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Management of water stress through different Irrigation scheduling and drought mitigation techniques on performance of wet seeded rice

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Abstract
The field experiment was conducted at Agricultural College and Research Institute, Killikulam during early kar season of 2020- 2021 for the management of water stress caused by different irrigation scheduling practices and drought mitigation technologies on physiological parameters, irrigation water parameters, grain and straw yield of wet seeded rice. The experiment was laid out in a split plot design with four main plots and four sub plots and replicated thrice. The main plot consists of various irrigation scheduling practices *viz*., irrigation based on the alternate wetting and drying, IW/CPE ratio, field water tube at 15 cm depletion and it was compared with conventional method of irrigation. The subplot consists of drought mitigation techniques like seed treatment with 1% PPFM + 1% foliar spray at critical stages, foliar spray of 50 ppm paclobutrazol at critical stages, Seed treatment with AM fungi + soil application @ 100g/m^2 and compared with control. ASD 16 rice variety was used for this study. The study results showed that continuous flooding recorded the better performance in term of relative water content, root length, root volume, dry matter production, grain and straw yield of 6762 and 7325 Kg ha^{-1}, respectively and same treatment having higher water consumption and in-turn lower water use efficiency. Application of 1% PPFM through seed treatment + 1% foliar spray gives the higher yield (6377 and 7130 kg ha^{-1}) among the sub plot treatments. Similarly, alternate wetting and drying method of irrigation coupled with 1% PPFM through seed treatment + 1% foliar spray produced the identical performance on physiological parameters, grain and straw yield along with high water use efficiency apart from saving of 27% of water than continuous flooding.

Keywords: Wet seeded rice-irrigation scheduling, drought mitigation techniques, total water consumption and yield

1. Introduction
Rice (*Oryza sativa.* L) is a significant staple grain, which was consumed by more than 3.5 billion people globally (Arash zibaee, 2013). In the world, 90 per cent of rice is being grown in the Asian countries and rice production is spread across 114 countries and cultivated in 144 million farms more than any other crops. Rice gives living not just for small scale farmers but also for many landless labourers who earn a living by working on these farms (Mohanty *et al.*, 2012). India leads the globe in rice growing area with 43.97 million hectares and second in production with 104.32 million tonnes next to China (203.14 m t) with an average productivity of 3.74 t ha^{-1} (Nirmala, 2017).
Rice in general consumed more water about 1250 to 1350 mm than other crops. Water stress during the phonological phases reduces the production of the rice (Suriyan Cha-um *et al.*, 2011). However, being a semi aquatic crop, a considerable amount of water may be conserved by using effective irrigation management throughout the rice growing season, which may assist to bring additional land under irrigation, particularly where water resources are scarce (Bouman *et al.*, 2005) [6]. Liu *et al.* (2013) [13] showed that AWD is the best water saving technique used in rice plants without any yield loss. About 15 to 30 per cent of irrigation water may be saved by adopting the AWD method. Correspondingly, irrigation of rice crop by using IW/CPE ratio is efficient in water saving than conventional irrigation (Sanjay *et al.*, 2017). During the recent past, irrigation with the help of Field water tube in rice at 10 to 15 cm depletion based on the various soil types also evidenced as a water saving technology than the submergence of water (Santheepan and Ramanathan, 2016) [18]. Furthermore, it was measured that about 25 per cent of yield loss have been found in rice due to intermittent drought. Hence drought management during the cropping season is crucial to achieving sustainability in rice. Taking up of different drought mitigation techniques will nullify the ill effect of soil moisture

stress. Balaji *et al.* (2019) [13] stated that, PPFM had a drought mitigation property when the crop was grown in rainfed areas. Similarly, Abbasi *et al.* (2015) [1] proved that application of paclobutrazol will reduces the harmful impacts of drought stress. In the same way AM fungi helps in reducing the moisture stress in growing plants (Pannerselvam *et al.*, 2017) [17]. Hence a field experiment was carried out to evaluate the suitable irrigation scheduling method and drought alleviation techniques for getting better yield and water productivity in wet seeded rice.

2. Materials and Methods

2.1. Experimental site and season

This study was conducted in the field number 36c of B Block, Agronomy farm, Agricultural College and Research Institute, Killikulam, Tamil Nadu and it was geographically located in the latitude of 8°46' N, 77°42'E longitude and 40 m from the MSL. This experiment was carried out during the early kar season of 2021 during March month. The soil type of the experiment area was sandy clay loam. Soil was slightly saline in nature with the pH of 7.7, EC 0.19 dsm^{-1} with organic carbon content of 5.9 g kg^{-1}. Macro nutrients content of the pre sowing soil was analysed which was 238 kg ha^{-1} of N, 17 kg ha^{-1} of P and 249 kg ha^{-1} of K.

