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Research Article

EFFECT OF DRIP IRRIGATION AND FERTIGATION ON THE PERFORMANCE OF SEVERAL RICE CULTIVARS IN DIFFERENT RICE ECOSYSTEMS IN INDIA

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Abstract: It has been reported earlier that paddy crop responded well to irrigation and fertilizer application through drip (drip-fertigation). The study was extended to different paddy growing environments located in different States of India. Working with farmers in these ecologies, some 15 rice cultivars were grown with drip fertigation. These were planted either by direct seeding (DSR) or by transplanting seedlings from nursery (TRP). These studies were conducted in the rainy season (*kharif*) or *rain –off season* (*rabi* or early summer). Location specific irrigation and fertigation schedules were followed. For comparison, normal flooded rice was also grown in adjacent plots with traditional method of irrigation (flood) and fertilizer application. The results confirmed that drip-fertigation offers clear advantage for rice production; yields are higher and water consumption lower in drip compared to flood, irrespective of the cultivar, planting method, season and location. While rice yields in drip were as high as 11.61 t/ha, the incremental yield enhancement due to drip-fertigation (over that in flood method) ranged from 14.7 % to 29.9%.

Keywords: Paddy, drip-fertigation, DSR, TRP

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Introduction

India is the world's second largest producer of Rice. It is cultivated over an area of 44.2 million ha, which is about 50 % of the total irrigated agriculture area of the country [1]. Short duration rice cultivation in rainy season (*Kharif*) is common in almost all States, wherever, water is available; however, its cultivation is more concentrated in Eastern states and Southern Peninsula. In some states, West Bengal, Assam, Andhra Pradesh, Tamil Nadu, and Kerala even three crops of rice in a year are raised. Clayey loam alluvial soil is the most suited for its cultivation, but often cultivated in soils slightly alkaline or acidic loams. Low land rice or wet rice is cultivated in puddled soil as semi-aquatic crop, the seedlings first raised in the nursery are transplanted in the puddled field, and the crop raised under inundated condition till few days before the crop is harvested .Ninety percent of rice cultivation is done under low land rice system in the world [2]. Under lowland puddled soil and transplanted rice system, the weed growth is minimal, as the transplanted seedlings gets head-start in their fight with weeds. Under low land system, water is consumed as much as 2295 mm/ha and 3000- 5000 litres utilized by the crop to produce one kg of grain [3]. The water productivity is as low as 0.15 kg/m3 in some cases. The unsustainable use of irrigation water for rice production is a major socioeconomic, environmental and health concern for the region [4]. Rice is also cultivated as dry land crop under rainfed conditions in about 28 % area, neither puddled, nor flooded, but by ploughing and harrowing the field dry and by direct sowing the seeds. The seed rate used is as low as 18-20 kg/ha. The yield is low compared to low land, puddled, flood system. Under aerobic rice system, specially evolved rice cultivars, which are drought tolerant, are cultivated as in Upland system with irrigation. The seeds sown directly (DSR) and the soil moisture maintained to field capacity throughout the period of crop growth. Aerobic rice genotypes displayed greater adaptation to water-limited cultivation. Compared with traditional low land rice system, water inputs in aerobic rice system were less than 50% (470-650 mm), water productivity 64-88% higher, and labour use was 55% lower [5-8]. Exploding demand for water is the critical challenge agriculture faces. Climate change, prolonged droughts ,water supply limits, continued population growth have put pressure on the availability of water, and forced to intensify the search for measures to conserve water in irrigated agriculture, the world's largest water user. Sustainable Rice Initiative (SRI) with total water use of 745-800 mm per ha, does away with standing water during the major growth phases and popular in South Asian countries. Hemalata, [9] working on summer paddy observed that drip irrigated, transplanted and direct seeded rice, maximize yield, save water and electricity in lifting ground water also water use efficiency (4-5 kg/ha mm). Gururaj Kombali [10] working on MAS-946-1 rice, using drip and fertigation found that drip fertigation at 1.5 PE up to maturity with 100 % recommended dose of fertilizers (RDF) through normal fertilizers for optimum yield and net returns. Parthasarathi *et al* [11] observed that lateral spacing of 0.8 m, and plants spaced at 20 cm X 10 cm with 1 lph drippers along with sub-surface drip irrigation treatment achieved good root growth with yield and water productivity when compared with conventional flood irrigation. They reported [11] that on an average the test farmers achieved 6.-7.5 t/ha yield using drip irrigation. Rajwade *et al* [12] observed 78 % water saving by giving life saving subsurface drip irrigation as compared to conventional low land rice system. Nitrogen uptake increased 16.2 % and fertilizer requirement reduced by 25 % by using fertigation. Anusha and Nagaraju [13] compared rice genotypes under drip irrigation with conventional puddled and transplanted system and observed that across genotypes drip irrigated rice recorded significantly higher yield 7934 kg/ha, 19% higher than that of conventional flood system(6659 kgs/ha),resulted in 58% water saving. Water productivity was highest under drip (11.80 Kg/ha mm) as compared to puddled and transplanted rice 4.17 kg/ha mm. The Research and Development team of Jain Irrigation system (JISL) has carried out extensive field trials on more than twenty five economic and cash crops using drip irrigation and fertigation technology.

