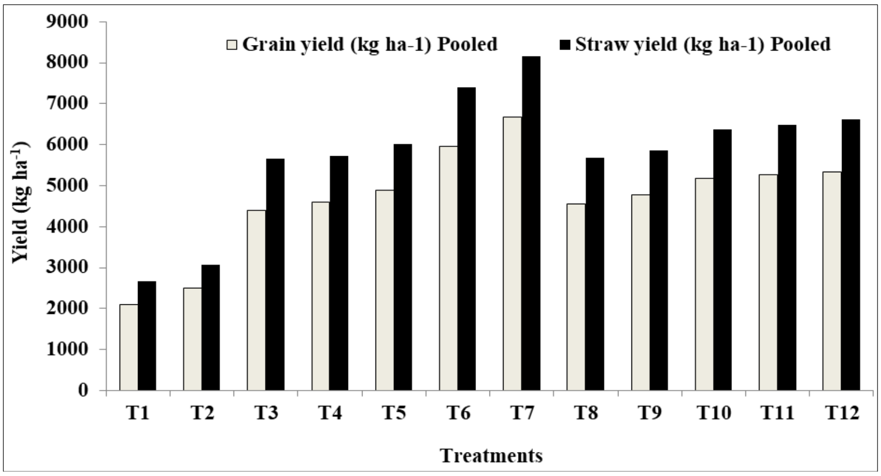
$$\text{Nutrient uptake by straw or grain (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{dry weight of grain or straw (kg ha}^{-1}\text{)}}{100}$$

The analyses and interpretation of the data was done using the Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test was 5 % probability and wherever 'F' test was found significant, the 't' test was performed to estimate critical differences among various treatments.

Results and Discussion

A. Grain and straw yield (kg ha^{-1}) of aerobic rice

The data on yield of aerobic rice indicated that drip fertigation with 125 % N, P and K of RDF through WSF recorded higher grain and straw yield in pooled analysis (6675 and 8158 kg ha^{-1}, respectively) and similar trend in first season (6381 and 7800 kg ha^{-1}) and second season (6969 and 8516 kg ha^{-1}, respectively) which was on par with drip fertigation of RDF with 100 per cent WSF (5969 and 7407 kg ha^{-1}, respectively) in pooled data (Fig 1). Higher dose of WSF resulted in increased grain and straw yield. The increase in grain yield was mainly associated with significant increase in effective productive tillers $panicle^{-1}$, number of grains $panicle^{-1}$ and test weight as observed in the experiment. The increase in yield components was due to adequate supply and efficient utilization of nutrients by plants. Similar results were also reported by Pandey and Nandeha (2004) [6]; Sarawgi and Sarawgi (2004) [7]. The lower yields obtained in control treatments might be due to non availability of nutrients to plants and lesser dry matter production ultimately affected the yield. Similar findings were reported by Sundrapandiyan (2012) [8] and Richakanna (2013) [9], Anitta *et al.* (2011).



* Pooled values of 2017 and 2018 are presented graphically

Fig 1: Effect of graded levels of nutrients and irrigation methods on yield and harvest index of aerobic rice

B. Effect of graded levels of nutrients and irrigation methods on plant nutrient content and nutrient uptake by aerobic rice

a. Nitrogen

Different nutrient levels and types of fertilizers applied through drip fertigation significantly influenced the N concentration in grain and straw of aerobic rice (Table 3). The concentration of nitrogen in grain varied from 1.26 to 1.59 per cent and straw from 0.69 to 1.02 per cent in pooled data and similar trend was noticed in first season (1.33 to 1.63 and 0.70 to 1.09 % in grain and straw, respectively) and in second season (1.22 to 1.54 and 0.68 to 0.95 % in grain and in straw, respectively). Significantly higher uptake of grain nitrogen (104.27, 107.32 and 105.80 kg ha^{-1} during first season, second season and pooled data) was recorded in the same treatment. The similar trend was observed for nitrogen uptake by straw (85.02, 80.90 and 82.96 kg ha^{-1} during first season, second season and pooled data) (Table 4). The highest nitrogen content and uptake by straw and grain was observed in the treatment T_7 that received 125 % N, P and K of RDF through WSF under drip irrigation and was followed by 100 % N, P and K of RDF through WSF (T_6) under drip irrigation.