2.2. Experimental Design

Split plot design with three replications and 16 treatment combinations were used for this experiment. The treatment comprises of irrigation scheduling in main plot and drought management practices in sub plot. Main plot consists of M_1 – irrigation through Alternate wetting and drying method, M_2 – based on IW/CPE ratio (0.8 from active tillering to panicle initiation and 1.0 from panicle initiation to harvest), M_3 – irrigation at depletion of 15 cm water by Field Water Tube and Continuous flooding (Farmer's practice) in M_4. In sub-plot, S_1 - seed treatment with 1% PPFM + 1% foliar spray at critical stages, S_2 - foliar spray of 50 ppm paclobutrazol at critical stages, Seed treatment with AM fungi + Soil application @ 100g/m^2 in S_3 and S_4 - control. ASD 16 rice variety was used for this study. Initially all the seeds were treated with 2.5% of HNO_3. Sowing was done with the help of drum seeder.

2.3. Data collection

2.3.1 Irrigation studies

Data regarding water studies like total water consumption, water use efficiency, water saving percentage and water productivity were calculated by using the following formula.

2.3.2. Water Use Efficiency

Calculated as per the equation given by Viets equation (1962),

$$WUE = \frac{Y}{W}\ (\text{kg ha}\ mm^{-1})$$

Where

Y = Grain yield (kg ha^{-1})

W = Total water used

2.3.3. Water Saving Percentage

$$WSP = \frac{\text{Water supplied in flooded plot – Water supplied in treated plots}}{\text{Water supplied in flooded plot}} \text{ x 100}$$

2.3.4. Water productivity

According to Chapagain and Yamaji (2010) water productivity was calculated as

$$\text{Water Productivity} = \frac{\text{Grain yield (kg)}}{\text{Total water consumed (m}^3\text{)}}$$

2.3.5. Yield attributes

Data regarding yield attributes such as Number of productive tillers, panicle length and 1000 grain weight, grain yield, straw yield were collected and statistically analysed.

2.3.6. Physiological data

Relative water content, proline, dry matter production, root length, root volume, chlorophyll and leaf area index were analysed using the data collected during the active tillering, panicle initiation and prior to harvest period. During the time of 8-10 AM, Physiologically active leaf (3^{rd} leaf from the top) was used to analyse the Relative Water Content. Bates method (1973) was used to analyse the proline content. Chlorophyll content was recorded using SPAD Chlorophyll meter.

3. Results and Discussion

3.1. Proline

Higher plants exhibit the increased proline accumulation when exposed to stress. Among the different irrigation scheduling practices, irrigation at 0.8 IW/CPE ratio at active tillering to panicle initiation and at 1.0 ratio between panicle initiation to harvest (M_2) showed higher proline accumulation of 3.02, 4.53 and 6.44 µmoles/ g of fresh weight at active tillering (AT), panicle initiation (PI) and harvest phases, respectively indicating the crop under moisture stress compared to flooded rice (M_4) which recorded low concentration of proline (0.94, 2.18 and 2.33 µ moles/ g of fresh weight). Uyprasat *et al.*, (2004) [20] results confirmed the increased proline content in leaves under drought conditions. The similar results also corroborated with Surya Cha-um *et al.* (2010). On contrary, irrigation of rice with alternate wetting and drying and irrigation at 15 cm depletion of field water tube showed the lesser and comparable proline content of 2.02 and 2.87; 3.58 and 4.05; 4.91 and 6.15 µmoles/ g of fresh weight,

respectively than adoption of IW/ CPE method of irrigation (Table.1)

In different drought mitigation techniques, application of paclobutrazol @ 50 ppm as foliar spray at critical stages (S_2) showed the higher proline accumulation of 2.20, 3.95 and 5.55 µ moles/ g of fresh weight at various phonological stages of rice which might be due to rise in ABA (Soumya *et al.* 2017) [19]. However, AM Fungi application (seed treatment + soil application at critical stages) showed statistically on par with paclobutrazol which gives 2.19, 3.63 and 5.49 µ moles/ g of fresh weight at AT, PI and harvest stage of crop. Pannerselvam *et al.*, (2017) [17] recorded that AM Fungi treated plants show high proline under drought. Lower proline accumulation of 2.16, 3.27 and 3.81 µ moles/ g of fresh weight at various phonological stages of rice were observed under control.

On interaction, IW/CPE ratio (0.8 at active tillering to panicle initiation and 1.0 ratio between panicle initiation to harvest) with foliar spray of paclobutrazol at critical stages (M_2S_2) have higher proline content. However it was on par with irrigation through IW/CPE ratio along with AM Fungi application. However, the amount of proline accumulated in continuous flooding and control (M_4S_4) was found lesser in content.

