JOURNAL OF PURE AND APPLIED MICROBIOLOGY, June 2016. Vol. **10**(2), p. 1211-1222

Effect of Fertigation and Residue Management on Performance of Direct Seeded Rice and Soil Biological Health Under Rice Wheat Rotation in Indo-gangetic Plain Zone of India

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https://doi.org/10.22207/JPAM.10.2.42

(Received: 17 February 2016; accepted: 16 April 2016)

A 2 year field trial was conducted during *kharif* 2012 and 2013 to investigate fertigation and residue management on performance of direct seeded rice and soil biological health. To this effect ten treatments consisting irrigation techniques as a main plot (5) and residue management as a sub plot (2) were tested in a split plot design with three replication The soil of experimental field was alkaline in reaction, with 0.33 percent organic carbon, 180 kg ha^{-1} available nitrogen and 47 kg ha^{-1} available phosphorous and 346 kg ha^{-1} potassium. Hybrid rice variety Arize 6129 was sown as a test crop. Remarkable effect was noted where drip fertigation performed better by recording significantly higher plant height, tiller density, biomass production at 30 and 60 DAS and yield attributing characters than the combination of sprinkler system during both the years. Drip fertigation system did not differ significantly from flood RDF in these parameters. Grain, biological yield, N, P and K uptake by grain and straw was significantly higher with drip fertigation. MBC and MBN differ significantly and higher value was recorded with drip fertigation. Finally maximum grain and straw yield of rice statistically on par to flood RDF and significantly higher than the remaining combinations was found with drip fertigation. Drip fertigation yielded 24.9 to 28.09, 19.0 to 23.0, 10.7 to 14.0 and 3.2 to 7.00 percent higher than sprinkler RDF, sprinkler fertigation, drip RDF and flood RDF. A significant interaction effect of fertigation and residue management on grain yield of rice was found.Furthermore, growth parameters, yield attributing characters, grain and straw yield, grain and straw nutrient uptake, microbial biomass carbon (MBC), microbial biomass nitrogen (MBN), increased significantly with residue incorporation. Thus, the study reveal that drip irrigation coupled with fertilizer application could be option of precise nutrient and water management of direct seeded rice since it yielded more with higher benefit cost ratio.

Keywords: Fertigation, Residue management, Performance, MBC, MBN, Direct seeded rice.

In India, rice is grown over an area of 43 million hectares with total production of 95 million tones amounting to 40% of the total food production (Fertilizer Statistics, 2010-11). In irrigated ecosystem rice is grown as transplanted crop. Rice –wheat cropping system is the most predominant cropping system in IGP which occupies 9.64 million hectares (Sharma *et al*., 2013).

Foreseeing, the water shortage in future and low water productivity in flooded condition,

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micro-irrigation systems (sprinkler and drip) have the potential to improve resource-use efficiency as compared to the conventional flood-irrigated system, where water-use efficiency is only 35-40%. As per assessment by the planning commission of India, it is primarily the increase in water use efficiency which can save India from a water famine disaster (Navalwala,1998). It is possible to increase the water use efficiency to 60% with the adoption of water use technologies. Pressurized and non-pressurized irrigation system has the potential to increase yield and input use efficiency besides saving of 25-50 % water and 10-20 % N. Using technology such as sprinkler and drip irrigation water use efficiency 85-95 % can be obtained. Drip irrigation apply both precisely and uniformly thus potentially increase yield, reducing sub surface drainage providing better salinity control and better disease management since only the soil is wetted whereas the leaf surface stay dry. Alternative irrigation systems such as sprinkler irrigation, is an anotheradvanced irrigation technique for water-saving and fertigation and in accurately controlling irrigation time and water amount (Li and Rao, 2003). The application of irrigation water with sprinklers has improved on-farm irrigation efficiencies up to 80% under the prevailing climatic conditions in the Indian sub-continent (Sharma, 1984).

Nitrogen fertilizers are major source of pollutants from agriculture. In the flooded puddled rice field, owing to different nitrogen losses viz. leaching, ammonia volatilization and denitrification the recovery of applied nitrogen is low. Extend of nitrogen loss through leaching, ammonia volatilization and denitrification from puddled rice are 5.6 to 8.3, 23.9 and 45-50 percent respectively (Aulakh*et al*., 1997). Fertigation is a new agricultural technique, which supplies water and fertilizer simultaneously (Castellanos *et al*., 2012 and Mahajan and Singh, 2006). It can supply water and fertilizer timely as well as rightly and improve nutrient uptake and water-use efficiency. Fertilizer application along with drip irrigation is proven technology for various horticulture and vegetable crops (Sivanappan, 2004). "Fertigation has shown to enhance overall plant-root activity, improve the mobility of nutritive substances, their consumption as well as reducing the contamination of surface and ground water," says a report of Food and Agriculture Organization (FAO, 2011).