Table-1 Rice Cultivars and their Traits

SN	Variety	Traits
1	JGL-1798	Duration 125-130 d:"Jagtial Sannalu" hybrid (Samba Mashuri X Kavya) medium slender grain yield 5.0-5.8 t/ha, resistant to gall midge and BLB, Kharif suitable
2	ADT-45(IR 50 XADT 37)	110 days ,short duration, semidwarf, erect, medium slender grain ,average yield 6.1t/ha, resistant to gall midge, moderately resistant to brown plant hopper
3	US-311	Duration 120-125 days, hybrid, yield 6.5-7.0 t/ha
4	MTU-1010	(Krishnaveni X IR 64) duration-120 days, Height 108 cm, semi-dwarf, erec panicle-compact ,dense fully exerted, long slender grain, shattering habit, test weight 25 gm;Rabi season, yield 6.0-6.5 t/ha.
5	MTU-3626	135 days duration Kharif and Rabi-125 days, semi dwarf-90 cm, dense, compact, fully exerted panicle, coarse, long, bold grain, non-shattering test weight-26.3 gm ,suitable for direct sowing Rabi, yield 6.5-7.0 t/ha.
6	MTU-4870	Semidwarf, grains short and bold, multiple resistance to pests and disease, yield 5-5.5 t/ha.
7	MTU7029 (Swarna)	Duration 150 days, Kharif season,Semi-dwarf, height 90 cm, medium slender grain, compact, fully exerted panicle, not shattering, test weight (1000 grains) 20gm, yield-6.0 t/ha High adaptability, low N responsive, tolerant to bacterial blight with stable yield
8	ARIZE-6944	Hybrid ,Duration-135-140 days, consistently 25-30% higher yield of the same duration, high productive tillers/plant, more grains/panicle, highly suited for DSR, >70% milling rice, Yield 6.5 t/ha.
9	ARIZE-6129	Duration 120 days,early,semi-tall,102 cm, long slender grain, resistant to leaf blast, high productive tillers,90% grain filling,275-300 grains/panicle, less water requirement, wider adaptability, suitable for DSR
10	BPT-5204	Duration-145-150 days, dwarf, slender fine grain, test weight-13.8 gm, yield 5.0-5.5 t/ha.
11.	PUSA1121	Duration-137 days, Tall, extra-long slender grain 9 mm, pleasantly aromatic, Suitable for transplanted/direct seeded Rice, Basmati qualities introgressed from traditional basmati varieties such as Basmati 370 and type -3
12.	PUSA-2	Semi-dwarf duration-120 days, typical basmati type, strong aroma
13	PR-118 (Punjab Agriculture University)	Resistant to most of the pathotypes of bacterial blight, 55.48 % head rice recovery.
14	PUSA-Sugandh	Duration 120 days, semi-dwarf, typical Basmati quality, strong aroma, extra-long grain
15	PR-115	Height 86 cm-90 cm, test weight-37.6-39.9 gm;yield-6.0-6.5 t/ha

Table-2 Farmer name, location, rice planting type, Drip line type, Rice variety and yield performance

