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Evaluation of Crop and Soil Dynamics under Various Moisture Regimes and Moisture Conservation Techniques in Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The present investigation was conducted to validate the various moisture regimes in transplanted rice and to study the effect of different moisture conservation techniques on performance of rice and soil after harvest of crop.
Study Design: Experiment was laid out in split plot design (SPD).
Place and duration of Study: The present investigation was conducted during the *kharif* season of 2018 and 2019 at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), India.
Methodology: The main factor consists of the moisture regimes *viz.* irrigation as CF (I_1), at FC (I_2) and at 25%DASM (I_3), the sub factors consist of six moisture conservation techniques *viz.* control, application of wheat residues @ 5t/ha, Pusa hydrogel @7.5 kg/ha, seed treatment with PF-6, PF-2

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and IRRI-1 @ 4g/kg seed. Observation on plant growth attributes *viz*., plant height and leaf area index were recorded at 30, 60 DAT and at harvest stage of the crop, while chlorophyll content was recorded at 30 and 60 DAT. The harvest index was calculated on the net plot area basis. Observation on soil dynamics *viz*., available NPK and OC were recorded both before and after harvesting of crop.

Results: Among different moisture regimes, the highest plant height, LAI and chlorophyll content was found under CF (I_1) followed by FC (I_2) during both the years. Among MCTs, the highest values of growth attributes and harvest index of rice were found with application of wheat residue @ 5 t/ha followed by Pusa hydrogel @ 7.5 kg/ha during both the years. Maximum value of harvest index was recorded under CF during first year, while it was highest under FC during 2019. Slight improvement in available nutrients were observed at 25% DASM treatment of moisture regimes and wheat residues @ 5 t/ha treatment of moisture conservation techniques over their other counterparts during both the years of experimentation.

Conclusion: On the basis of study, it may be concluded that irrigation should be scheduled at FC (2-3 days after disappearance of water on surface) in transplanted rice and application of wheat residues @ 5 t/ha in rice is an appropriate moisture conservation technique for improving the physiological growth and productivity, besides enhancing the soil fertility.

Keywords: CF; DASM; FC; MCTs; pusa hydrogel; seed treatment; wheat residues.

1. INTRODUCTION

Rice (*Oryza sativa* L.), a member of Poaceae family is of immense importance to food security of Asia, where more than 90% of the global rice is produced and consumed. It is the staple food of about 3 billion people and the demand is expected to grow continuously as population increases [1]. Looming water crisis, water intensive nature of rice cultivation, appropriate scheduling of irrigation *i.e.*, when and how much water etc. are vital for optimizing the rice yield. Continuous flooding of water is suggested to get a higher yield of rice but under paucity of water, judicious management of water is essential for its economic use [2]. Rice is a water guzzling crop and requires on an average about 5000 litres of water to produce 1 kg of rice grains [3,4]. The prevailing practices resulting in the depletion of water table due to excessive pumping out during peak summer and also there is labour problem owing to their scarcity making rice cultivation less profitable [5]. Researchers are developing water-saving technologies such as alternate wetting and drying, continuous soil saturation [6], direct dry seeding, ground cover systems [7] and system of rice intensification but all these systems use prolonged periods of flooding and hence water losses still remain high [8].

The retention of wheat straw as a surface mulch could be beneficial for moisture and nutrients conservation, and enhancing yield and water productivity in addition to reducing air pollution and loss of soil organic matter. Mulching increased soil water content and this led to significant improvement in crop growth and yield determining attributes where water was limiting, Mulch conserved soil water, and delayed the need for Mulch improved crop performance when water was limiting, and occasionally increased yield.

Hydrogel is a synthetic polymer, which is able to absorb and hold the water, 80-180 times of its volume for a longer period of time. The hydrogel acts as a reservoir to store and release a steady stream of water and nutrients which plants need to grow. Plant roots are able to absorb water from the crystal bead of hydrogel [9]. Microbes have also showed the ability to protect the crop from moisture stress. Plant growth promoting bacterial (PGPB) strains such as *Pseudomonas fluorescens* (PF 1) and *Bacillus subtilis* (EPB5, EPB22, EPB 31) has an immense capacity to induce water stress in field crops. Plant growth data such as shoot length, root length and dry weight of rice plant were analysed after 45 days, the results suggested that all *Pseudomonas* strains enhanced plant growth in rice and among various strains, *P. fluorescens (*PW-5) produced the maximum shoot, root and dry weight with respective increase of 157.7, 408.1 and 233.8% as compared to control [10].

2. MATERIALS AND METHODS

The present investigation was conducted during the *kharif* season of 2018 and 2019 at Crop Research Centre of SVPUA&T, Meerut on a fixed site to validate the various moisture regimes and different moisture conservation techniques in transplanted basmati rice. The climate of this region is characterized by sub-tropical and semi-arid with hot and dry summer (April to June), hot and humid monsoon period (July to September), mild winter (October to November) and cold winters (December to February). The total amount of rainfall received during crop period was 936.9 mm in 2018 and 631.8 mm in the year 2019, out of which about 98% was received during July to September in both the year. The experimental field soil was sandy loam in texture, low in organic carbon and available nitrogen, medium in available phosphorus and potassium. The experiment was laid out in split plot design with a combination of 3 main and 6 sub factor treatments, replicated thrice. The main plot factor consists of the moisture regimes *viz.,* irrigation as continuous flooding (CF), irrigation at field capacity (FC) and irrigation at 25% depletion of available soil moisture (DASM) and sub plot factors consists of six moisture conservation techniques *viz.,* control, wheat residues @5t/ha, Pusa hydrogel @7.5 kg/ha, seed treatment with *Pseudomonas fluorescencs* (PF 6), *Pseudomonas fluorescencs* (PF 2) and *Trichoderma harzianum* (IRRI 1) @ 4g/kg seed.