After harvesting wheat grains, many farmers in Northwest states of the IGP collect wheat straw with specially designed machine for using it as fodder leaving behind about 20 to 25% (1.5-2.0t/ha) wheat straw in the field. The wheat straw left on the field is also burnt before preparing for rice transplanting. Despite of nutrient loss, greenhouse gases are also emitted due to burning of crop residue. Farmers have the apprehension that wheat stubbles will adversely affect the rice yield. A 3-year field study conducted by the department of Soil science, PAU Ludhiana, however, showed no adverse of incorporating partial wheat residue on rice yield (Thind, personal communication). The return of crop residue to fields is an important way to conserve and sustain soil productivity (Perucci *et al*.,1997). To get the benefit of residue incorporation, the timing of residue incorporation is important. Incorporation of wheat residue just before rice transplanting in flooded condition may result in accumulation of phenolic acid in the soil and increased CH_4emission

MATARIALS AND METHOD

Experimental details

A field experiment was conducted during *kharif* season 2012 and 2013 at Crop Research Centre of SardarVallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.), the area lie at a latitude of 29°40' North and longitude of 77°42' East with an elevation of 237 metres above mean sea level. Mean weekly maximum temperature varied from 34.9 ^{0}C in 30th week (July, 23-29) to 31.6 ^{0}C in 36th week (September, 3-9), and the mean weekly minimum temperature ranged from 21.1 ^{0}C in 43rdweek (October, 22-28) to 38.0 ^{0}C in 29th week (July, 16-22) during 2012. Mean weekly relative humidity fluctuated from 90.0 % in 34th week (August, 20-26) to 56.8 % in 42nd week (October, 15-21) during 2012, whereas it ranged from 81.3 % in 37th week (September, 9-15) to 32.5 % in 29th week (July, 15-21) in the consecutive kharif season. The total of 648 mm rainfall was received during 2012 and 778 mm during 2013.The treatments comprised five irrigation methods in a first factor *viz.,* fertigation with drip system, drip irrigation with usual recommended fertilizer management, fertigation with sprinkler system, sprinkler irrigation with usual fertilizer management and farmer's practice usually flood irrigation and fertilizer management (150 N, 32.75 P, 62.5 K kg/ha) and two residue management optionsin a second factorascombine harvesting of wheat/ residue retention and farmer's practice- manual wheat harvesting/ residue removal replicated thrice in a split plot design.

Site descriptions

The experimental field was well drained, sandy loam in texture (46.2 % sand, 18.4 % silt and 17.4 % clay, Bouyoucos hydrometer method), alkaline in reaction (pH 8.41, Glass electrode pH meter), medium in organic carbon (0.33 %), low in available nitrogen (180.6 kg/ha) and high in available phosphorus (47.0 kg/ha) and potassium (346.0 kg/ha) with an electrical conductivity of 1.6 dS/m (1:2, soil: water suspension, Solbridge conductivity meter method), Bulk density 1.42 Mg/m^3 and Infiltration (0.14 cm hr^{-1}). All the physic-chemical properties were analyzed as per the standard procedures given by Jackson (1973).

Crop growth

The crop was grown as per agronomic package of practice with varieties ARIZE 6129(Rice hybrid) with the spacing (rows) of 20 cm. Seeding was done directly in the main field with the help of zero till seed-cum-fertilizer drill maintaining the seed rate of 25 kg (± 2kg) ha^{-1}. It was preceded by preparatory tillage as per treatments. The sowing was done on 19-06-2012 and15-06-2013 while harvesting on 15-10-2012 and08-10-2013 during first and second year, respectively.Recommended dose of fertilizer 150 kg N/ha as urea and DAP, 32.3 kgP/ha as DAP and 62.5 kg K/ha as MOP and 5.25 kg Zn as ZnSO4.7H2O was applied to rice. Three foliar sprays of 1 % ferrous sulphate were given for correcting iron deficiency.