SN	Farmer Name	Location	Planting Type	Season	Drip Type	Rice Variety	Yield t/ha		% Yield Increase Over Flood	Remarks
							Drip	Flood		
1	V.RangaRao	Medak, Telengana (TGA)	DSR (direct seeded)	July,2009	J-Turbo line	US311	9.386	7.41	26.7	
2	G.Srinivas	Medak,TGA	Transplanted (TRP)	Jan,2011	J- Turbo line	MTU1010	8.15	6.42	26.9	
3	G.Srinivas	Medak,TGA	TRP	July 2011	J- Turbo line	MTU1010	8.4	7.5	14.7	
4	D.Chandra Appa Rao	Vizag,Andhra Pradesh (AP)	TRP	Jan-11	J- Turbo line	MTU-3626	7.41	5.928	25.07	
5	Siva Reddy	Kadapa,AP	TRP	Jul-11	J- Turbo line	MTU 4870	9.386	7.41	26.7	B:C = 1.5
6	Mahipal Yadav	Kareemnagar, TGA	TRP	Jun-13	J-Turbo Aqura	MTU1010	8.892	7.163	24.1	
7	Repeated	Kareemnagar, TGA	TRP	Oct,2013	J-Turbo Aqura	MTU1010	6.42	4.94	29.9	Partially damaged by hailstorm
8	Shankar Reddy	Kurnool,AP	DSR	Jun-13	J-Turbo Aqura	MTU 1010	7.9	6.175	27.9	
9	Veeraraju Chaudary	East Godavari, AP	TRP	Jun-2013	J-Turbo Aqura	BPT5204	8.586	6.669	28.7	
10	MVV Satyanarayana	East Godavari, AP	TRP	Jun-2013	J-Turbo Aqura	MTU-7029 Swarna	8.892	6.916	28.6	
11	Mrs.Kranti	Vijayanagaram AP	TRP	Jun-2013	J-Turbo Aqura	Arize-6449	7.163	5.681	26	
12	Nanda kumar varma	Durg, Chhattisgarh	TRP	Mar,2010	J-Chapin tape	MTU-1010	7.41	6.175	20	B:C = 1.5
13	R.Vijay	Kota,Rajastan	TRP	July,2009	J-Turboline	Pusa-1121	8.398	7.163	17.2	B : C = 1.9
14	S.Taparia	Kota,Rajastan	TRP	July,2010	J-Turboline	pusa1121	8.4	6.916	21.4	
15	Govt.seed farm	Patiala,Punjab	DSR	Jul-11	J- turbo aqura	PR115	6.363	5.43	17.2	Grain test wt. 39.9gm
16			DSR	Jul-11	Microsprinkler		5.829	6.363	7.34	Test Wt,37.6 gm
17	Diddar singh	SBS nagar,Punjab	DSR	Jun-10	J-Turbo Aqura	Arize 6129	8.01	6.916	15.8	B: C = 1.8
18	V.Annamalai	Tiruvannamala Tamil Nad (TN)	DSR	Feb-12	J-Turbo line	ADT-45	9.633	7.657	25.8	
19	Solamalai	Madurai,TN	DSR	Aug-13	J- Turbo line	JGL-1798	11.61	9.139	27	
20	Sekhar Badsavale	Raigarh, Maharashtra	DSR	Dec-09	J-Turbo line	Pusa sugandh	5.928	4.693	26.31	

The water requirement of water guzzling crops like, rice sugarcane, banana, cotton under drip has been reduced to 45-50 % less than what it is under flood irrigation. JISL has demonstrated that more than 50-% water could be saved as compared to conventional flood irrigation and yield can be increased to 25-30% more. and the quality of the produce also improved in these crops. Drip irrigation coupled with fertigation and precision farming technology standardized in these crops are responsible for increasing the yield potential and improving quality, while effecting saving in water, fertilizers, energy and labour. Soman [7] and Soman *et al* [8] reported that aerobic rice hybrid ADT-45 and genotypes 27-P31,27-P63, PHB-71, ARIZE-6129, and ARIZE-6444 using drip irrigation with poly/paddy husk mulch, produced yields 4.5t-8.19 t/ha, harvested early by 8-10 days,17.7 to 25.2 % more yield than the conventional flooded cultivation system and in 27-P31, the maximum water productivity was 0.713 kg grain/m^3 water. Encouraged by the promising results of trials carried out in JISL's farms In Jalgaon, Maharashtra and Udumalpet in Tamilnadu, Research trials in Government/ Agriculture university farms, Demonstration trials in Farmers' field, R & D farms covering seven different states, during two main seasons-Rainy (*Kharif*) and winter (*Rabi*) under varied ecosystems of the country were carried out using the drip irrigation and fertigation technology in Rice during 2009-2014. About 15 rice genotypes/hybrids [Table-1] were used in these trials and the results are discussed in this paper.