3.2. Relative Water Content (RWC)

The amount of water present in the plant sample is relative water content. RWC will reduce when plant exposed to moisture stress. In different irrigation regimes, higher relative water content was noticed in continuous flooding (M_4). The water relative content in flooded rice was 92.65, 90.4 and 88.4 per cent at active tillering (AT), panicle initiation (PI) and harvest stages. Dasgupta *et al.* (2015) [8] showed the similar results that submerged rice has high RWC compared to moisture stress plants. The next best treatment was alternate wetting and drying method of irrigation (M_1) accounting 85.5, 83.7 and 83.2 per cent, respectively. Irrigation scheduling through IW/CPE ratio (0.8 at active tillering to panicle initiation and 1.0 ratio between panicle initiation to harvest) showed the lowest relative water content of 73.6, 75.3 and 71.8 per cent.

Application of 50 ppm paclobutrazol at critical stages (S_2) showed higher RWC of 87.0, 87.2 and 85.7 per cent at active tillering (AT), panicle initiation (PI) and harvest stage of crop. Soumya *et al.* (2017) [19] also proved that paclobutrazol increases RWC by enhancing water retention under moisture stress condition. Seed treatment with 1% PPFM and foliar spray of 1% PPFM (S_2) was performed statistically on par with application paclobutrazol. The least relative water content was found in control (S_4) at all stages of rice.

Various irrigation scheduling practices and drought mitigation techniques had significant effect on relative water content. Continuous flooding and foliar spray of paclobutrazol (50 ppm at critical stages) has highest RWC of 94.4%, 94.3% and 92.1% at AT, PI and harvest stages, respectively. The alternate wetting and drying method coupled with paclobutrazol application at critical stages (M_1S_2) noticed the similar values to continuous flooding and foliar spray of paclobutrazol. IW/CPE ratio with control plot (M_2S_4) recorded the lowest RWC (Table2).

3.3. SPAD value

Different Irrigation scheduling cause significant variation on SPAD values in rice. Continuous flooding (M_4) recorded higher SPAD values of 41.0, 41.1 and 39.1 at all the stages of observation. Still, it was statistically at par with alternate wetting and drying method of irrigation. Lower SPAD values were found in rice irrigation through IW/CPE ratio.

Among the drought mitigation techniques, application of paclobutrazol increased the chlorophyll meter reading in all stages of crop. The values are 39.6, 42.5 and 41.42 at AT, PI and harvest stages, respectively. The increase in chlorophyll content is might be due to stomatal conductance and biosynthesis of chlorophyll precursor by application of paclobutrazol. This result was conformity with Dewi *et al.*, 2016. However, it was statistically on par with PPFM seed treatment 1% + foliar spray 1% (S_1) enhanced chlorophyll content and the similar findings also reported by Aswathy *et al.* (2020) [2]. The minimum SPAD values are found in control plot (S_4).

On interaction effect, the continuous flooding with application of paclobutrazol @ 50ppm at critical stages shows increased SPAD values of 42.7, 43.9 and 41.4 at active tillering, panicle initiation and harvest stages. Irrigation regimes of alternate wetting and drying method along with foliar spray of 50 ppm paclobutrazol (M_1S_2) was noticed the statistically comparable SPAD values. IW/CPE ratio with control plot (M_2S_4) registered the lowest SPAD values.

3.4. Root length

Root length helps in moisture and nutrient uptake from various depth of soil under stress condition. In different irrigation regimes, rather than the normal results, root length of rice crop contradictly registered maximum root length of 14.6, 22.0 and 27.6 cm at active tillering, panicle initiation and at harvest stages under irrigating the rice at 15 cm water depletion of field water tube (M_3). However, the root length values due to alternate wetting and drying (M_1) was statistically similar to field water tube at 15 cm water depletion. Vasuki, (2020) [21] results showed the greater root length in FWT at 15 cm in water depletion might be due to prevailing good aeration and the plant itself to promote the root growth to observe the water at deeper layer. The minimum root length of 11.1, 19.2 and 24.5 cm was noticed in continuous flooded plots (M_4).

Among different stress mitigation methods, higher root length of 15.6, 24,7 and 32.6 cm were noticed in seed treatment and soil application of AM Fungi (S_3) at active tillering, panicle initiation and harvest stages of crop. Higher root length observed in AM treated plots compared to without AM Fungi application. This similar result was also evidenced by Mary *et al.* (2018) [10].