Observations on growth attributes *viz*., plant height and leaf area index were recorded at 30, 60 DAT and at harvest stage of the crop, while chlorophyll content (SPAD value) was recorded at 30 and 60 DAT. The harvest index was calculated on the net plot area basis. Five hills were tagged randomly in each net plot and their height was recorded in centimetres with the help of meter scale from the ground surface to the tip of fully expanded leaf, before panicle emergence and up to the panicle tip after its emergence. Height of plants of all the five hills was summed up and averaged to express plant height in cm. From the samples collected for dry matter estimation, leaves of 5 hills were plucked at 30 and 60 DAT and their leaf area was measured with the help of leaf area meter (LA-3100). The leaf area for each sample recorded wasaveraged to give leaf area in cm^2.The following relationship was used to compute LAI [11] at each stage,

$$\text{LAI} = \frac{\text{Leaf area (cm2)}}{\text{Land area (cm2)}}$$

A chlorophyll meter (SPAD-502, Soil-Plant Analysis Development) Section, Minolta Camera Co., Ltd., Japan) was used to take SPAD reading at 30 and 60 DAT on the uppermost fully expanded leaf, plot wise. Five leaves/plot from different hills were selected and SPAD reading was taken around the midpoint of each leaf blade, 30 mm apart, on one side of the midrib [12]. Harvest index is the ratio of the economic yield and biological yield, it was worked out using the formula given by [13] as,

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (q/ha)}}{\text{Biological yield (q/ha)}} \text{ X } 100$$

Observation on soil dynamics *viz*., available nitrogen, phosphorus, potassium and organic carbon were recorded, treatment wise after harvesting of the crop during both the years. Available nitrogen was estimated by alkaline potassium permanganate ($KMnO_4$) method wherein organic matter in the soil is oxidized with hot alkaline $KMnO_4$ solution. The ammonia evolved during oxidation is distilled and trapped in boric acid mixed indicator solution. The amount of NH_3 trapped is then estimated by titrating it with standard acid [14]. The available phosphorus content of soil was determined by the Olsen's method [15]. 2.5 g of dried soil sample containing a pinch of Darco G-60 was extracted with 50ml of 0.5M $NaHCO_3$ (pH 8.5) for 30 minutes. Five ml of filtrate was taken in 25 ml volumetric flask and add 2-3 drops of p-nitro phenol indicator which resulted into yellow colour development. After that, 5N H_2SO_4 (drop by drop) was added until yellow colour disappears to acidify it up to 5 pH and then 4 ml of ascorbic acid solution was added to the flask and finally make up the volume. The blue colour was obtained, the intensity of blue colour which is proportional to phosphate was read on the spectrophotometer at a wave length of 730 nm by using a red filter. A blank was also run by adding the entire chemicals, except soil. The available phosphorus was worked out as,

Available phosphorus (kg/ha) = ppm of P calculated from standard curve × dilution factor ×2.24.

The available potassium content of soil was determined by the method described by Hanway and Heidel [16] as 5.0 g of processed soil was taken into 100 ml conical flask and extracted with 25 ml of neutral normal ammonium acetate solution. The filtrate was aspirated into the atomizer of the calibrated flame photometer and reading was noted and thus the available potassium estimated as,

Available potassium (kg ha^{-1}) = ppm K ×dilution factor × 2.24.

The organic carbon in the soil was estimated through Walkely and Black method as described by Jackson [17].

3. RESULTS AND DISCUSSION

3.1 Study on Rice

3.1.1 Plant height

The plant height of rice increased with the advancement of crop age and reached to maximum at harvest during both the years of experimentation, although the pace of increment was highest between 30 to 60 DAT. The variation in plant height due to moisture regimes and moisture conservation techniques was significant at all the stages of crop growth during both the years of investigation (Fig. 1a and1b). The maximum plant height of rice was recorded in continuous flooding (I_1) at all the stages of crop growth, which differed significantly than all other treatments, except with I_2 (field capacity) at 30 DAT during both the years. However, the minimum plant height of rice was recorded with 25% DASM (I_3) at all the stages of crop growth during both the years. The maximum plant height of 103.6 and 101.5 cm was observed in I_1 and the minimum plant height of 94.9 cm and 93.4 cm at harvest stage was observed in I_3 during 2018 and 2019, respectively. At harvest stage of crop, continuous flooding (I_1) resulted into 9.2 and 8.7 % more plant height over I_3 during 2018 and 2019, respectively. Irrigation applied at FC might have collectively resulted in better plant height due to sufficient supply of moisture regimes has vital role in nutrients absorption as solvent and career of food material. Similar findings were also reported by Balasubramanian et al. [18].

Among the different moisture conservation techniques, wheat residues @ 5 t/ha, being on par with Pusa hydrogel @ 7.5 kg/ha at all the stages of crop growth, except 60 DAT and at harvest during 2019 had significantly tallest plants over rest of the treatments at all the stages of crop growth during both the years. Moreover, seed treatments with *Pseudomonas fluorescencs* strains PF 6 (M_4) and PF 2 (M_5) and *Trichoderma harzianum* IRRI 1 (M_6) @ 4g/kg seed were also statistically alike in this regard at all the stages of crop growth during both the years, except 60 DAT during 2019. Although, the shortest plants were recorded under control (M_1) at all the stages of crop growth during both the years. At harvest stage, the maximum plant height of 102.6 and 102.1 cm was observed in M_2 during 2018 and 2019, respectively. While, the minimum plant height (96.6 cm and 95.0) cm was observed in M_1 during 2018 and 2019, respectively. The plant height at harvest stage of crop noticed an increase of 6.1 and 7.5 % in treatment M_2 over control during 2018 and 2019, respectively. Increase in plant height with wheat residue retention on soil surface might be due to maintenance of adequate and continuous moisture to plant which maintained good establishment of roots, suppressed weeds and after decomposition provide the plant nutrients too, which helps the plants to grow vigorously. Further, enhancement of various metabolic processes and increased availability of nutrients also ensure the accelerated cell division and elongation i.e., the pre requisites for improvement in plant height. Kumar et al. [19] has also been made similar observations.

