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Water management for enhancing water use efficiency and weed control efficiency in different rice establishment methods in eastern Uttar Pradesh

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Abstract
To evaluate the suitable and promising irrigation management practices in different crop establishment methods, Field experiment was carried out Crop Research Station, (ANDUAT), Masodha, Ayodha. To assess the agronomic efficiency, plant water potential and water use efficiency under irrigation management practices along with Split plot design was adopted with 3 main plots of irrigation management {i1: Flooding throughout crop growth (3 +/- 2 cm), i2: Saturation maintenance up to PI and (3 +/- 2 cm) after PI and i3: Alternate wetting and drying (irrigation at 5-7 days interval with 5 cm/ha of water (5 cm irrigation at 3 DADPW) up to PI and (3 +/- 2 cm) after PI} and 6 subplots of crop establishment methods {T1: Mechanical Transplanting method on puddled soil (crop management methods same as for puddled transplanted rice), T2: Direct wet seeding on puddled soil (Use of Drum seeder/ dibbling of sprouted seed at 25 x 25 cm) fb crop management practices as per direct wet seeded rice, T3: Normal hand transplanting (20 x15 cm with flooding water management, 3-4 seedlings transplanted at 25-30 days old seedlings), T4: Aerobic rice T5: Direct broadcast dry seeding on well prepared unpuddled soil fb crop management practices for direct dry drill seeded rice and T6: Optional-Location specific} of three replication. The highest grain yield was recorded at saturation with use of drum seeder 5.44 t/ha, followed by transplanting 4.38 t/ha crop establishment. The different method of irrigation recorded maximum mean highest garin yield (3.98 t) followed by alternate waiting and drying.

Keywords: Management practices, different crop establishment methods, transplanting, flooding water

Introduction
Rice consumes around 4000-5000 litres of water to produce one kg grain, which is three times higher than other cereals. Rice is a semi- aquatic plant and the farmers are habituated to irrigate as much water as possible through continuous land submergence based on a wrong notion that yield could be increased with increased water use. Traditional rice production system not only leads to wastage of water but also causes environmental problems and reduces fertilizer use efficiency. The fact that rice is the only cereal which can grow in deep water does not necessarily mean rice plants must be grown only in ponded water. In India, rice occupies an area of 44 m ha with an average production of 90 m tonnes, with productivity of 2.0 tonnes/ha. Demand for rice is growing every year and it is estimated that in 2025 AD, the requirement would be 140 m tonnes. According to the projections made by the Population Foundation of India, India's population will be 1,546 million by the end of 2030. It is estimated that the demand for rice will be 121.2 m tonnes. In order to achieve this target, the productivity of rice has to be brought to the level of 3.3 tonnes/ha from present level of 2.2 tonnes/ha (Anjani *et al.*, 2014) [2]. Rice cultivation requires large quantity of water and for producing 1 kg rice, about 3,000–5,000 litres of water is required depending on the different rice cultivation methods such as transplanted rice. Due to increasing water scarcity, a shifting trend towards less-water demanding crops against rice is noticed in most parts of the India and this warrants alternate methods of rice cultivation that aims at minimal use of water and high crop productivity. There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by 2 to 3 fold compared to current yield levels

(Shantappa *et al*., 2014) [8]. Increasing water scarcity is becoming real threat to rice cultivation. Hence water-saving technology which also maintains soil health and sustainability as well as economically beneficial, needs to be developed. Water shortage is becoming severe in many rice growing areas in the world. Introduction of aerobic rice, growing high yielding rice in non-puddled and non-flooded aerobic soil with the support of external inputs like supplementary irrigation, manures and fertilizers; can reduce water use in rice production by as much as 50% (Bouman, 2005) [3, 10]. In aerobic rice, weeds cause yield loss to an extent of 50-100% (Mishra and Singh, 2007) [6]; they are the major hurdle for large scale adoption of aerobic rice.

Increasing water scarcity is becoming real threat to rice cultivation. Hence water-saving technology needs to be developed which not only economically beneficial but also maintains soil health. Any approach that would lessen the amount of water use without compromising the rice yield would certainly be a welcome strategy. Introduction of SRI is an alternative practice to solve water crisis, and as a methodology for increasing the productivity of irrigated rice. AWD is also called 'intermittent irrigation' or 'controlled irrigation 'which can reduce the water requirement by 30 % in irrigated rice system

Field experiments were initiated to study effect of different establishment methods, irrigation water levels and weed-management practices on growth and yield parameters of rice.

Materials and Methods

To evaluate the suitable and promising irrigation management practices in different crop establishment methods, Field experiment was carried out Crop Research Station, (ANDUAT), Masodha, Ayodha, which is situated at 26.47^{0}N (latitude), 82.12 ^{0}E (longitude) and at 113 m (altitude). Soil of the experimental field is sandy loam with pH 7.2, organic carbon 0.40%, Nitrogen 200 kg/ha, P2O5 24 kg/ha and K2O 234 kg/ha. To evaluate the suitable and promising irrigation management practices in different crop establishment methods. To assess the agronomic efficiency, plant water potential and water use efficiency under irrigation management practices in different crop establishment methods. The experiment laid out for split plot design, with three replication. NDR 2065 medium duration rice variety tested with plot size was 5 x 5 m^2 per plot of the experiment. The irrigation management methods as main plots (to make water management precise and easier) and crop establishment methods as sub plots.