Weed management strategies were adoptedas per recommendation under for direct seeded rice. In zero till plots, pre-sowing application (4 days before seeding) of glyphosate @ 1.0 Kg a.i. ha^{-1} was made as spray in 400 liters of water. Further pendimethalin @ 1.0 Kg a.i. ha^{-1} was applied 2 days afterseeding as pre-emergence in direct seeded plots.Bispyribac @20 g a.i. ha^{-1} was applied at 25 days stage as post emergencefollowed by one hand weeding at 55 days stage irrespective of the treatments. Moreover, irrigation scheduling was done as per the treatment throughcrop evapotranspiration, irrigation interval, requirement and duration, applied water measurement and water productivity.

Data collection

Various growth parameters *viz.,* plant height (cm), tiller density(m^{-2})and plant biomass (g m^{-2})were recorded at 30 and 60 DAS, yield attributes were measured at maturity stage. Grain yield was estimated fromthe produce of net plot area, treatment wise and finally expressed at 14 % moisture.

Plant sampling and analysis

The uptake of N, P and K by grain and straw was determined by plants analysis. The plant samples were dried at 70 °C in a hot air oven. The dried samples were ground in a stainless steel Thomas Model 4 Wiley ® Mill. Further, the N content in plant was determined by digesting the plant samples in H_2SO_4, followed by analysis of total N by the Kjeldahl method (Page, 1982) using a Kjeltec™ 8000 auto analyzer (FOSS Company, Denmark). Whereas, the P content in plant was resolute by the vanadomolybdo-phosphoric yellow colour method and the K content was determined in di-acid (HNO3 and HClO4) digests by the flame photometeric method (Page, 1982). The uptake of the nutrients (NPK) was calculated by multiplying the nutrient content (%) with their respective yield (kg/ha^{-1}) and then divided by 100 to get the uptake in $kgha^{-1}$.

Biological studied

Microbial biomass carbon (µg/g)

Microbial biomass in soil was determined in terms of biomass carbon following the method of Vance *et al.* (1987). About 100 g of soil was taken for the study. About 20 g soil sample was extracted immediately after fumigation by shaking with 0.5M K_2SO_4 for 30 minutes. Another sample of 20 g soil was fumigated with $CHCl_3$vapor for 24 hours as described by Jenkinson and Powlson (1976). Following fumigation, excess $CHCl_3$ was removed by repeated evacuation and soil was extracted with 0.5M K_2SO_4 as mentioned above. Soil extracts were filtered using Watman No. 42 filter paper. Remaining soil was used for moisture determination.

After extraction, 2 ml of 0.04 N $K_2C_2O_7$ was taken in 250 ml conical flask, 5ml of H_2SO_4/H_3PO_4 (2:1) mixture and 8 ml of extract were added in it and allowed to cool for about half an hour (30 minutes). Then the suspension was diluted with 20 ml of water. Duplicate blank containing 8 ml of 0.5M K_2SO_4 was digested in the same manner. Excess dichromate was determined by the back titration with 0.005N ferrous ammonium sulphate using phenon-throline ferrous sulphate complex solution as indicator. Biomass carbon was calculated as follows:

$$\text{Soil water content (WS) \%} = \frac{\text{Weight of wet soil(g) - weight of oven dry soil(g)}}{\text{weight of oven dry soil(g)}} \times 100$$

Weight of soil sample taken for microbial biomass measurement (MS):

$$\text{MS (g)} = \frac{\text{weight of wet soil (g)}}{\{100 + \text{WS (\%)}\}} \times 100$$

Total volume of extraction in the extracted soil (VS):
VS (ml) = Weight of wet soil (g) – oven dry weight of soil (g) +

Extracted volume

Volume of $K_2C_2O_7$ solution consumed by FAS in any

$$\text{Sample (Y ml)} = \frac{\text{N of FAS} \times \text{titrae value}}{\text{N of } K_2C_2O_7 (0.2N)}$$

Extractable carbon

$$\text{EC } (\mu g\ ml^{-1}) = \frac{600 \times (2 - Y)}{10}$$

Total weight of extractable carbon in the fumigated (EC_F) and unfumigated soil (EC_{UF}) samples

$$EC_F \text{ or } EC_{UF}\ (\mu g\ g^{-1}) = \text{EC } (\mu g\ ml^{-1}) \text{ x } \frac{\text{VS (ml)}}{\text{MS (g)}}$$

Microbial biomass carbon in soil (MB-C)

$$\text{MB-C } (\mu g\ g^{-1}) = \frac{(EC_F - EC_{UF})}{K_{EC}}$$

Where,

K_{EC} = 0.25 ± 0.05, representing the efficiency of extraction of microbial biomass carbon

Microbial biomass nitrogen (µg/g)