3.1.2 Leaf area index

Leaf area index increased with the advancement of crop age and reached to maximum at 60 DAT and thereafter, declined slightly. The higher leaf area index was recorded during 2018 as compared to 2019. Among the moisture regimes, the leaf area index did not differ significantly at all the stages of crop growth, except at 30 DAT during both the years. At 30 DAT, continuous flooding maintained the maximum leaf area index being at par with field capacity, though the minimum leaf area index was recorded under 25% DASM during both the years (Fig. 2a and 2b).The increase in leaf area index (LAI) was might be due to the fact that sufficient availability of moisture increased the absorption of nutrients which results the plants in fully turgid condition along with higher green leaves with enlarged size. This led to higher leaf area and finally the LAI. The lowest LAI was recorded with 25% DASM, this is mainly due to the limited supply of moisture and nutrients under this treatment. Sandhu and Mahal [20] also reported similar results.

Moisture conservation techniques resulted into significant variation in leaf area index at all the stages of crop growth during both the years. Significantly maximum leaf area index was recorded with the application wheat residue @ 5t/ha than all other moisture conservation techniques during both the years except Pusa hydrogel 7.5 kg/ha at 30 DAT during 2019. Seed treatments with microbial inoculants such as PF 6 and IRRI 1 @ 4g/kg were also at par to each other and superior than control and PF 2 at all the stages of crop growth, except at 60 DAT during both the years. The higher leaf area index may be attributed to increased soil moisture and nutrient availability for a longer period of time under mulched plots which reflected the more leaf expansion as compared to control. Wheat residue retention delay the senescence as sufficient moisture was maintained in crop root zone. Our results are in close conformity with those of Yadav et al. [21].

3.1.3 Chlorophyll content (SPAD value)

With the advancement in crop age, a marked reduction in chlorophyll content was noted irrespective though the variation was of the treatments being highest at 30 DAT, non-significant due to moisture regimes and moisture conservation techniques during both the years, except at 60 DAT during 2018 through MCT.The highest value (43.2, 42.9 and 37.4, 37.1 at 30 and 60 DAT during 2018 and 2019, respectively) of SPAD meter was recorded in continuous flooding followed by water applied at field capacity. Moreover, application of irrigation at 25% DASM showed the lowest value (42.4, 42.0 and 36.6 at 30 DAT and 60 DAT during 2018 and 2019, respectively) of SPAD meter during both the years of study (Fig. 3a and 3b). Among moisture conservation techniques, at 30 and 60 DAT, the SPAD value were differed slightly, except 60 DAT during 2018 where the variation was statistically significant. At 60 DAT during 2018, the highest SPAD value was recorded with the application of wheat residue @ 5t/ha which was at par with the application of Pusa hydrogel @ 7.5kg/ha and microbial inoculant IRRI 1 @ 4g/kg. However, seed treatment with PF 6, PF 2 and IRRI 1 @ 4g/kg were statistically at par with each other in the regard. While, the lowest SPAD meter was recorded under control (42.0, 36.0 and 41.8, 35.6) during 2018 and 2019, respectively. The adequate soil moisture, harvesting of light and photo protection partially helpful in development of chlorophyll content in rice. Yang et al. [22] also reported the similar observations.

3.1.4 Harvest index (%)

The maximum harvest index of 38.2 % was recorded from rice under farmer’s practice (continuous flooding) during first year, while during second year it was noticed with irrigation at field capacity. Although, the lowest harvest index (37.1 and 36.6 %) was recoded with the application of irrigation at 25% DASM during both the years of study (Fig. 4).It may be due to proper moisture availability at panicle initiation and grain development stage which in turn increase the dry matter production/plant and the translocation of photosynthates towards sink. Similar opinions were also stated by Fonteh [23].

Further, the harvest index varied between 36.3 to 38.9 and 35.5 to 39.9 % during first and second year due to moisture conservation practices, respectively. Though, the highest harvest index of 38.9 and 39.9 % was recorded with the application of wheat residue @ 5 t/ha followed by application of Pusa hydrogel @ 7.5 kg/ha during first and second year, respectively. This improvement was mainly due to the better growth parameters, more synthesis as well as translocation of photosynthates and increased grain yield which may be possible through improved moisture and nutrients availability under these treatments. However, the minimum harvest index of rice was recorded under control during 2018 and 2019, respectively.

3.2 Soil Dynamics

As per the findings of soil dynamics, all the available nutrients along with organic carbon content declined slightly in comparison to initial values in the soil, irrespective of the treatments after each cropping cycle except wheat residues (Table 1).

3.2.1 Available nitrogen (kg/ha)

Among the he moisture regimes, the maximum available nitrogen of 208.6 and 203.9 kg/ha was recorded under irrigation at 25% DASM followed by application of irrigation at field capacity, while the minimum available nitrogen of 204.0 and 199.3 kg/ha was recorded with continuous flooding during 2018 and 2019, respectively. Among the moisture conservation techniques, the maximum available nitrogen of 208.6 and 204.7 kg/ha was recorded with the application of wheat residue @ 5 t/ha followed by under control and seed treatment with PF 2 @ 4 g/kg, while the minimum available nitrogen of 201.1 and 197.3 kg/ha was recorded with the application of Pusa hydrogel @ 7.5 kg/ha during first and second years, respectively. But the variation was significant only during 2018.