Higher N content in straw and grain and its uptake with increased rates of nitrogen applied in the form of WSF was observed, probably due to enhanced mineralization under aerobic environment and higher availability of nutrients and their supply to the roots might have helped in nutrient absorption and mobilization compared to conventional fertilizers through drip and surface irrigation. Under package of practice (T_3), N losses might have caused by leaching of nutrients that resulted in lower N content in comparison with the treatments that received recommended dose of nitrogen as water soluble fertilizers through drip fertigation. Nitrogen is very much susceptible for leaching, whereas drip fertigation enhances the improvement in N content of crop by reducing the losses. Similar results have been reported by Singh *et al.* (2002) [12]; Geetha (2015) [11]. Uptake of N was found to be higher during first season than the second season was due to increased dry matter yield obtained in 2018 compared to 2017 may be because of the application of higher rate of nutrients and higher dry matter production and yield.

The lowest content and uptake of nitrogen in grain and straw was observed in the treatment T_1 that did not receive any fertilizers under surface irrigation, this was on par with T_2 (Absolute control with drip irrigation) was mainly attributed to lack of nutrients in these treatments and low content of N along with reduced yields.

Table 3: Effect of graded levels of nutrients and irrigation methods on nitrogen content (%) of aerobic rice

Treatments	Grain			Straw		
	2017	2018	Pooled	2017	2018	Pooled
T_1	1.30	1.22	1.26	0.70	0.68	0.69
T_2	1.32	1.23	1.28	0.73	0.69	0.71
T_3	1.50	1.42	1.46	0.85	0.80	0.83
T_4	1.37	1.25	1.28	0.79	0.72	0.76
T_5	1.47	1.28	1.38	0.90	0.82	0.86
T_6	1.58	1.45	1.55	0.91	0.88	0.90
T_7	1.63	1.54	1.59	1.09	0.95	1.02
T_8	1.34	1.24	1.27	0.75	0.70	0.73
T_9	1.45	1.25	1.35	0.87	0.81	0.84
T_{10}	1.53	1.44	1.49	0.86	0.85	0.86
T_{11}	1.59	1.49	1.53	1.05	0.93	0.99
T_{12}	1.56	1.48	1.52	0.90	0.86	0.88
S.Em±	0.03	0.04	0.04	0.01	0.01	0.01
CD @ 5%	0.10	0.12	0.11	0.04	0.03	0.04

Table 4: Effect of graded levels of nutrients and irrigation methods on nitrogen uptake (kgha^{-1}) by aerobic rice

Treatments	Grain			Straw		
	2017	2018	Pooled	2017	2018	Pooled
T_1	25.49	27.23	26.36	17.84	18.88	18.36
T_2	30.85	32.55	31.70	21.12	22.54	21.83
T_3	64.01	64.14	71.39	44.79	48.34	46.57
T_4	58.93	58.79	65.29	42.48	43.68	43.08
T_5	67.43	66.42	73.82	50.78	52.56	51.67
T_6	89.69	90.94	95.24	64.81	67.68	66.25
T_7	104.27	107.32	105.80	85.02	80.90	82.96
T_8	57.10	58.70	64.28	39.86	42.26	41.06
T_9	64.83	63.35	70.86	47.62	50.90	49.26
T_{10}	76.81	77.13	84.42	52.66	56.17	54.42
T_{11}	80.95	82.16	87.33	64.68	63.19	63.94
T_{12}	78.73	83.32	88.66	56.84	59.62	58.23
S.Em±	6.17	5.51	5.82	4.56	4.40	4.46
CD @ 5%	18.10	16.15	17.07	13.36	12.91	13.09

Legend

T_1-Absolute control with surface irrigation	T_7 - 125 % N, P and K of RDF – WSF
T_2-Absolute control with drip irrigation	T_8 – 50 % N, P and K of RDF – Conventional fertilizer (CF)
T_3 - Package of practice with surface irrigation	T_9 – 75 % N, P and K of RDF – CF
T_4 - 50 % N, P and K of RDF – Water soluble fertilizer (WSF)	T_{10}- 100 % N, P and K of RDF – CF
T_5 - 75 % N, P and K of RDF – WSF	T_{11}- 125 % N, P and K of RDF – CF
T_6 - 100 % N, P and K of RDF – WSF	T_{12}- 100 % N & K of RDF - WSF and 100 % P of RDF – CF

b. Phosphorus

Significantly higher values for P content in grain (0.52, 0.46 and 0.49 % in first season, second season and pooled data, respectively) and straw (0.28, 0.23 and 0.25 % in first season, second season and pooled data, respectively) was obtained in the treatment that received125 % N, P and K of RDF through WSF (T_7) (Table 5). Plants treated with graded levels of P showed increase in P content with increase in the amount of P added both as WSF and CF and the similar results were obtained by Rakesh (2015) [13], might be due to the increase in availability of P at higher P levels. P applied through WSF recorded higher P content in plants due to high soluble P and its application at the root zone through drip fertigation which enable higher availability compared to CF.