Main plots

3 irrigation management practices Main plot treatments: I1 – Flooding through crop growth (3 +/- 2 cm) I2 - Saturation maintenance up to PI and (3 +/- 2 cm) after PI I3 – Alternate wetting and drying (AWD—flooding to a water depth of 5 cm when water level drops to 5 cm Below ground level from 15 DAT to PI- with the help of Boumans Water tube).

Sub plot treatments

Any 4-5: Methods of crop establishment suitable to that area Wet system: 1. Mechanical Transplanting method on puddled soil (crop management methods same as for puddled transplanted rice) 2. Direct wet seeding on puddled soil (Use of Drum seeder of sprouted seed at 25 x 25 cm) fb crop management practices as per direct wet seeded rice 3. Normal manual Transplanting (20 x 15 cm with flooding water management, 3-4 seedlings transplanted at 25-30 days old seedlings).

Identify a suitable plot with least interference of water seepage from adjoining rice fields as irrigation water input needs to be quantified. The selected plot should be made weed free following Stale Seed Bed Method i.e., spraying Glyphosate weedicide @ 0.75-1.00 kg a.i./ha 10 – 12 days prior to opening the fields, followed by ploughing once, allow germination of left over weed seed, and then prepare the field for sowing rice by shallow ploughing to fine tilth and levelling of the field. Chemical Weed control with recommended herbicides one pre emergence of pendamathlin @ 3 l/ha, application and one post emergence Nomini gold @ 0.250l/ha application.

Details of the plastic water tube-I3 (Bouman tube)

AWD is also called 'intermittent irrigation' or 'controlled irrigation' Alternate flooding, compared with the traditional continuous flooding system, AWD using lowland rice cultivars can reduce water input by 15-30% without yield loss.

Puddled rice situation: M1-Manual transplanting method 1

This method is practiced in areas of fertile soil, abundant rainfall and plentiful supply of labour. To begin with, seeds are sown in nursery and seedlings are prepared. After 4-5 weeks (better make it 3-4 weeks, younger seedlings are necessary for high yields) the seedlings are uprooted and planted in the field which has already been prepared for the purpose. The entire process is done by hand. It is, therefore, a very difficult method and requires heavy inputs. But at the same time it gives some of the highest yields. 2. Land preparation: Plow, harrow, puddle, and level the land; construct channels at regular intervals to facilitate easy drainage 3. Optimum sowing time: For TPR, complete the nursery sowing before the onset of heavy rains; early to mid-June for IGP 4. Seed preparation & sowing: pre-germinate the seeds by soaking for 24 h in water or 1% KCl solution and incubating for 24-36 h and then broadcast or drum-seed 5. Water management: Keep a water level of 2-3 cm for the first 10 days after transplanting (DAT) so as to make the transplanted seedlings recover fast from the transplanting shock and establish well. Then, follow AWD irrigation during vegetative phase (10-45 DAT); maintain 3-5 cm water level during reproductive phase (45-75 DAT); drain the field after physiological maturity (75-90 DAT); 30- 40% water saving from reduced deep drainage, seepage & runoff in transplanted rice, soil during plowing; apply 14-18 kg/ha P and first dose of 20 kg/ha K before last harrowing & leveling; apply 90-120 kg/ha N in 3 splits, 33% basal just before transplanting, 33% at tillering, and 33% at Panicle Initiation (PI).

M2-Mechanised transplanting methodology

Raising seedling for Tansplanter Trays (60cm x 28 cm) are filled with sieved soil (2.5 cm soil depth). Seeds are uniformly placed (100 g/tray) on soil, covered with thin soil layer and water through rose cans. Use 15 day old seedlings. Foliar spray of 2% nitrofoska (19:19:19) may be given.

M3-Wet direct seeded rice using drum seeders

With early seedling vigor, rapid growth, weedϖ suppressive ability – Seed qualityϖ & seed rate: High yielding fine grain variety 30- 40 kg/ha & coarse grain 45-60 kg/ha of clean, quality seed to ensure uniform germination & good crop stand (150-200 plants m2); high seed rates reduced weeds by 41-48%.

M4-Wet direct seeded rice by broadcasting
High yielding fine grain variety 30-40 kg/ha & coarse grain 45-60 kg/ha of clean, quality seed to ensure uniform germination & good crop stand (150-200 plants m-2); high seed rates reduced weeds by 41-48%.