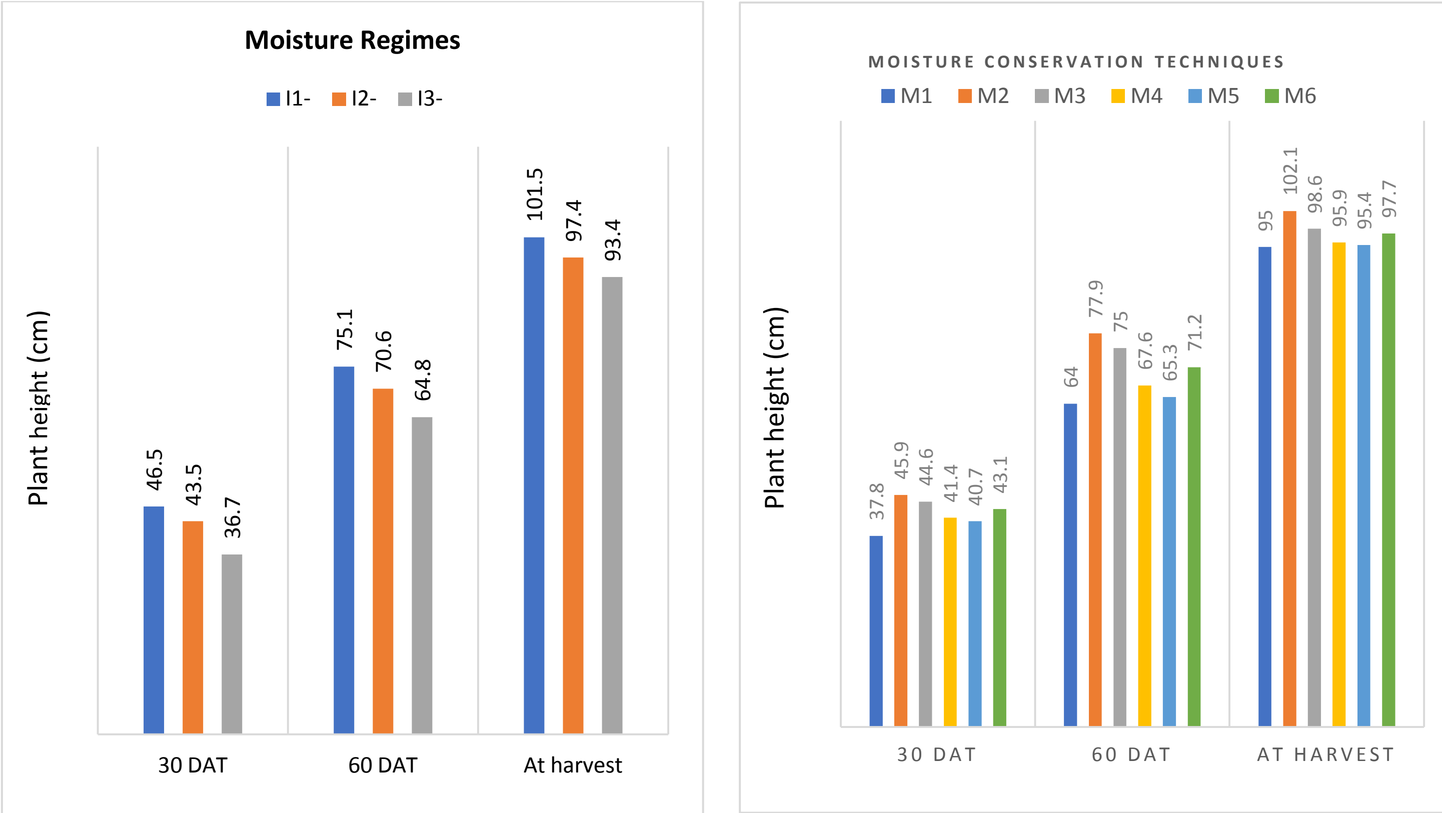


Fig. 1a. Effect of moisture regimes and moisture conservation techniques on plant height (cm) at different stages of rice (2018)