On interaction, irrigation at 15 cm water depletion using FWT and soil application of the AM fungi (M_3S_3) produced the maximum root length of 15.7, 22.7 and 33.5 cm at AT, PI and harvest stages, respectively. Following alternate wetting and drying method of irrigation along with AM fungi soil application (M_1S_3) performed the next best treatment. The lesser root length of 10.3, 18.3 and 21.2 cm at AT, PI and at harvest stages of crop was observed in the continuous flooding along with control (M_1S_4)

3.5. Root Volume

The identical trend also observed in root volume due to various irrigation regimes used in wet seeded rice. Irrigation using field water tube at 15 cm water depletion (M_3) increased the root volume significantly. The maximum values of 18.0, 26.4 and 30.2 cc were recorded at active tillering, panicle initiation and harvest stages. Alternate wetting and drying (M_1) was found to be statistically comparable root volume with FWT. Increased root volume was due to dense proliferation and root thickening. This was reported by Maheswari *et al.* (2007) [14]. The lowest root volume of 12.1, 18.9 and 24.7 cc at active tillering, panicle initiation and harvest stages, respectively was observed in continuous flooding condition (M_4).

The maximum root volume of 17.6, 26.2 and 29.5 cc at active tillering, panicle initiation and harvest stages were registered under soil application of AM fungi (S_3). However, PPFM application through 1% seed treatment and 1% foliar spray at critical stages produced the similar root volume. The minimum root volume was noticed in the control.

Among different interaction effect, irrigation at 15 cm water depletion through FWT and soil application of the AM fungi (M_3S_3) recorded higher root volume of 20.1, 29.7 and 33.1 cc at AT, PI and harvest stages. This was comparable with the irrigation through alternate wetting and drying method coupled with soil application of AM fungi (M_1S_3). Continuous flooding and the control have the lower root volume.

3.6. Dry Matter Production

Among different irrigation scheduling methods, continuous flooding (M_4) showed the maximum dry matter accumulation of 2592, 8893 and 14329 kg ha^{-1} at active tillering, panicle initiation and harvest stages of crop and alternate wetting and drying (M_1) gives statistically similar dry matter production which produced 2422, 8306 and 13612 kg ha^{-1}, respectively. The least dry matter accumulation (1639, 5639 and 9853 kg ha^{-1}) was noticed in IW/CPE ratio (M_2) at all stages of the crop.

Application of PPFM (S_1) (seed treatment 1% + foliar spray 1% at critical stages) produced higher dry matter production of 2420, 8469, 13998 kg ha^{-1} at AT, PI and harvest stage. It was statistically comparable with soil application of AM fungi (S_3). The control (S_4) produced minimum dry matter accumulation of 1906, 6124 and 10545 kg ha^{-1} at different stages of observations.

In interaction effect, higher DMP (2926, 9974 and 15984 kg ha^{-1} at AT, PI and harvest stages) was observed in continuous flooding + PPFM application (M_4S_1). However, the alternate wetting and drying method along with the PPFM application @ 1% seed treatment and 1% foliar spray at critical stages also shows statistically similar dry matter accumulation (M_1S_1). The IW/CPE ratio (0.8 ratio AT to PI and 1.0 PI to harvest) and control (M_2S_4) observed lowest dry matter accumulation (1354, 3583 and 8164 kg ha^{-1}) at AT, PI and harvest stage of the crop.

3.7. Yield attributes

Various irrigation treatments show a significant effect on yield parameters. Number of productive tillers (296 m^{-2}), panicle length (23.0 cm) and test weight (22.9 g) were found to be greater in continuous flooding (M_4). Kumar *et al.* (2013) [11] expressed that increased in yield attributes of rice is due to sufficient available moisture under submergence condition. It was statistically on par with irrigation scheduling with AWD (M_1). Adoption of IW/CPE ratio (M_2) (0.8 ratio AT to PI and 1.0 PI to harvest) have less number of productive tillers (218 m^{-2}), panicle length (19.4cm) and 1000 grain weight (17.9g). On drought management, application of PPFM (1% seed treatment + 1% foliar application at critical stages) (S_1) produced more of productive tillers (285 m^{-2}), panicle length (22.6 cm) and 1000 grain weight (22.6 g). Although, soil application of AM Fungi (S_3) also produced statistically similar values on wet seeded rice yield attributing characters. The lower productive tillers (212 m^{-2}), panicle length (19.5 cm) and 1000 grain weight (19.6 g) were noticed in control plots (S_4).

On interaction, continuous flooding along with PPFM application (1% seed treatment + 1% foliar application at critical stages) (M_4S_1) produced the higher productive tillers (338 m^{-2}), panicle length (25.2) and 1000 grain weight (24.4).

However, adoption of alternate wetting and drying method of irrigation + application of 1% PPFM through seed treatment and 1% foliar spray at critical stages produced statistically comparable number of productive tillers, panicle length and 1000 grain weight. Irrigation based on the IW/CPE ratio and control (M_2S_4) produced minimum yield attributes.