Drip irrigated aerobic rice recorded significantly higher uptake of phosphorus by grain and straw (35.22 and 20.56 kg ha^{-1}, respectively) in pooled data and similar trend was observed in first and second season in treatment T_7 that received 125 % N, P and K of RDF through WSF compared to other treatments (Table 6). Higher uptake of P by rice due to application of higher grades of fertilizers attributed to increased availability of P in soil and also higher content of P along with higher biomass production, which has also been observed by Chetan Das kurrey (2014) [14], Abebe and Merkuza (2016) [16].

Significantly lower content of P in grain and straw were found in absolute control with surface irrigation (T_1) and was on par with absolute control under drip irrigation (T_2) that did not receive any fertilizer nutrients could be attributed to lack of nutrient supply through inorganic fertilizers. The similar results were obtained for P utake by aerobic rice. This may be due to low yields resulting from absence of P and K fertilizers in these plots. The results are in conformity with the findings of Sood (2005) [16]; Mishra *et al.* (2008) [17]; Verma (2002) [18].

Table 5: Effect of graded levels of nutrients and irrigation methods on phosphorus content (%) of aerobic rice

Treatments	Grain			Straw		
	2017	2018	Pooled	2017	2018	Pooled
T_1	0.38	0.36	0.37	0.13	0.11	0.12
T_2	0.39	0.38	0.39	0.15	0.12	0.14
T_3	0.42	0.41	0.42	0.22	0.17	0.20
T_4	0.43	0.38	0.41	0.18	0.15	0.16
T_5	0.47	0.41	0.44	0.20	0.17	0.19
T_6	0.48	0.45	0.47	0.26	0.22	0.24
T_7	0.52	0.46	0.49	0.28	0.23	0.25
T_8	0.41	0.36	0.39	0.15	0.13	0.14
T_9	0.46	0.40	0.43	0.19	0.16	0.18
T_{10}	0.47	0.42	0.44	0.23	0.18	0.21
T_{11}	0.51	0.44	0.48	0.25	0.21	0.23
T_{12}	0.47	0.43	0.45	0.24	0.20	0.22
S.Em±	0.02	0.02	0.02	0.01	0.02	0.02
CD @ 5%	0.06	0.06	0.06	0.03	0.06	0.05

Table 6: Effect of graded levels of nutrients and irrigation methods on phosphorus uptake (kgha^{-1}) by aerobic rice

Treatments	Grain			Straw		
	2017	2018	Pooled	2017	2018	Pooled
T_1	7.45	8.04	7.75	3.31	3.05	3.18
T_2	9.11	10.05	9.58	4.34	3.92	4.13
T_3	17.92	18.52	20.30	11.59	10.39	10.99
T_4	18.70	18.62	20.70	9.39	9.36	9.38
T_5	21.41	21.27	23.54	11.53	10.92	11.23
T_6	27.31	28.22	30.10	18.80	16.92	17.86
T_7	33.44	32.06	35.22	21.53	19.59	20.56
T_8	17.52	17.46	19.42	7.97	7.55	7.76
T_9	20.39	20.27	22.48	10.64	10.15	10.40
T_{10}	23.48	22.50	25.21	14.14	12.16	13.15
T_{11}	25.79	24.26	27.42	15.70	14.41	15.06
T_{12}	23.72	24.21	26.22	14.91	13.66	14.29
S.Em±	2.14	1.57	2.05	1.07	0.97	1.02
CD @ 5%	6.29	5.98	6.02	3.14	2.85	2.99

Legend

T_1-Absolute control with surface irrigation	T_7 - 125 % N, P and K of RDF – WSF
T_2-Absolute control with drip irrigation	T_8 – 50 % N, P and K of RDF – Conventional fertilizer (CF)
T_3 - Package of practice with surface irrigation	T_9 – 75 % N, P and K of RDF – CF
T_4 - 50 % N, P and K of RDF – Water soluble fertilizer (WSF)	T_{10}- 100 % N, P and K of RDF – CF
T_5 - 75 % N, P and K of RDF – WSF	T_{11}- 125 % N, P and K of RDF – CF
T_6 - 100 % N, P and K of RDF – WSF	T_{12}- 100 % N & K of RDF - WSF and 100 % P of RDF – CF

c. Potassium

Content of K in rice grain ranged from 0.49 to 0.66, 0.47 to 0.55 and 0.49 to 0.60 per cent in first season, second season and pooled data, respectively and straw K content ranged from 1.20 to 1.79, 1.18 to 1.52 and 1.19 to 1.66 per cent in first season, second season and pooled data, respectively (Table 7). Higher content of K was observed with the application of 125 % N, P and K of RDF through WSF (T_7) and higher uptake of potassium by aerobic rice was obtained in the same treatment which recorded 41.99, 38.33 and 43.19 kg ha^{-1} in grain and 139.82, 129.44 and 134.63 kg ha^{-1} in straw during first season, second season and pooled analysis, respectively and was on par with T_6 treatment for K content and uptake (Table 8).