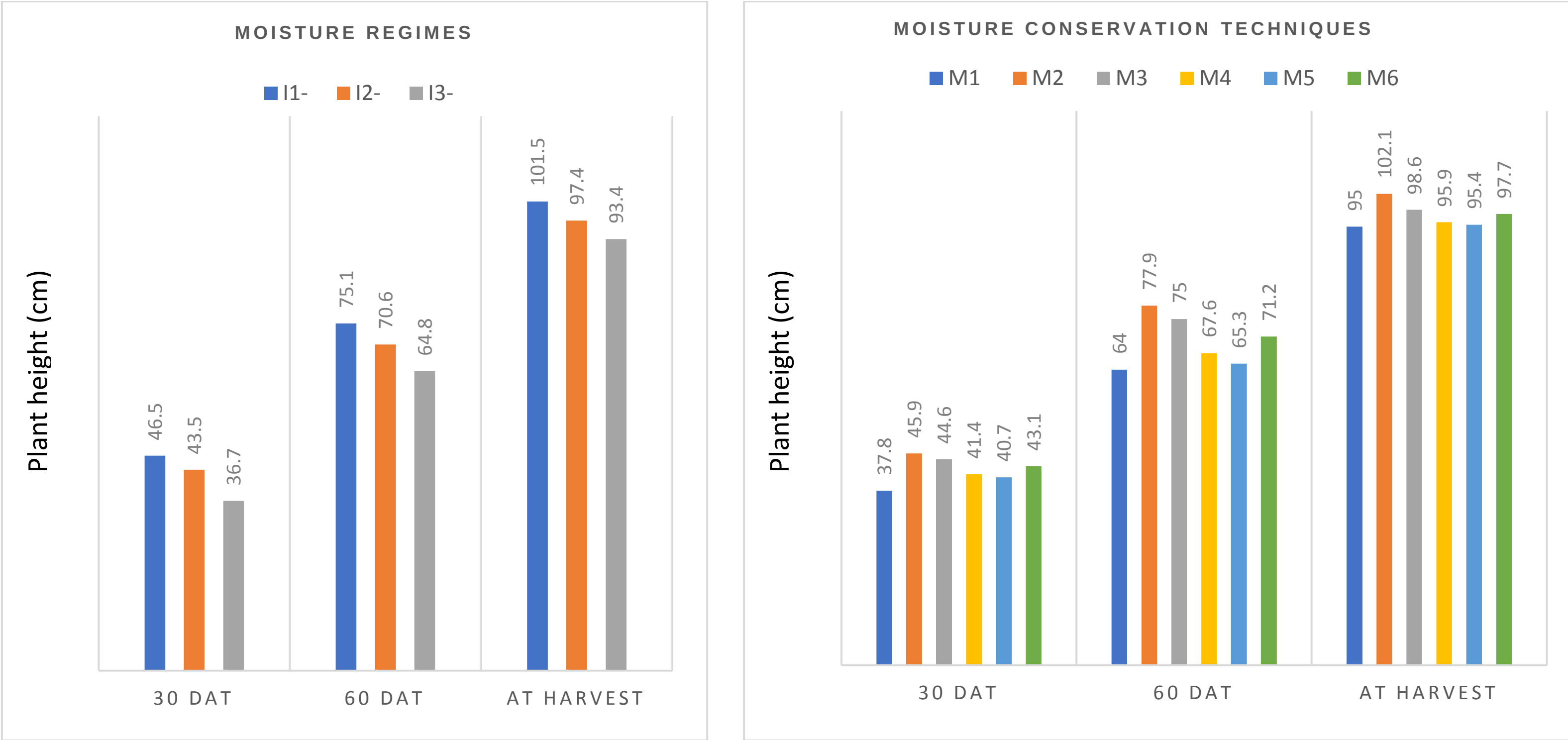


Fig. 1b. Effect of moisture regimes and moisture conservation techniques on plant height (cm) at different stages of rice (2019)

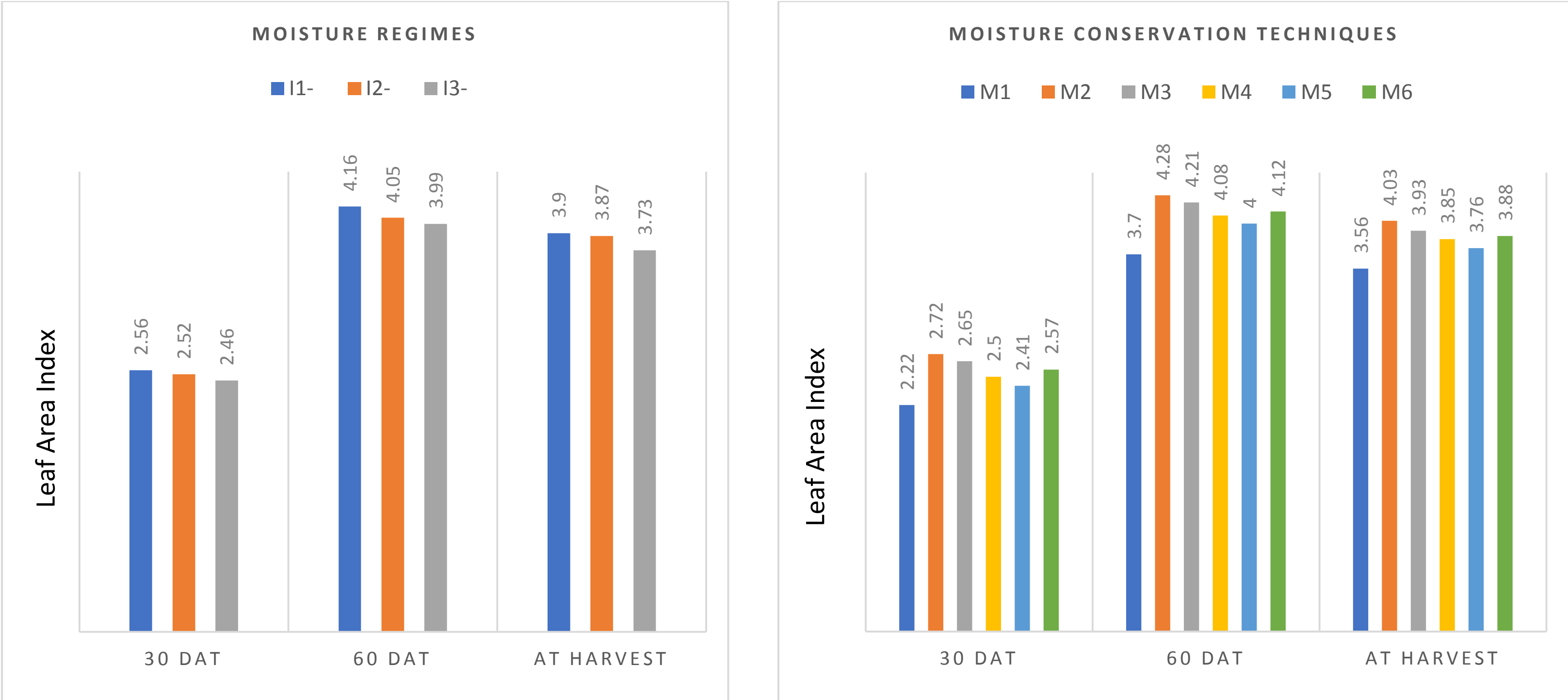


Fig. 2a. Effect of moisture regimes and moisture conservation techniques on leaf area index at different stages of rice (2018)