The main objectives are, to determine yield stability and pattern of response of genotypes to drip irrigation and fertigation treatments across varied ecosystems and 2. To demonstrate the efficacy of drip and fertigation technology in saving water and fertilizers, increasing yield and improving quality to wide spectrum of farmers in the country and motivate them to use water and fertilizer saving technologies.

Materials and Methods

The demonstration trials were carried out in farmers' field in seven States

1. Andra Pradesh (AP) covering Vizag, Kadapa, Kurnool, East Godavari and Vijayanagaram districts
2.Telengana covering Medak, Karimnagar, Nalgonda districts
3. Chhattisgarh, Durg district
4. Rajasthan, Kota district
5. Punjab Patiala, and Ludhiana districts
6. Tamil Nadu Cuddalore, Tiruvannamalai, Madurai districts, and
7. Maharashtra, Raigarh district

During 2009 to 2014.Monsoon or *"Kharif*" June-July sowing, as also Winter or "*Rabi*" Oct-December sowing done. Direct seeded rice (DSR) as also seedling transplanted rice crops were raised. The cultivars/genotypes used were tried earlier by the respective farmers under low land rice system and the important traits of the varieties are given in [Table-1]. Details such as name of the farmer, address., rice varieties used for direct sowing/transplanted crop, drip line used, and the season of sowing, harvest data *etc.* are given in [Table-2]. The soil type varied from sandy loam to clayey loam. Standard agronomical practices are followed by the farmers in these trials. The field was, dry ploughed, harrowed, levelled, irrigated to germinate weeds, again ploughed back, harrowed, raised beds of 15 cm height and 120 cm wide were formed. A basal dose of 25 t of organic cattle manure, 345 kg SSP,25 kg each of zinc sulphate and ferrous sulphate per ha were incorporated. Two laterals of 16 mm with 4 Lph drippers at 50 cm spacing along the drip line are placed at 40 cm interval in each bed. In case of direct sowing, (DSR) pre-germinated seeds, two in each hole at 20 cmX15 cm were dibbled at two cm depth. In case of transplanted crop, seedlings from the nursery were transplanted on to the wet beds irrigated by drip. Irrigation was applied as per the schedule [Table-3]. The quantum of irrigation varied from location to location based on the evapotranspiration (ET) and the season of the crop. Fertilizers were injected through a ventury system. The fertigation schedule [Table-4a and 4b] indicating the nutrients supplied at different stages of growth and quantities of recommended dose of nutrients applied. The fertilizers in water soluble form in splits applied through drip at a frequency of two occasions per week to mitigate the high pH of the soil. Weeds were controlled by application of Pendimethalin at 1.25 l/ha after 3 days sowing, plus manual weeding at critical stage of growth 45 days after sowing. Routine observation for stem borer and leaf roller were made and appropriate treatment given. The conventional flood system plot was prepared by puddling, seedlings transplanted and the same rate of fertilizers was applied in four splits. Other practices were according to conventional system. Observations on yield and yield components recorded, yield per ha calculated, percentage increase/ decrease over control (conventional low land puddled, flood system) calculated. Besides these observations on all the farms, four individual farmers were selected for detailed study, one each from Punjab, Rajasthan, Chhatisgarh, and Andhra Pradesh; cost of inputs including amortized cost of drip system, total and net returns, Benefit: Cost ratio *etc.* were calculated.

Table-3 Irrigation schedule for Drip Method $

SN	Period	Mean Daily Evaporation (mm/day)	Crop Water Requirement (l/ha/day)
1	June 1 fn	5.53	12289
2	June 2 fn	5.53	55300
3	July 1 fn	5.42	60222
4	July 2 fn	5.35	59444
5	Aug 1 fn	5.23	69733
6	Aug 2 fn	4.91	65466
7	Sept 1 fn	4.87	54111

$ This table (used for Andhra Pradesh for June planting, Kharif) is an example for the different schedules followed in different locations mentioned in the paper.

Table-4a Fertilizer recommendations for each state (basis for fertigation schedules)

Fertilizer (NPK)				
State of India	N	P	K	kg/ha
Andhra Pradesh (& Telangana)	180	62.5	75	
Chhattisgarh	220	55	125	
Maharashtra	100	50	50	
Punjab	150	60	45	
Tamil Nadu	150	50	50	

Table-4b Ratios of N and K used to prepare Fertigation schedule in each of the farmer fields.