Total nitrogen is measured under strong acidic condition by kjeldahl digestion and the ammonium is measured by distillation. Ammonium is released from amines, peptides and amino acids in $0.5MK_2SO_4$ soil extracts of fumigated and non-fumigated soil sample. Nitrate is additionally reduced to ammonium under strong acidic condition in the presence of $KCr(SO_4)_2$ Zn powder and $CuSO_4$as reducing agents. Add 10 ml of the reducing agent and approx. 300 mg Zn powder to 30 ml of the K_2SO_4 soil extracts and leave for at least 2hr at room temperature**.** Add 0.6 ml of $CuSO_4$ solution, 8 ml of con H_2SO_4, and heat gently for 2 hr until all the water has disappeared, and then heat for 3 hr at maximum temperature. Allow the digest to cool before distillation with 40 ml 10M NaOH the evolved NH3 is absorbed in 2% H_2BO_3.Titrate the resulting solution with 10 µMHCL to Ph 4.8. Biomass nitrogen was calculated as follows;

Calculation of extractable total N.

N (µg/g soil) = (S-B) M*N*(VK+SW)/a*DM

Where,

S-HCL consumed by sample extract (µL), B- HCL consumed by blank extract (µL), M- molarity of HCL, N- Molecular mass of nitrogen (14), VK- volume of K2SO4 extractants (mL), SW Total amount of water in spoil sample (mL), A- Sample aliquot (mL), DM- total mass of dry soil sample (g)

Calculation of microbial biomass nitrogen

Biomass N= EN/kEN

EN- (total N extracted from fumigated soils) - (total N extracted non fumigated soils)

kEN- values for kEN range from 0.18 to 0.54

Statistical analysis

The data obtained were subjected to statistical analysis as outlined by Gomez and Gomez (1984). The treatment differences were tested by using "F" test and critical differences (at 5 per cent probability).

RESULTS AND DISCUSSION

Growth attributes

All the growth attributes *viz.,* plant height, tiller density and plant biomass varied significantly due to both irrigation techniques and residue management in direct seeded rice during both the years (Table 1). Rice raised under drip fertigation had produced taller plant (41.95 to 83.28 and 43.35 to 85.27cm),more tiller density(222.58 to 427.33 and 231.50 to 433.95 m^{-2}) and plant biomass (203.48 to 519.28 and 206.97 to 522.58g m^{-2}) at 30 to 60 DAS during 2012 and 2013, respectively as compared to rest of the treatments. Flood RDFmeasured maximum plant height 43.30 and 43.00 cm during 2012 and 2013, respectivelyat 30 DAS which was statistically on par with drip fertigation and drip

Table 1. Effect of fertigation and residue management on growth parameter of direct seeded rice

Treatment	Plant height (cm)				Tiller density (m^{-2})				Plant biomass ($g\ m^{-2}$)			
	2012		2013		2012		2013		2012		2013	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Irrigation techniques												
Drip fertigation	41.95	83.28	43.35	85.27	222.58	427.33	231.50	433.95	203.48	519.28	206.97	522.58
Drip RDF	42.35	81.13	42.10	83.59	195.33	400.00	205.50	407.62	181.88	471.94	185.32	475.06
Sprinkler fertigation	40.35	80.08	40.37	82.25	190.55	389.00	198.00	397.12	165.03	427.00	167.76	430.76
Sprinkler RDF	41.70	78.70	41.55	79.80	182.60	380.00	193.00	388.95	152.04	400.78	154.90	403.11
Flood RDF	43.30	82.40	43.00	84.20	212.78	420.00	221.50	422.10	195.15	505.63	198.80	508.91
S.Em±	0.41	0.77	0.38	0.77	3.65	2.98	3.48	5.91	4.22	8.12	4.30	8.17
CD at 5%	1.36	2.53	1.26	2.56	12.09	9.87	11.54	19.56	13.97	26.89	14.22	27.86
Residue management												
With Residue	42.38	82.71	42.57	84.29	210.00	416.93	218.20	423.32	183.05	472.03	186.32	475.07
Without Residue	41.48	79.53	41.58	81.76	191.54	389.60	201.60	396.58	175.98	458.62	179.19	461.50
S.Em±	0.14	0.27	0.14	0.28	2.33	3.54	2.68	3.79	1.60	3.85	1.63	3.88
CD at 5%	0.46	0.85	0.46	0.88	7.44	11.29	8.54	12.11	5.12	12.92	5.21	12.37