Potassium content in rice and also uptake was found to increase with the increased levels of K fertilizer application in the form of WSF and CF. However, application of WSF was found to be superior to CF in increasing grain and straw content at all the different grades of fertilizer application. This may be attributed to higher solubility of K through WSF and the continuous supply of K throughout the crop growth period through drip irrigation. Higher potassium content was recorded may also be due to fertigation with 125 per cent of recommended dose of nitrogen and the positive interaction that occurs between nutrient N and K.

The lowest value for K content in grain and straw and its uptake was recorded in absolute control with surface irrigation (T_1), this was on par with absolute control with drip irrigation (T_2) due to lack of fertilizer application in these treatments that did not receive any fertilizers. Comparatively higher K content in plant was recorded in drip fertigation than surface irrigation due to the presence of more available K under aerobic environment, since leaching of K is less under aerobic condition. Similar results were reported by Shiram (2014).

Table 7: Effect of graded levels of nutrients and irrigation methods on potassium content (%) of aerobic rice

Treatments	Grain			Straw		
	2017	2018	Pooled	2017	2018	Pooled
T_1	0.49	0.48	0.49	1.20	1.18	1.19
T_2	0.50	0.47	0.49	1.23	1.20	1.22
T_3	0.59	0.49	0.54	1.65	1.44	1.55
T_4	0.54	0.45	0.50	1.33	1.24	1.28
T_5	0.65	0.54	0.59	1.46	1.35	1.41
T_6	0.63	0.51	0.57	1.73	1.50	1.62
T_7	0.66	0.55	0.60	1.79	1.52	1.66
T_8	0.53	0.44	0.49	1.26	1.21	1.24
T_9	0.62	0.52	0.57	1.37	1.35	1.36
T_{10}	0.60	0.50	0.55	1.68	1.45	1.57
T_{11}	0.64	0.53	0.58	1.63	1.49	1.56
T_{12}	0.59	0.52	0.56	1.70	1.48	1.59
S.Em±	0.02	0.03	0.03	0.02	0.01	0.02
CD @ 5%	0.06	0.08	0.07	0.05	0.03	0.04

Table 8: Effect of graded levels of nutrients and irrigation methods on potassium uptake (kgha^{-1}) by aerobic rice

Treatments	Grain			Straw		
	2017	2018	Pooled	2017	2018	Pooled
T_1	9.61	10.71	10.16	30.59	32.77	31.68
T_2	11.69	12.44	12.07	35.58	39.79	37.69
T_3	25.18	22.13	26.36	86.94	87.00	86.97
T_4	23.33	22.05	25.17	71.08	75.23	73.16
T_5	29.71	28.02	31.84	82.40	86.54	84.47
T_6	35.70	31.99	36.70	123.29	115.37	119.33
T_7	41.99	38.33	43.19	139.82	129.44	134.63
T_8	22.65	21.34	24.43	67.14	73.05	70.10
T_9	27.72	26.35	29.90	75.22	84.62	79.92
T_{10}	29.85	26.78	31.06	102.87	95.82	99.35
T_{11}	32.08	29.22	33.58	100.74	101.25	101.00
T_{12}	29.88	29.28	32.37	107.37	102.59	104.98
S.Em±	2.84	2.45	2.63	7.99	6.93	7.43
CD @ 5%	8.32	7.18	7.73	23.43	20.33	21.80

Legend

T_1-Absolute control with surface irrigation	T_7 - 125 % N, P and K of RDF – WSF
T_2-Absolute control with drip irrigation	T_8 – 50 % N, P and K of RDF – Conventional fertilizer (CF)
T_3 - Package of practice with surface irrigation	T_9 – 75 % N, P and K of RDF – CF
T_4 - 50 % N, P and K of RDF – Water soluble fertilizer (WSF)	T_{10}- 100 % N, P and K of RDF – CF
T_5 - 75 % N, P and K of RDF – WSF	T_{11}- 125 % N, P and K of RDF – CF
T_6 - 100 % N, P and K of RDF – WSF	T_{12}- 100 % N & K of RDF - WSF and 100 % P of RDF – CF