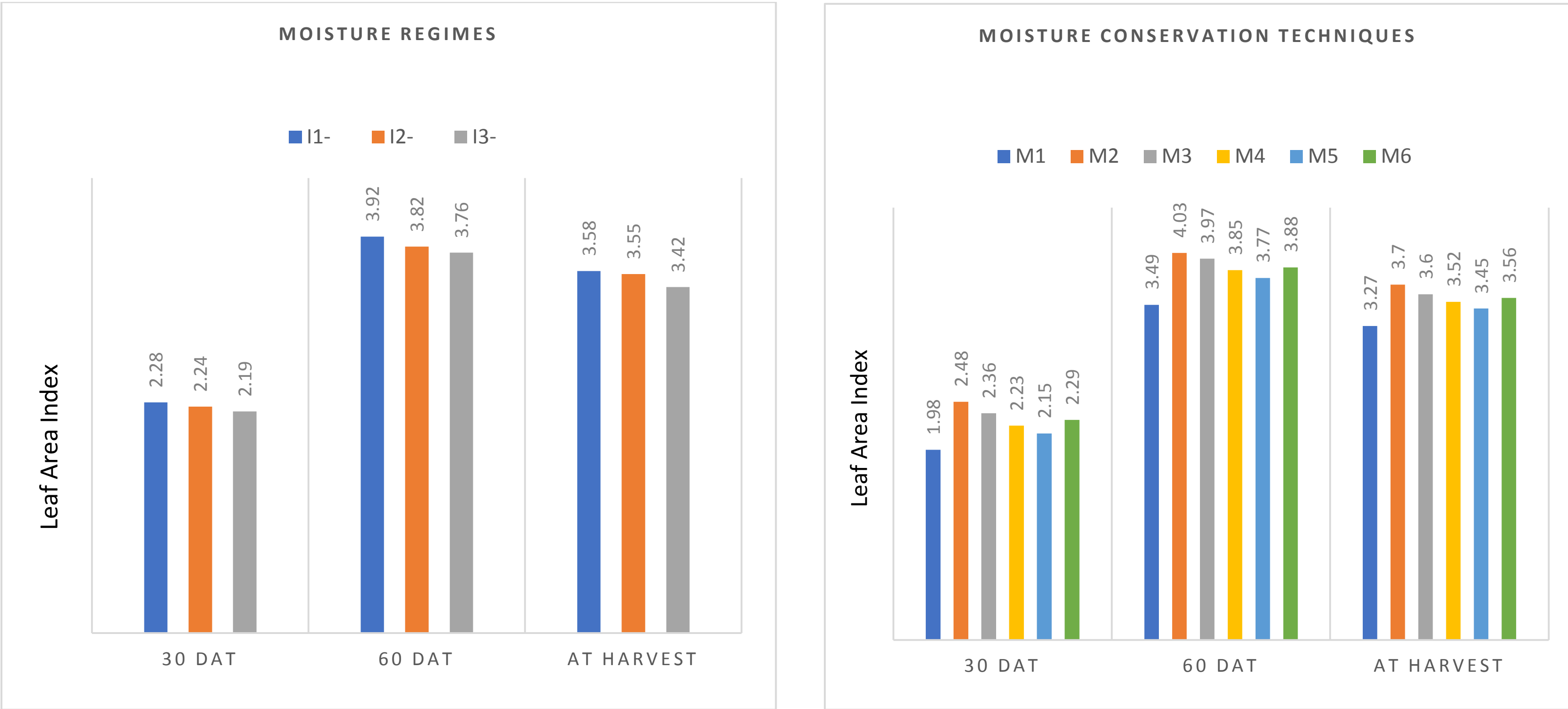


Fig. 2b. Effect of moisture regimes and moisture conservation techniques on leaf area index at different stages of rice (2019)

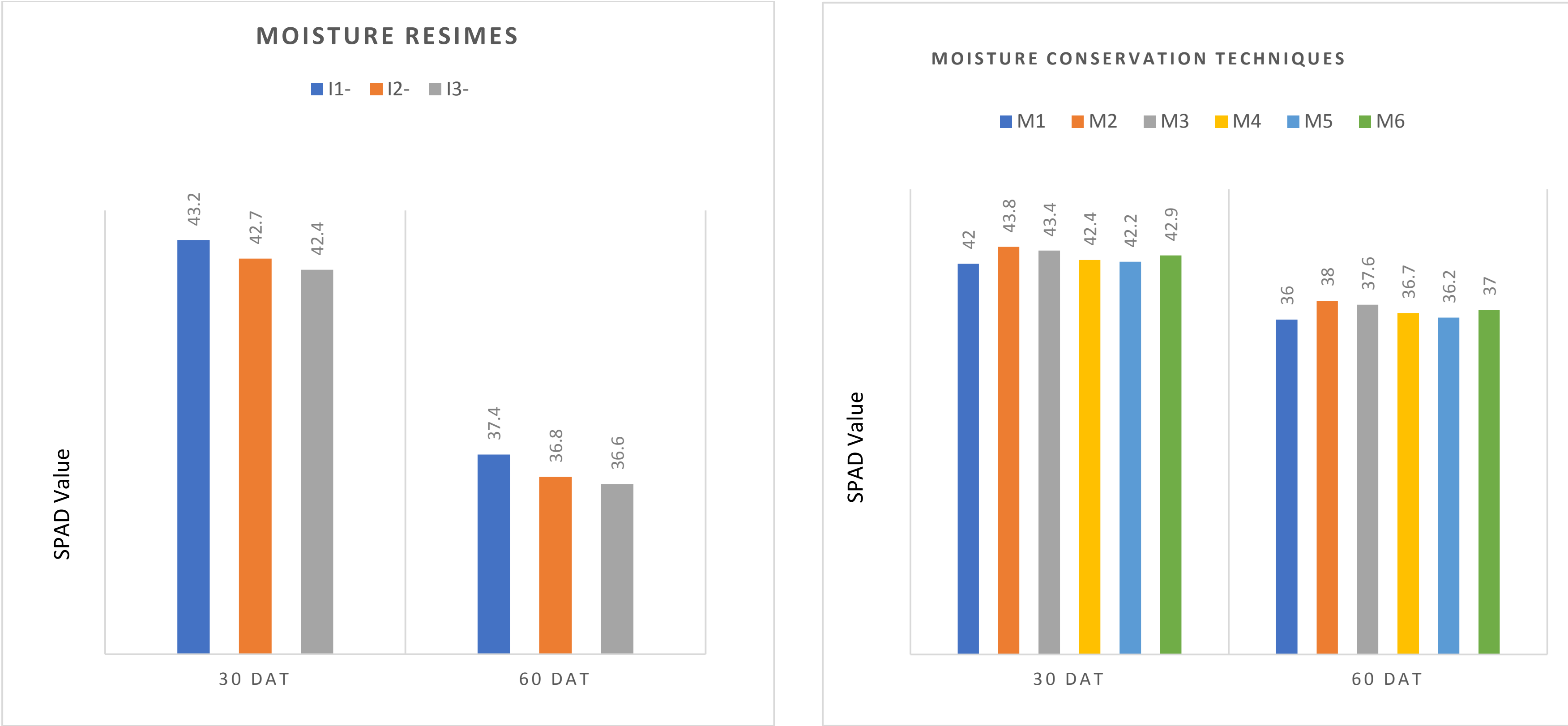
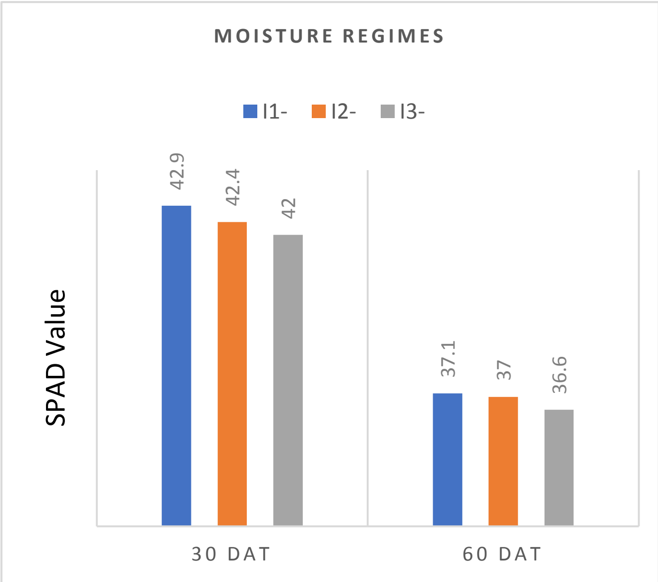