3.8. Grain and straw yield

The higher grain yield of 6762 kg ha^{-1} and straw yield of 7325 kg ha^{-1} was noticed under the continuous flooded rice (M_4). Conversely alternate wetting and drying (M_1) produced statistically comparable grain and straw yield (6327 and 7105 kg ha^{-1}). Santheepan and Ramanathan (2016) [18] findings also revealed that higher grain and straw yields registered under alternate wetting drying methods. IW/CPE ratio (0.8 ratio from AT to PI, 1.0 ratio from PI to harvest) gives lower grain (4285 kg ha^{-1}) and straw yield (4992 kg ha^{-1}), respectively.

Among different water stress mitigation techniques, 1% seed treatment + 1% foliar spray of PPFM at critical stages (S_1) noticed higher grain and straw yield (6377 and 7130 kg ha^{-1}). Yurimoto *et al.*, 2020 also documented the similar results. It was statistically on par with the soil application of AM fungi (S_3) with the grain yield (6025 kg ha^{-1}) and straw yield of (6865 kg ha^{-1}), respectively. Control (S_4) produced the lowest grain and straw yield (4880 and 5538 kg ha^{-1}).

The continuous flooding along with application of PPFM (M_4S_1) produced higher grain and straw yield of 7648 and 8356 kg ha^{-1}, respectively. However, it was on par with the irrigation through alternate wetting and drying method coupled with application of PPFM (seed treatment 1% + foliar spray 1%) (M_1S_1). The IW/CPE ratio (0.8 ratio AT to PI and 1.0 PI to harvest) and control (M_2S_4) produced the lower grain and straw yield (Fig.1).

3.9. Total water consumption

Total water consumption was arrived based on the total quantity of water utilized by the crop. In different irrigation scheduling, Conventional method i.e., continuous flooding (M_4) registered maximum water consumption of 1345mm during growth period of crop. Vasuki *et al.*, (2020) [21]; Mohanapriya *et al.*, (2018) agreed with their results and it shows that continuous flooding consumed more amount of water than any other method of rice irrigation. Remarkably irrigation with alternate wetting and drying consumed 1043 mm of water which accounted 26.6 per cent of water saving than continuous submergence. IW/ CPE ratio (M_2) (0.8 ratio AT to PI and 1.0 PI to harvest) recorded lower water consumption rate of 780 mm.

Among drought mitigation practices, a range of 973mm to 1063 mm of irrigation water was consumed during the growth of wet seeded rice. Higher amount of water consumed in the seed treatment with 1% PPFM + 1% foliar spray (1063mm). Application of AM fungi in soil (S_3) consumed lower water of 973 mm.

3.10. Water saving percentage

Water consumption in continuous flooded condition was referred for the calculation of water saving percentage.

Irrigation based on the IW/CPE ratio (0.8 ratio AT to PI and 1.0 PI to harvest) registered the highest water saving percentage (41.8%) among irrigation regimes even though the yield produced in this treatment was low compared to other treatments. Next to IW/CPE ratio, adoption of 15cm water depletion through field tube recorded accounted 33.9 per cent water saving. Lampayan (2013) [12], reported that irrigation using latest technique called field tube, saved 30% than submerged condition. AWD shows reasonable water saving percentage (26.6%) over continuous flooding. The different drought mitigation methods did not show any notable effect on the water saving percentage.

3.11. Water Use Efficiency

Water Use Efficiency obtained through the grain yield to the quantity of water utilized by each treatment. The WUE was found maximum in alternate drying and wetting method (M_1) which recorded 6.1 kg hamm^{-1}. Next to alternate wetting and drying, adoption of 15 cm water depletion through field water tube registered 6.0 kg hamm^{-1} of WUE. The research findings of vasuki *et al.* (2020) [21] showed that irrigation through 15 cm water depletion using field water tube has higher water use efficiency than flooding condition. The continuous submergence (M_4) recorded lower WUE (4.7 kg hamm^{-1}).

Among different mitigation practices, soil application of AM Fungi (S_3) recorded high Water Use Efficiency of 6.0 kg hamm$^{-1.}$ The AM Fungi had positive effect on moisture uptake which was reported by Pannerselvam *et al.* (2017) [17]. Control (S_4) registered the lower water use efficiency of 5.2 kg hamm^{-1}. The irrigation scheduling and stress mitigation methods did not cause any positive effect on WUE of wet seeded rice.

3.12. Water Productivity

Water productivity is the unit of water used to produce per unit of grain yield. Various scheduling of irrigation had significant effect on water productivity. Alternate wetting and drying (M_1) registered higher water productivity of 0.61 kg of grain m^{-3} of water consumed. However, adoption of 15 cm water depletion (M_3) through FWT recorded similar water productivity of 0.60 kg grain m^{-3}. The reason might be due to higher yield produced with lesser water consumption in these treatments. The similar results were also agreement with Mohanapriya *et al.*, 2019 [15]. Continuous flooding recorded the lower water productivity, which need large quantity of water to produce per unit grain yield of 0.47 kg of grain m^{-3}.