*Fertigation Schedule	
Stage of Crop	N: K ratio
till 10 DAP#	01:00
11-35 DAP	03:01
36-55 DAP	01:01
55-65 DAP	01:03
71-85 DAP	00:01

*All P fertilizer is applied as basal during field preparation along with FYM (manure), Zn, and Fe.

#DAP= Days after germination in Direct seeded or plant establishment in Transplanted rice.

Results and Discussion

In drip irrigated and fertigated farms, the performance, in terms of grain yield varied between 5.928 t- and 11.61 t/ha showing wide variation in yield, amongst the fifteen genotypes used; and was maximum 11.61 t/ha from genotype JGL 1798, in Madurai, Tamil Nadu, during monsoon *(Kharif*) 2013 with direct seeded crop [Table-5]. This was followed by hybrid ADT-45 yielding 9.63 t/ha, during *Rabi*, 2012, direct seeded crop, from Tiruvannamalai, TN. The hybrids US-311, MTU 4870 ranked third in respect of yield, recording 9.386 t/ha during *kharif*, 2009, direct seeded, in Medak, Telengana and Kadapa, AP respectively. MTU-1010, which was tried as transplanted crop, in two seasons by the same farmer in Medak, AP, during 2011 yielded 8.4 t/ha in *Kharif*, and 8.15 t/ha in *Rabi*. The same variety, MTU-1010, as transplanted crop, during 2013 In Karimnagar, Telengana, yielded 8.89 t/ha in June monsoon season, and when repeated in October same year the yield was low 6.42 t/ha. However, in Kurnool, AP, as direct seeded crop during, *Kharif*, 2013, recorded 7.9 t/ha. In Durg, Chhatisgarh, transplanted during March,2010 the yield was 7.41 t/ha. It is a semi-dwarf, erect variety of 120 days duration, highly adaptable, tolerant to BPH (Brown plant hopper sheath blight) and blast (*Pyricularia grisea*), widely grown with stable yields. Its performance under different ecosystems conforms to its ascribed attributes. Another semi-dwarf variety of MTU series, Swarna, MTU-7029 of 150 days duration, medium slender grain, as transplanted *Kharif* crop, 2013 yielded 8.892 t/ha in East Godavari, AP. The genotypes Pusa-1121, in Kota, Rajasthan, as transplanted crop (25 cm X 25 cm) during *Kharif*, 009 and 2010, in loamy soil, recorded 8.398 t/ha yield in two different farmers' fields. It was cultivated in 6 ha area by the farmer and obtained B:C ratio of 2.3. The water saving was 40 % as compared to conventional, flood irrigated system. Pusa -1121 is a tall variety of 137 days duration, Basmati type, with extra-long slender grain, fragrant, suitable for both transplanted and direct seeded system. They also obtained 8.398 t/ha yield of Pusa-2 in the subsequent season. Pusa- Sugandh another Basmati type, of 120 days duration, semi dwarf, extra-long slender grain with excellent aroma, during *Rabi* (sown in December,2009) yielded 5.928 t/ha in Raigad, Maharashtra as against 4.199 t/ha under flood system. In the government Seed farm, Patiala, Punjab, during July 2012,the genotype PR115, recorded yield of 6.363 t/ha under drip and fertigation system, while using sprinkler irrigation, the same genotype yielded 5.829 t/ha. ARIZE-6129 a genotype of 120 days duration, early, semi-tall 102 cm height, long, slender grain, resistant to leaf blast, yielded 8.01 t/ha in *kharif* (sowing June,2010) in Ludhiana, Punjab, and the Benefit: cost ratio being 1.8. Another genotype ARIZE-6449, yielded 7.163.t/ha in Vijayanagaram, Andhra Pradesh. The genotype BPT-5204, during *Kharif*, 2013, transplanted crop, recorded yield of 8.586 t/ha in East Godavari, Andhra Pradesh, A critical examination of the performance of 15 genotypes in over 20 farmers' field covering