Fig. 3a. Effect of moisture regimes and moisture conservation techniques on chlorophyll content (SPAD Value) at different stages of rice (2018)



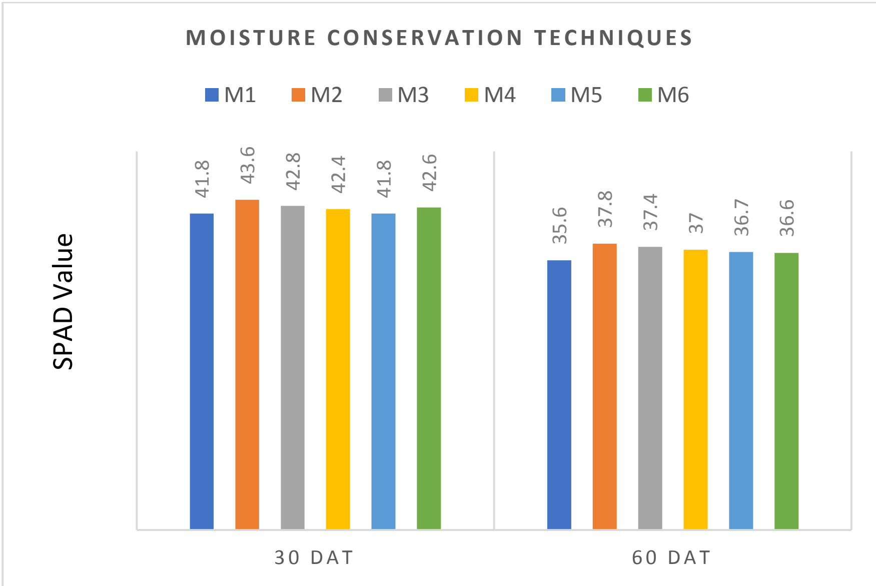


Fig. 3b. Effect of moisture regimes and moisture conservation techniques on chlorophyll content (SPAD Value) at different stages of rice (2019)