Among different drought mitigation techniques, seed treatment and soil application of AM Fungi (S_3) and PPFM application @ 1% seed treatment + 1% foliar spray at critical stages recorded higher and comparable water productivity of 0.60 and 0.59 kg of grain m^{-3} of water consumed, respectively. The minimum water productivity was noticed on the control plot (S_4).

Table 1: Effect of irrigation scheduling and moisture stress mitigation techniques on proline content (µmol/ g of fresh weight) in wet seeded rice

	Active tillering					Panicle initiation					At Harvest				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	1.92	2.11	1.94	2.1	2.02	3.18	4.12	3.21	3.82	3.58	4.98	5.28	5.11	4.27	4.91
M_2	2.97	2.85	3.21	3.06	3.02	4.36	5.13	4.76	3.87	4.53	6.41	7.44	7.34	4.56	6.44
M_3	2.87	2.76	2.72	3.11	2.87	4.31	4.41	4.21	3.26	4.05	6.21	7.12	6.97	4.29	6.15
M_4	0.95	1.07	0.87	0.88	0.94	2.13	2.14	2.35	2.11	2.18	2.27	2.36	2.54	2.13	2.33
Mean	2.18	2.20	2.19	2.16		3.50	3.95	3.63	3.27		4.97	5.55	5.49	3.81	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.05	0.07	0.13	0.14		0.06	0.12	0.22	0.24		0.13	0.14	0.26	0.27	
CD (p= 0.05)	0.16	0.17	0.32	0.33		0.19	0.26	0.50	0.53		0.27	0.28	0.63	0.57	

Table 2: Effect of irrigation scheduling and moisture stress mitigation techniques on Relative Water Content (%) in wet seeded rice

	Active tillering					Panicle initiation					At Harvest				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	87.4	89.6	88.6	77.6	85.8	83.4	88.2	85.7	77.6	83.7	83.1	87.4	83.6	78.5	83.2
M_2	78.5	77.6	70.5	67.9	73.6	78.3	80.8	75.7	66.4	75.3	72.7	77.5	73.2	63.9	71.8
M_3	83.5	86.7	71.5	72.5	78.5	84.3	85.7	80.4	71.8	80.6	81.5	85.8	72.5	70.3	77.5
M_4	92.2	94.4	93.5	90.5	92.6	88.4	94.3	89.6	88.2	90.4	88.2	92.1	88.5	84.7	88.4
Mean	85.4	87.0	81.0	77.1		83.6	87.2	82.6	76.5		81.4	85.7	79.5	74.4	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SEd	2.3	2.3	3.1	3.0		2.3	2.2	2.8	2.7		2.2	2.2	2.7	2.6	
CD (p= 0.05)	5.1	5.0	6.7	6.4		5.0	4.9	6.0	5.9		4.8	4.9	5.8	5.7	

Table 3: Effect of irrigation scheduling and moisture stress mitigation techniques on SPAD value in wet seeded rice

	Active tillering					Panicle initiation					At Harvest				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	40.4	40.6	41	33.2	38.8	42.5	42.7	42.0	35.2	40.6	39.5	39.4	39.9	31.2	37.5
M_2	34.4	34.8	33.6	32.7	33.9	35.6	41.6	35.6	32.0	36.2	33.6	39.61	32.3	30.4	34.0
M_3	38.4	37.9	36.8	34.2	36.8	38.6	41.6	38.8	35.7	38.7	38.9	38.4	38.7	32.8	37.2
M_4	39.6	42.7	41.4	40.0	41.0	41.7	43.9	41.8	36.9	41.1	36.7	41.4	40.7	37.6	39.1
Mean	37.9	39.6	38.0	35.2		39.6	42.5	39.6	35.0		37.2	39.7	37.9	33.0	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SEd	1.1	1.0	1.3	1.2		1.1	1.1	2.0	2.1		1.0	1.1	2.0	2.0	
CD (p= 0.05)	2.3	2.2	2.9	2.7		2.5	2.5	4.4	4.7		2.3	2.4	4.3	4.5	

Table 4: Effect of irrigation scheduling and moisture stress mitigation techniques on root length (cm) in wet seeded rice