seven States under different ecosystems shows that almost all genotypes performed as per their ascribed attributes. Under drip fertigation, the maximum grain yield of 11.61 t/ha was from genotype JGL1798,in Madurai, Tamil Nadu and the minimum was from PR-115, 6.363 t/ha and 5.829 t/ha under sprinkler system ,in the Government Seed Farm, Patiala, Punjab. All these genotypes recorded yield between 9.139 t/ha (JGL1798) and 4.94 t/ha (MTU1010) under flood irrigated conventional system (control). The increase in yield in drip irrigated rice fields over those of flood irrigated ones ,irrespective of genotypes varied from 14.7 % (MTU-1010,*Kharif* crop) to 29.9 % (MTU 1010,transplanted,*Rabi* crop). The minimum yield obtained in this variety under flood could also be due to hail storm damage. However, the overall performance of the genotypes show that drip irrigation coupled with fertigation with appropriate dose and proportion of water soluble fertilizer ,given twice a week ,enabled the crop to perform to its optimum potential. The savings in water in drip irrigated rice fields and increased water productivity and grain yields under aerobic rice systems have been reported by Soman *et al* [8 and 14], Hemalata [9] Gururaj Kombali [10], Parthasarathi *et al* [11] and Anusha and Nagaraj [13].The results have explicitly demonstrated that drip irrigation and fertigation technology with appropriate proportion of nutrient fertilizers in dissolved form when injected in irrigation water at twice a week interval had resulted in maximum fertilizer-use-efficiency and optimum yield response and saving in water (not measured in the present studies) and recorded enhanced yield in drip irrigated farms from 17.2 to 29.9 % over the flood irrigated fields, thus establishing the efficacy of drip irrigation and fertigation technology in increasing the yield of grains over conventional flood irrigated system. While the agronomists and extension scientists of Jain Irrigation have taken efforts to popularize using drip irrigation and fertigation technology amongst the rice farmers in the country, using latest extension methods, the challenges remain *viz*: Generally, the farmers' response to new technologies is slow, even when there is yield advantage. As the majority of farmers are small/marginal (holding <2.0 ha), cash incentives like subsidized rate for drip system is expected from the government which is presently not available for rice cultivation using drip. Considering that millions of hectares of rice are cultivated using conventional, puddled, flood system, and the huge water saving , yield advantage and ease in cultivation involved in using drip system, the government and the farmers should jointly make efforts to spread the area under such water saving technologies so as to avert impending water crisis in the country.

Application of research: In a water starved country like India, drip fertigation technology as found suitable for different rice cultivars in different rice ecologies would be an appropriate solution for continued cropping of rice.

Research Category: Irrigation management of rice

Abbreviations: DSR- direct seeded rice, TRP-Transplanted rice

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References

[1] Anon (2016) *Agricultural Statistics at a glance-Directorate of Economics and Statistics, Govt. of India, New Delhi*.
[2] Dawe D. (2005) *Plant Production Sci*., 8-221-230.
[3] Ghosh A., Singh O.N., Rao K.S. (2010) *Irrigation and Drainage,* 60 (2) 174-178.
[4] Bouman B.A.M., Humphreys E., Tuong T.P. and Barker R. (2009) *Advances in Agronomy,* 92.
[5] Sandhu Nitika, Sunita Jain, Battan K.R.and Jain R.K. (2012) *Physiol. Mol. Biol. Plants*., 18 (1), 33-43.
[6] Kumar V., Ladha J.K. (2011) *Advances in Agronomy*,111,297-413.
[7] Soman P. (2012) *Asian Irrigation Forum, Asian development Bank, Manila, April* 11-13, 2012. ADB. Manila, Philippines.
[8] Soman P., Sundar Singh, Balasubrahmanyam V.R. and Chaudhary Amol (2018) *International J. Agri .Sci*., 10(10), 6040-43.
[9] Hemalata Nirala (2015) *Ph.D thesis. Indira Gandhi Krishi Viswavidyalaya, Raipur, India*.
[10] Gururaj Kombali (2013) *Ph.D. Thesis, Univ.of Agric.Sciences, Bengaluru, India*.
[11] Parthasarathi T., Mohandas S., Senthilvel and Eli Vered (2013) *Environment and Ecology*, 31(4 A),1826-29.
[12] Rajwade Y.A., Swain D.K. and Tiwari K.N. (2013) *Agriculture: Towards a New Paradigm of Sustainability, ISBN*:978-93-83083-64-0. 293-300.
[13] Anusha S. and Nagaraju (2015) *Mysore J of Agril.Sci*., 49 (2),193-197.
[14] Soman P., Sarwan Singh, Bharadwaj A.K., Pandiaraj T. and Bhradwaj R.K. (2018) *International Journal of Current Microbiology and Applied Science,* 7 (2).