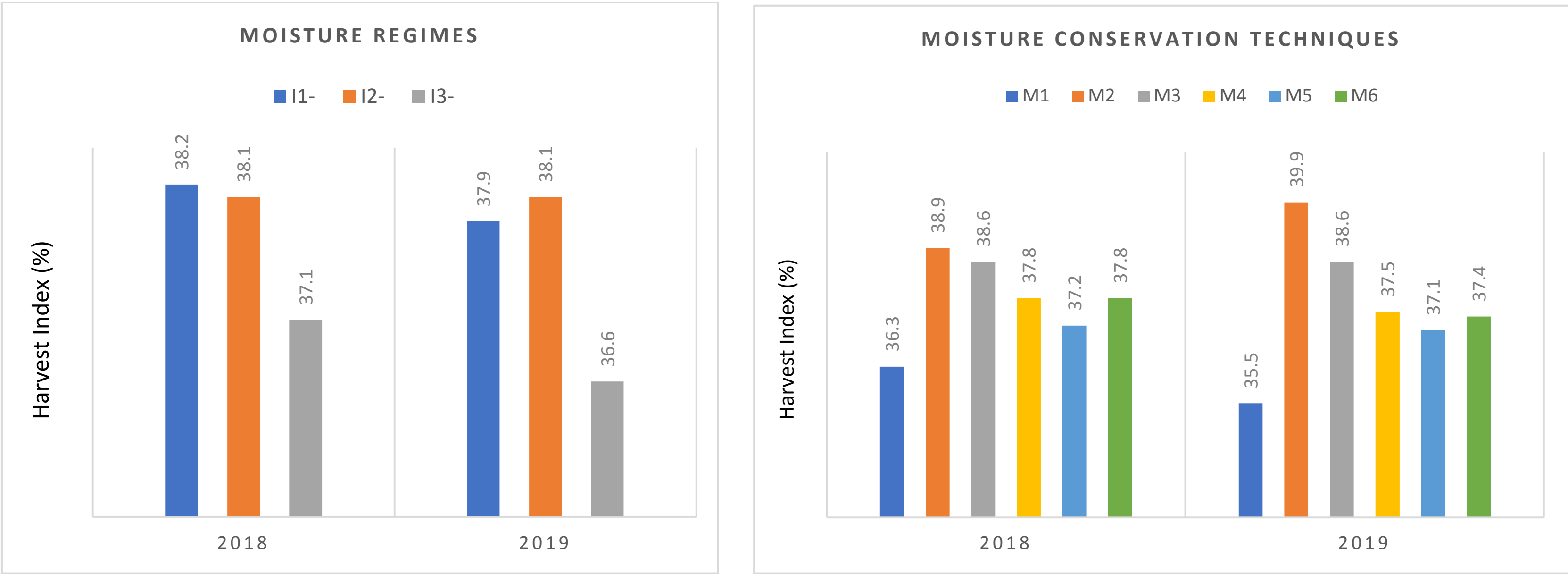


Fig. 4. Effect of moisture regimes and moisture conservation techniques on harvest index (%) of rice

Table 1. Effect of moisture regimes and moisture conservation techniques on soil dynamics

Treatments	Available nutrients (kg/ha)						Organic carbon (%)	
	Nitrogen		Phosphorus		Potassium			
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Moisture Regimes								
I_1- Continuous flooding	204.0	199.3	13.1	12.7	180.1	173.0	0.456	0.449
I_2- At Field Capacity	205.8	201.4	13.6	13.3	181.2	176.4	0.465	0.455
I_3- At 25% DASM	208.6	203.9	14.0	13.7	182.3	180.6	0.471	0.458
SEm ±	1.6	1.8	0.4	0.7	4.7	3.3	0.005	0.003
CD (P=0.05)	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Moisture Conservation Techniques								
M_1-Control	208.3	203.7	13.4	13.4	182.0	178.4	0.463	0.461
M_2-Wheat residues @ 5 t/ha	208.6	204.7	13.8	13.7	183.2	180.5	0.476	0.489
M_3- Pusa hydrogel @ 7.5 kg/ha	201.1	197.3	12.7	12.4	179.3	175.1	0.449	0.439
M_4- *P. fluorescencs* (PF 6) @ 4g/kg	206.3	201.9	14.2	13.4	180.8	174.6	0.467	0.444
M_5- *P. fluorescencs* (PF 2) @ 4g/kg	207.0	201.8	14.4	13.7	181.6	176.5	0.470	0.450
M_6- *T. harzianum* (IRRI 1) @ 4g/kg	205.6	200.1	13.1	12.8	180.3	175.0	0.458	0.441
SEm ±	1.5	2.5	0.8	0.9	3.6	2.8	0.013	0.011
CD (P=0.05)	4.5	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	0.031
Initial	208.5	206.2	14.4	13.6	184.0	181.2	0.472	0.465

3.2.2 Available phosphorus (kg/ha)

Due to moisture regimes available phosphorus did not show any significant difference during both the years. The maximum available phosphorus 14.0 and 13.7 kg/ha was recorded with the application of irrigation at 25% DASM whereas, the minimum available phosphorus of 13.1 and 12.7 kg/ha was recorded with the application of irrigation as continuous flooding in rice during 2018 and 2019, respectively. Among the moisture conservation techniques, the maximum available soil phosphorus (14.4 and 13.7 kg/ha) was recorded under seed treatment with PF 2 followed by seed treatment with PF 6 @ 4 g/kg and application of wheat residue @ 5 t/ha. Whereas, the lowest available soil phosphorus (12.7 and 12.4 kg/ha) was noticed with the application of Pusa hydrogel @ 7.5 kg/ha during first and second years, respectively.

3.2.3 Available potassium (kg/ha)

The data showed a non-significant difference in available potassium content in soil due to moisture regimes and moisture conservation techniques during both the years. Application of irrigation at 25% DASM had the maximum available potassium in soil after rice harvesting followed by irrigation at field capacity, whereas the minimum available potassium in soil was recorded under continuous flooding during both the years. Among the moisture conservation techniques, the maximum available potassium in soil was recorded with the application of wheat residue @ 5 t/ha followed by control, while the lowest available potassium in soil was recorded with the application of Pusa hydrogel @ 7.5 kg/ha (179.3 kg/ha) during 2018 and with PF 6 @ 4g/kg seed (174.6 kg/ha) during 2019.

3.2.4 Organic carbon (%)

Data pertaining to organic carbon content (%) after harvest indicated that moisture conservation techniques during second year influenced it, while moisture regimes showed non-significant difference during both the years of study. Application of irrigation at 25% DASM exhibited the highest organic carbon in soil (0.471 and 0.458 %), while irrigation as continuous flooding led to lowest organic carbon in soil during both the years. Due to moisture conservation techniques, significantly maximum organic carbon (%) was recorded with the application of wheat residue @ 5 t/ha followed by control, while the lowest organic carbon in soil (0.449 and 0.439 %) was recorded with the application of Pusa hydrogel @ 7.5 kg/ha followed by IRRI 1 @ 4 g/kg seed of first and second crop, respectively. The highest available nutrients and organic carbon observed under 25% DASM due to less accumulated nutrients by the crop. Wheat residue play a key role in nutrient availability after proper decomposition it supplies the plant nutrients, beside increasing the organic carbon content in soil. Similar results were also reported by Dhiman et al. [24].

4. CONCLUSION

The highest values of plant growth parameters and HI was recorded undercontinuous flooding followed by the water applied at field capacity in transplanted basmati rice, while the slight reduction was noticed among all the soil parameters in respect of their initial values, but the order was $I_3>I_2>I_1$. All the physiological parameters were improved withwheat residues applied @ 5 t/ha followed by Pusa hydrogel @ 7.5 kg/ha, while the minimum values were recorded under control followed by seed inoculation with *Pseudomonas fluorescencs* (PF 2) @ 4g/kg.Moreover, the positive nutrients balance was also observed underwheat residues @ 5 t/ha during both the years of experimentation under sandy loam soil of western U.P.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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