	Active tillering					Panicle initiation					At Harvest				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	12.3	13.6	15.6	15.1	14.2	23.5	18.9	24.7	19.7	21.7	28.6	22.1	32.6	24.1	26.9
M_2	13.6	12.8	14.3	10.3	12.7	21.4	19.3	22.5	22.1	21.3	25.7	21.3	31.8	24.5	25.8
M_3	14.5	13.8	14.2	15.7	14.6	22.8	21.6	22.4	20.3	22.0	27.3	23.7	33.5	25.7	27.6
M_4	10.9	9.7	12.4	11.5	11.1	18.7	17.3	22.6	18.3	19.2	25.3	20.2	31.4	21.2	24.5
Mean	12.9	11.9	14.1	12.6		21.6	19.2	23.6	20.1		32.3	21.8	26.7	23.9	

	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.3	0.3	0.5	0.5		0.2	0.5	1.0	1.1		0.3	0.8	1.4	1.6	
CD (p= 0.05)	0.7	0.7	1.4	1.3		0.7	1.2	2.2	2.4		1.0	1.8	3.3	3.6	

Table 5: Effect of irrigation scheduling and moisture stress mitigation techniques on Root volume (cc) wet seeded rice

	Active tillering					**Panicle initiation**					**At Harvest**				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	17.6	15.3	18.8	14.2	16.7	26.6	21.4	25.6	22.2	23.9	32.7	24.6	27.8	23.4	27.1
M_2	17.8	16.7	19.2	14.3	17.3	25.7	20.5	28.4	23.5	24.8	28.8	28.6	30.4	24	28.6
M_3	19.5	16.6	20.1	15.6	18.0	28.4	22.1	29.7	24.1	26.4	30.7	28.5	33.1	28.3	30.2
M_4	13.1	11.7	12.3	9.6	12.1	20.4	17.4	19.5	18.7	18.9	22.5	26.6	26.6	23.2	24.7
Mean	17.0	15.1	17.6	13.8		25.5	22.3	26.2	20.3		28.4	27.1	29.5	24.7	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.4	0.4	0.4	0.9		0.6	0.6	1.2	1.3		0.7	0.7	1.4	1.5	
CD (p= 0.05)	0.8	0.9	0.9	2.0		1.3	1.4	2.7	2.9		1.6	1.6	3.2	3.3	

Table 6: Effect of irrigation scheduling and moisture stress mitigation techniques dry matter production (kg ha^{-1}) of wet seeded rice

	Active tillering					**Panicle initiation**					**At Harvest**				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	2759	2465	2471	2069	2422	9974	8561	8654	6251	8306	15467	13549	14856	10875	13612
M_2	1745	1676	1781	1354	1639	6586	5642	6745	3583	5639	11187	10065	9995	8164	9853
M_3	2267	2157	2296	1926	2162	7289	6932	6824	7467	7128	13654	12278	13347	10456	12434
M_4	2986	2349	2683	2274	2592	10245	8156	9756	7196	8893	15984	13178	15167	12685	14329
Mean	2420	2162	2327	1906		8469	7323	8049	6124		13998	12268	13416	10545	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SEd	92	90	93	93		309	305	317	318		509	513	514	515	
CD (p= 0.05)	198	194	200	201		665	656	683	685		1096	1102	1106	1108	

Table 7: Effect of irrigation scheduling and moisture stress mitigation techniques on yield attributes of wet seeded rice

	Number of productive tillers m^{-2}					**Panicle length (cm)**					**1000 grain weight (g)**				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	327	261	287	239	281	23.8	22.9	23.2	19.0	22.2	24.0	22.3	23.4	19.5	22.3
M_2	248	273	237	186	218	19.2	19.9	18.5	20.1	19.4	20.1	19.5	20.2	19.1	17.9
M_3	274	261	227	201	249	22.1	21.4	23.5	19.3	21.6	22.1	20.4	19.9	19.7	20.5
M_4	338	308	294	258	296	25.2	21.9	24.2	20.8	23.0	24.4	23.2	23.7	20.4	22.9
Mean	285	265	282	212		22.6	21.5	22.4	19.8		22.66	21.39	21.80	18.68	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M	
SEd	7.32	7.02	7.71	7.56		0.59	0.60	0.62	0.61		0.60	0.60	0.61	0.61	
CD (p= 0.05)	15.7	15.12	16.59	16.26		1.27	1.29	1.34	1.31		1.29	1.29	1.32	1.30	

Table 8: Effect of irrigation scheduling and moisture stress mitigation techniques on grain and straw yield (kg ha^{-1}) of wet seeded rice

	Grain yield (kg ha^{-1})					**Straw yield (kg ha^{-1})**				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	7148	6149	6403	5769	6327	8054	6980	7467	6189	7105
M_2	4889	4380	4863	3410	4385	5455	5329	5348	3836	4992
M_3	5983	5312	5684	4476	5363	6926	6178	6578	5578	6315
M_4	7648	6387	7139	5865	6762	8356	6330	8065	6550	7325
Mean	6377	5557	6025	4880		7130	6204	6865	5538	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	235	233	238	236		260	263	264	265	
CD (p= 0.05)	506	501	512	508		559	566	568	570	