RDF. At 60 DAS also maximum plant height was recorded with flood RDF which was on par with drip fertigation, drip RDF and sprinkler fertigation. Maximum tiller density during both the years at 30 as well as 60 DAS was found with drip fertigation which was on par with flood RDF and significantly superior rest of the combinations. Similar trends was also noticed in case of biomass production fertigation got slight edge on RDF by recording higher growth parameters Moreover sprinkler RDF noticed minimum growth attributes at 30 and 60 DAS during both the year, except plant height at 30 DAS during 2012 which was remained lowest under sprinkler fertigation. Better response of plant growth parameters towards drip followed by flood irrigation techniques may be described due to continuously moist soil surface with drip irrigation which will also ensure optimum nutrient supply to plant roots with smooth mobility. Since with sprinkler system mostly phyllosphere was wetted and less water reach to rhizosphere therefore with comparatively restricted root growth and nutrient mobility plant growth may affect slightly.These results are in line with the findings ofSingh *et al.* (2010); Castellanos *et al.* (2012) and Mahajan and Singh (2006)

Statistical analysis revealed significant difference among the residue management modules in whicha plot retaining residue recoded significantly more plant height, tiller density and

Table 2. Effect of fertigation and residue management on yield attributes and yield of direct seeded rice

Treatment	Yield attributes				Yield (q ha^{-1})			
	Filled grain		Unfilled grain		Grain yield		Biological Yield	
	2012	2013	2012	2013	2012	2013	2012	2013
Irrigation techniques								
Drip fertigation	169.45	173.90	32.20	34.55	66.30	69.60	160.30	168.40
Drip RDF	161.20	163.15	41.90	43.40	59.90	61.07	148.80	151.77
Sprinkler fertigation	154.05	160.45	57.70	59.40	55.72	56.60	140.85	143.80
Sprinkler RDF	149.45	153.40	61.35	62.90	53.10	54.39	136.99	138.39
Flood RDF	167.70	169.05	33.15	36.10	64.25	65.05	155.75	159.50
S.Em±	1.59	1.60	0.84	0.85	0.72	1.88	2.69	3.25
CD at 5%	5.28	5.26	2.79	2.81	2.39	6.22	8.92	10.76
Residue management								
With Residue	162.72	165.40	44.02	46.30	61.20	63.03	150.76	156.09
Without Residue	158.02	162.58	46.50	48.24	58.51	59.65	146.31	148.65
S.Em±	0.54	0.53	0.14	0.13	0.21	0.23	1.41	1.03
CD at 5%	1.72	1.70	0.45	0.41	0.66	0.78	4.50	3.27
Interaction	NS	NS	NS	NS	Sig.	Sig.	NS	NS

Table 3. Interaction effect of fertigation and residue management on yield

Treatment	2012					2013				
	Irrigation techniques									
	Drip fertigation	Drip RDF	Sprinkler fertigation	Sprinkler RDF	Flood RDF	Drip fertigation	Drip RDF	Sprinkler fertigation	Sprinkler RDF	Flood RDF
Residue Management	67.60	61.95	56.23	53.70	66.50	71.00	63.52	57.00	55.04	68.60
Without residue	65.00	57.85	55.20	52.50	62.00	68.20	58.62	56.20	53.74	61.50
				SEm±	C.D. at 5%	SEm±	C.D. at 5%			
Compare residue management means within the same level of irrigation techniques				1.02	3.16	2.66	7.25			
Compare irrigation techniques means at the same residue management				2.61		6.32				

Table 4. Effect of fertigation and residue management on N, P and K uptake of direct seeded rice

Treatment	Nitrogen uptake (kg ha^{-1})				Phosphorus uptake (kg ha^{-1})				Potassium uptake (kg ha^{-1})			
	Grain		Straw		Grain		Straw		Grain		Straw	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Irrigation techniques												
Drip fertigation	96.06	98.29	28.12	28.26	13.24	14.19	8.16	9.46	14.27	14.93	128.39	140.88
Drip RDF	81.82	83.70	23.97	24.14	11.43	11.51	7.57	8.04	12.09	12.54	108.18	119.97
Sprinkler fertigation	71.86	72.95	20.61	20.68	10.17	10.46	6.33	7.13	10.45	10.84	92.20	105.07
Sprinkler RDF	61.98	63.17	16.40	16.73	9.70	9.89	6.00	6.09	9.54	9.80	82.37	95.81
Flood RDF	78.41	80.05	22.13	22.27	11.87	11.63	7.01	7.99	12.59	12.97	114.00	124.50
S.Em±	1.81	2.32	0.59	0.63	1.89	0.74	0.58	0.48	0.141	0.212	1.85	1.92
CD at 5%	5.98	7.69	1.96	2.08	1.83	1.15	1.01	0.93	0.47	0.70	6.13	6.35
Residue management												
With Residue	82.93	87.79	24.15	24.70	12.27	12.65	7.46	8.39	12.73	13.10	113.40	126.33
Without Residue	73.12	71.47	20.34	20.13	10.29	10.42	6.57	7.09	10.85	11.33	96.66	108.16
S.Em±	0.50	0.54	0.32	0.29	1.03	1.36	0.73	2.00	0.214	0.128	0.76	1.04
CD at 5%	1.59	1.71	1.03	0.93	0.83	0.95	0.70	1.15	0.68	0.41	2.41	3.31