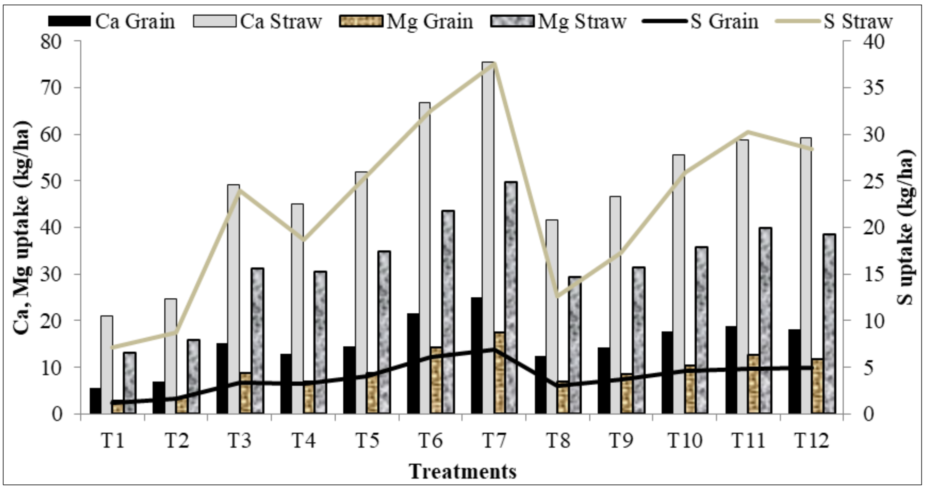
d. Secondary nutrients

Though there was no significant difference among the treatments, higher content of Ca in grain and straw was observed in the treatment receiving 125 % N, P and K of RDF through WSF (T_7) and on par with 100 % N, P and K of RDF through WSF (T_6). The similar results were obtained for Ca uptake by rice grain and straw. The treatments that received fertilizers through drip fertigation recorded the highest calcium content and was found to be further high with the application of WSF than CF may be due to balanced rate of cation absorption as reported by Geetha (2015) [11]. The lowest Ca content and uptake by rice grain and straw was recorded in absolute control with surface irrigation (T_1) followed by absolute control with drip irrigation (T_2) due to lack of fertilizer application and poor root growth in these treatments.

The content of Mg in rice grain ranged from 0.15 to 0.27, 0.11 to 0.24 and 0.13 to 0.26 per cent in first season, second season and pooled data, respectively and in rice straw from 0.50 to 0.63, 0.49 to 0.59 and 0.50 to 0.61 per cent in first season, second season and pooled data, respectively (Table 12-13). There was no significant difference among the treatments, however, higher content of Mg in straw and grain was observed in treatment receiving 125 % N, P and K of RDF through WSF (T_7) and on par with 100 % N, P and K of RDF through WSF (T_6). Uptake of Mg by rice grain and straw was higher in the same treatment. The higher quantity of fertilizers applied through drip fertigation recorded the highest Mg content and further was found to be high with the application of WSF than CF, this might be due to balanced rate of cation absorption and the content of Mg in plant was more under aerobic situation with drip fertigation because of less leaching of Mg from the soil under aerobic situation which resulted in more absorption (Geetha, 2015) [11].

The sulphur content in grain of aerobic rice did not show significant difference among the treatments. However, highest values of grain S content was obtained in the treatment T_7 that received 125 % N, P and K of RDF through WSF. No much variation in grain and straw S content observed in both the seasons as the WSF and CF did not differ much in supplying plant available S, however WSF was found to perform better in improving S content in rice grain and straw compared to CF. This finding was confirmed with Punitha (2016) [21] and Shruthi (2017) [20].

Whereas, significantly higher uptake of S by rice grain of 7.28, 6.55 and 6.92 kg ha^{-1} during first season, second season and pooled analysis, respectively was recorded in the treatment T_7 that received 125 % N, P and K of RDF through WSF and during first season, second season and pooled analysis, respectively (Fig 2). With respect to uptake of S by rice straw, higher values were observed in the same treatment (40.25, 34.92 and 37.59 kg ha^{-1} during first season, second season and pooled analysis, respectively). Increase in sulphur uptake by aerobic rice may be due to balanced application of inorganic fertilizers which enhanced the availability. The findings are in agreement with Shanmugam and Veeraputhran (2001) [22]. Lower values for content and uptake of S by rice grain and straw was obtained in treatment T_1 (Absolute control with surface irrigation) and was on par with treatment T_2 (Absolute control with drip irrigation).



* Pooled values of 2017 and 2018 are presented graphically

Fig 2: Effect of graded levels of nutrients and irrigation methods on uptake (kgha^{-1}) of secondary nutrients by aerobic rice

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