Table 9: Effect of irrigation scheduling and moisture stress mitigation techniques on water use efficiency and water productivity of wet seeded rice

	Water use efficiency (kg ha mm^{-1})					**Water productivity (kg m^3)**				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	6.4	5.8	6.3	5.9	6.1	0.64	0.59	0.63	0.58	0.61
M_2	6.0	6.2	5.6	5.6	5.9	0.60	0.62	0.56	0.56	0.59
M_3	6.5	6.2	6.1	5.4	6.0	0.63	0.62	0.60	0.58	0.60
M_4	5.2	5.2	5.3	4.0	4.7	0.52	0.52	0.53	0.40	0.47
Mean	5.9	5.8	6.0	5.2		0.59	0.58	0.60	0.53	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.15	0.16	0.34	0.35		0.015	0.016	0.032	0.036	
CD (p= 0.05)	0.33	0.35	0.80	0.77		0.033	0.034	0.075	0.080	

Table 10: Effect of irrigation scheduling and moisture stress mitigation techniques on water use efficiency and water productivity of wet seeded rice

	Total water consumption (mm)					Water saving%				
Treatments	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**Mean**
M_1	1098	1108	994	970	1043	26.4	21.1	25.5	33.3	26.6
M_2	810	789	784	738	780	42.9	36.6	41.4	46.3	41.8
M_3	924	920	877	846	892	34.9	29.1	31.7	38.5	33.9
M_4	1420	1348	1237	1376	1345	-	-	-	-	
Mean	1063	1041	973	983		34.7	28.9	32.9	39.4	

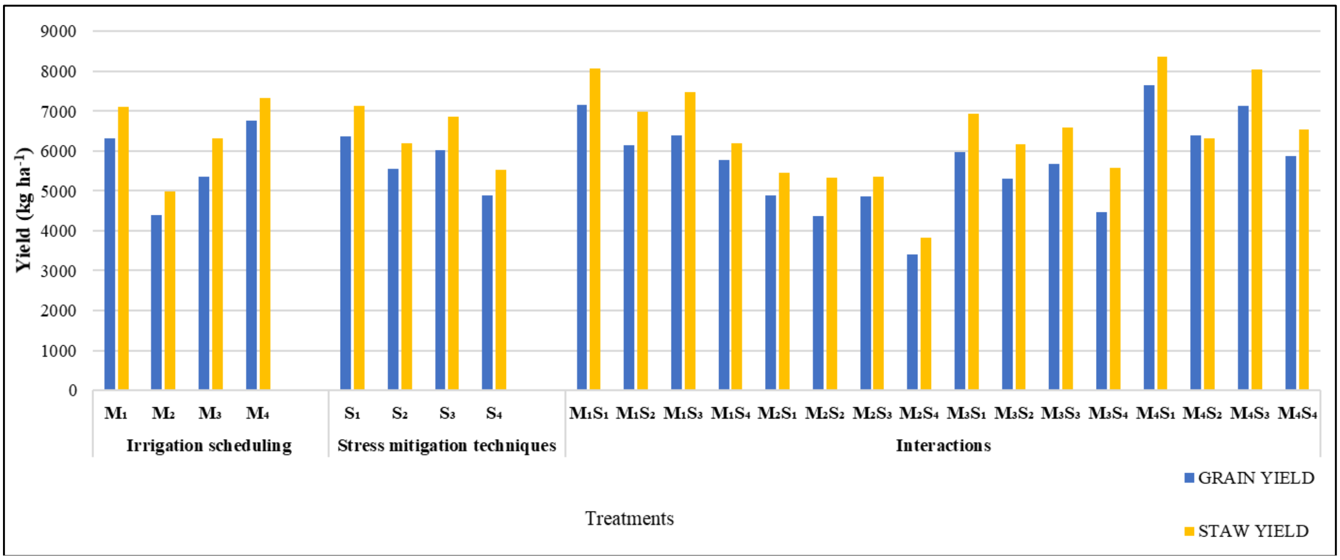

Fig 1: Effect of different irrigation scheduling and moisture stress mitigation on grain and straw yield of wet seeded rice

4. Conclusion

Water scarcity was the important problem faced by the majority of the farmers especially in paddy growing areas. Moreover, unavailability of water during the critical stages of the crop was also the major factor which reduces the crop yield. In these circumstances, there are many alternate ways to overcome the moisture stress during the critical stages. This study suggests that, irrigation scheduling method through alternate wetting and drying along with moisture stress mitigation technique through PPFM application @ 1% seed treatment + 1% foliar spray at critical stages produced higher yield, low water consumption with higher water productivity which helps the farmers to avoid the moisture stress during the critical stages of the crop and to decrease the yield loss in water stress areas.

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