plant biomass at 30 and 60 DAS during 2012 and 2013as against a plot which did not have residue. Residue is a sort of organic matter and it is well documented that apart from supplementing the chemical fertility, residue (organic matter) also improve water holding capacity and the other physico-chemical properties. The improvement in plant growth characters with residue incorporation is therefore obvious. Since a fallow period of about 60-65 days is available after the harvest of wheat the impact of residue incorporation on rice yield is positive. A pre-rice sole green crop or dual purpose short duration pulses like mungbean (*Vignaradiata*) for pulse grains and green manuring can be raised to utilize this fallow period (Yadvinder-Singh *et al*. 1991).Aulakh*et al*. (2001) observed improved growth and yield of rice when wheat straw was incorporated with green manure (*Sesbaniaaculeata*). Incorporation of wheat straw (high C:N ratio) with sesbania green manure (low C:N ratio) alleviated the adverse effect of wheat straw alone in rice in RW system

Yield performance

Analyses of values under different irrigation techniques used in the context of filled and unfilled grains shown considerable statistical differences among themselves. The data presented in Table 2 revealed that a plot which received drip fertigation had recorded maximum filled grain during both the years. The highest and lowest filled and unfilled grain under drip fertigation was more and less statistically similar with flood RDF and significantly superior with all other treatments. Sprinkler RDF had recorded lowest filled grain (149.45 and 153.40) and highest unfilled grain (61.35 and 62.90) during 2012 and 2013, respectively.This variation may be due to earlier better vegetative growth that will respond to reproductive growth. Much sterility was found with sprinkler system than drip or flood. The sterility was 27.2 and 29.2 percent during 2012 and 27 and 29 percent during 2013 with sprinkler fertigation and RDF respectively. This may be due to possible moisture stress associated with sprinkler system. Rahman

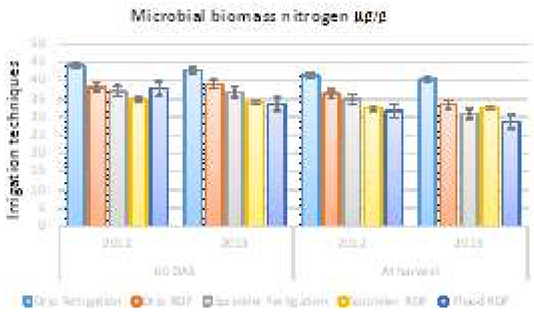

Fig. 1. Microbial biomass nitrogen as influenced by irrigation techniques

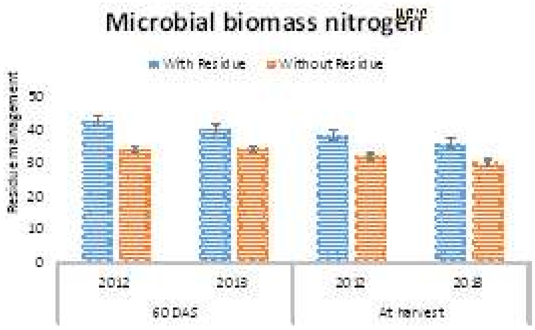

Fig. 2. Microbial biomass nitrogen as influenced by residue management

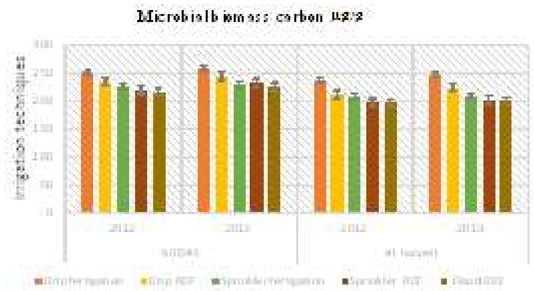

Fig. 3. Microbial biomass carbon as influenced by irrigation techniques

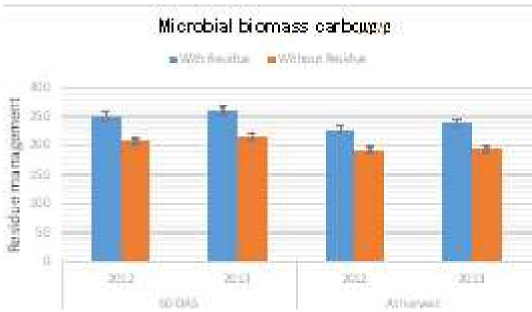

Fig. 4. Microbial biomass carbon as influenced by residue management

et al. (2002) reported that the number of filled grain per panicle significantly decrease with the moisture stress at critical stages of booting, flowering and grain filling.

Further scrutiny of data revealed a non-significant variation between residue management practices. Although, a plot which did not retained residue recorded lowest filled grain (158.02 and162.58) and most unfilled grain (46.50 and 48.24) as compared with their counterpart during 2012 and 2013, respectively. Application of nutrients facilitates root growth, which can extract soil moisture from deeper layers. Furthermore, application of fertilizers facilitates early development of canopy that covers the soil and intercepts more solar radiation and thereby reduces the evaporation(Singh *et al*., 2010). Mulching with many types of organic materials, including chopped grass and clover material has been demonstrated to positively contribute to improved plant growth, development and enhanced yield (Hanson *et al*., 2001 and Hugh *et al*., 2003).

The higher grain and biological yield of rice statistically on par to flood RDF and significantly higher than the remaining treatments was found with drip fertigation during both the years (Table 2). Application of RDF conventionally in flooded condition produced significantly higher grain and biological yield of direct seeded rice than sprinkler RDF, fertigation, and drip RDF during 2012 but was on par to drip RDF during 2013. Grain and biological yield of rice during 2012 differ significantly due to method of fertilizer application within a similar irrigation technique fertigation yielded higher than conventional RDF. Such effect was not noticed during 2013 where yield differ significantly among the treatments of drip irrigation but not in case of sprinkler method. The effect of method of fertilizer application was much pronounced with drip irrigation than sprinkler during both the years. Drip fertigation resulted in (10.7 and 14.0) and (13.2 and 17.3) percent increase in rice grain and biological yield than drip RDF during 2012 and 2013 respectively.In our study since yield attributing characters with drip fertigation were significantly higher than drip RDF, sprinkler fertigation and RDF during both the years,therefore higher grain and biological yield with drip fertigation is well expected. These results are in conformity with those reported earlier by Rahman *et al*. (2002) and Mahajan and Singh (2006)

Moreover, grain and biological yield of rice during both the year also increased significantly with the residue incorporation in comparison to that without residue. The extent of increase was 4.6 and 3.0 for grain yield and 5.7 and 5.0 percent for biological yield during 2012 and 2013 respectively. These results are in accordance with Liao Li Jun *et al.* (2008) who reported that drip irrigation led to higher yield with much lower applied water in comparison to block irrigation experiment. Govindan and Grace(2012) also reported that drip irrigation at 150 per cent PE+ drip fertigation of 100 per cent (RDF)+ azophosmet+humic acid recorded 19 per cent yield increase as compared to drip irrigation at 125 per cent PE+100 per cent RDF through drip. The increase in rice grain yield with drip irrigation at 150 per cent PE+ drip fertigation of 100 per cent RDF+azophosmet+humic acid was mainly attributed by greater and consistent availability of soil moisture and nutrients which resulted in better crop growth, yield components and ultimately reflected on the grain yield.

Interaction effect of fertigation and residue management on yield

The interaction effect of fertigation and residue management of grain yield of rice during 2012 as well as 2013 was significant (Table 3). Drip RDF and flood RDF with residue incorporation yielded significantly higher than drip RDF and flood RDF without residue during 2012, however, during 2013 no one irrigation technique with residue incorporation could show the significant effect over without residue incorporation. Fertigation treatments differ significantly with residue incorporation and without residue incorporation during both the years. With exception of flood RDF, drip fertigation yielded significantly higher than the remaining irrigation techniques with residue incorporation during 2012 as well as 2013. Sprinkler RDF yielded significantly lower than the remaining irrigation techniques with residue incorporation during 2012, but during 2013 the same treatment was also found statistically similar to sprinkler fertigation. Flood RDF with residue incorporation was found significantly better than drip RDF, sprinkler fertigation and sprinkler RDF during 2012 but differ significantly from sprinkler fertigation and sprinkler RDF only during 2013. Since growth and yield attributing parameters were higher or significantly higher with drip fertigation and residue incorporation therefore this type of significant interaction is well expected

Flood RDF without residue incorporation was found significantly better than drip RDF, sprinkler fertigation, sprinkler RDF during 2012 but during 2013 only sprinkler RDF differ significantly from flood RDF. In absence of residue incorporation drip fertigation yielded significantly higher rice grain yield 65.00 and 68.20 qha^{-1} than the other irrigation techniques during 2012 as well as 2013 respectively. Minimum and significantly lower rice grain yield (52.50qha^{-1}) than the remaining techniques during 2012 was found with sprinkler RDF while it was statistically similar to sprinkler fertigation and drip RDF during 2013.

Nutrients uptake

The data presented in Table 4 revealed that uptake of nitrogen (96.06, 98.29, 28.12 and 28.26 kg ha^{-1}), phosphorous (13.24 ,14.19,8.16 and 9.46kg ha^{-1}) and potassium (14.27, 14.93, 128.39 and 140.88 kg ha^{-1}) by rice grain and straw during 2012 to 2013, respectively was significantly maximum with drip fertigation followed by flood RDF during both the years. Likewise sprinkler RDF remained inferior over other treatments during both the year in the contest of N, P and K uptake by grain and straw.Furthermore, residue incorporation also resulted in significantly higher N, P and K uptake by rice grain and straw over residue removal. In most cases uptake of N, P and K by rice grain and straw with drip fertigation was significantly higher than the remaining combinations of fertigation techniques. Since straw as well as grain yield and their N, P and K contents were significantly higher with drip fertigation, significantly higher accumulation of N, P and K by rice grain and straw is well expected. Similarly rice grain and straw yield as well as their N, P and K content were also higher with the practice of residue incorporation therefore significantly higher accumulation is obvious. These observations are in consonance with the findings of Bhanu and Mahavishan (2008) on lady's finger.Tumbare (2004) on capsicum found significantly higher uptake of nutrients due to fertigation over conventional surface irrigation. Highest content and uptake was recorded with drip fertigation and residue retained plots and no other system could attain equality at any of the stages in any of the years.

Microbial biomass carbon and nitrogen

Microbial biomass carbon and nitrogen in soil measured at two interval ie. 60 DAS and harvesting are depicted in Figure 1 to 4. It was found that MBC and MBN (μg/g) in soilwas significantly higher with drip fertigation than the remaining techniques of irrigation. MBC was 44.10 and 42.84 μg/g at 60 DAS during 2012 and 2013, respectively and 41.52 and 40.35 at harvest. Microbial biomass nitrogen, it was 249.55 and 259.36 at 60 DAS and 237.78 and 247.28 at harvest stages during 2012 to 2013, respectively. Remaining combination of irrigation techniques and mode of fertilizer application were found more and less similar in respect of MBC and MBN. Higher MBC and MBN in drip fertigation may be supposed due to possible higher population of microbes in soil with continuity in nutrient supply and optimum moisture. Microbial biomass nitrogen and carbon at 60 DAS and harvesting differ significantly with residue management. Significantly higher MBN and MBC at 60 DAS and harvesting was found with residue incorporation during both the years. Residue incorporation resulted in 24.9 and 16.9 percent higher MBN at 60 DAS during 2012 and 2013. Similarly MBN was higher by 19.2 and 19.5 percent at harvest during 2012 and 2013 respectively. Similarlythe increase in MBC due to residue incorporation was 17.37 percent at 60 DAS and 15.01 percent at harvest during 2012 while 17.72 percent and 18.65 percent during 2013. Moreover, Microbial biomass nitrogen and microbial biomass carbon declines with the advancementin crop growth during both the years. This effect is obvious since addition of residue to soil will stimulate the microbial population. When crop residues are returned to the soils, the improvement of soil biological properties affects soil microbial diversity and population, thereby creating a suitable environment for root growth of plants and soil microbes. It also improves the chemical and physical conditions of soils by increasing cation exchange capacity, termed buffering effect, and enhancing aggregation, aeration and water retention (Senesi and Loffredo,1999 and Vineet-Kumar *et al*., 2015).

CONCLUSION

Interestingly yield penalty was recorded with all the micro irrigation systems except drip. Foreseeing the water scarcity, drip irrigation coupled with fertilizer application could be option of precise nutrient and water management of direct seeded rice since it yielded more with higher soil biological health. Further study revealed that residue retention ensures better performance of direct seed rice and also improves biological properties of soil than residue removal. However study also suggests that detail and long term study should carry out on nutrients dynamics and irrigation scheduling for drip.

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