M5-Optional treatment
Data collection
The following data were collected

- Grain yield and Straw Yield t/ha: Grain yield in kg obtained from each plot was converted to tonnes per hectare. Straw yield in kg obtained from each plot was converted to tonnes per hectare.
- Weed population at active tillering (no/m2): The average number of weed population tillers from one sqm randomly selected.
- Weed dry weight at active tillering (g/m2): The average g/m2 of weed population from one sqm randomly selected.
- Weed population panicle initiation (no/m2): The average number of weed population of the panicle initiation stage from one sqm randomly selected.
- Weed dry weight at panicle initiation (no/m2): The average gram of weed population of the panicle initiation stage from one sqm randomly selected.
- Plant height: Height of the plant in centimeter from the base of the main stem to the tip of the panicle was recorded as the average of five randomly selected plants.
- Number of tillers per m2: The average number of tillers from one sqm randomly selected plants was taken.
- Number of panicle per m2: The average number of fertile tillers from one sqm randomly selected plants was taken.
- Panicle weight (g): The average panicle weight (g) from 5 panicle randomly selected was taken.
- Test Weight (g): Test weight in grams obtained from 1000 seeds from each plots.

Data analysis
The data so obtain were subjected to statistical analysis after necessary transformation for final statistical analysis.

Results and Discussion
Grain yield
In a field experiment conducted by (Jadhav *et al*., 2003) [5] with upland rice cv. Sugandha revealed that irrigations scheduled at 1.8 and 1.2 IW/CPE ratios recorded significantly higher grain yield than the other irrigation at IW/CPE of 0.6. Rice crop irrigated at 1.2 IW/CPE ratio resulted in highest yield and maximum water use efficiency compared to other treatments (Singh *et al*., 2003) [4, 6, 9]. Aerobic rice yields were lower by an average of 28 per cent in the dry season and 20 per cent lower in wet season (Ambrocio *et al*., 2004) [10]. Yield is the complex character and it depends on many morphological and bio-chemical events that occur within plant during the crop growth and development. Optimization of the physical inputs through appropriate bio-hydrochemical technologies along with better crop-establishment techniques, proper water and weed-management practices can results better yields. The Data presented in table 1 and figure 1, revealed that The highest grain yield was recorded at saturation with use of drum seeder 5.44 t/ha followed by transplanting 4.38 t/ha crop establishment The different method of irrigation recorded maximum mean highest grain yield (3.98 t) followed by alternate waiting and drying, presented in table & figure 1.

Straw yield
Straw mulching helped conserve moisture in the soil profile reduced crack development during the fallow period but did not reduce the bypass loss during land preparation. Straw yield was significantly higher in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M2) of 14.67 t/ha.

Growth establishment methods

- **No of tiller/m2:** Significantly influenced the growth attributes such as plant height, number of tillers per square meter and panicle/m2 (Table 1 & figure 1). No of tiller/m^2 was significantly higher in, I 3- Alternate wetting and drying (M2) the mean was 293.75 (tillers/m^2).
- **No of panicle/m2:** No of panicle/m2 was significantly higher in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M2) the mean value of 273.50.
- **Panicle weight g/panicle:** Panicle weight g/panicle was significantly higher in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M1) the mean value of 3.71.
- **Test weight g:** Test weight g/1000 seeds was significantly higher in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M2) the mean value of 26.15.
- **Weeds:** Weed control efficiency in different rice establishment methods are presented in table & figure 2.
- **Weed population at active tillering (no/m2):** Weed population at active no./m2 was significantly lower in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M2) the mean value of 0.50 no.
- **Weed dry weight at active tillering (g/m2):** Weed dry weight at active g/m2 was significantly lower in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M2) the mean value of 0.48 g.
- **Weed population panicle initiation (no/m2):** Weed population at panicle initiation no./m2 was significantly lower in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M2) the mean value of 16.50 no.
- **Weed dry weight at panicle initiation (g/m2):** Weed dry weight at panicle initiation g/m2 was significantly lower in, I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI (M2) the mean value of 3.45 g. This is consistent with findings of previous studies in rice systems (Akter *et al*., 2017; Ganguly *et al*., 2015) [1, 4].

The differential trade-off among different rice establishment methods in U.P. indicated is direct seeding (use of Drum seeder/dibbling of sprouted seed at 25 x 25 cm) long with saturation maintenance up to PI and (3 +/- 2 cm) after PI resulted the highest grain yield (5.44 t/ha), the best performed has advantage. Among irrigation management treatments, saturation maintenance up to PI and (3 +/- 2 cm) after PI method resulted the highest grain yield (4.07 t/ha) than those of other treatments. Among establishment methods direct seeding (use of Drum seeder/dibbling of sprouted seed at 25 x 25 cm) fb crop management practices as per direct wet seeded rice resulted the highest yield (4.65 t/ha).

Table 1: Evaluation of water management for enhancing water use efficiency and weed control efficiency in different rice establishment methods (Yield and yield attributing character)

Treatment							
Main plot irrigation management practices	**Crop establishment methods**	**Grain yield (t/ha)**	**Straw yield (t/ha)**	**Tillers/m2 (No.)**	**Panicle/m2 (No.)**	**Panicle wt (g)**	**Test wt (g)**
I 1- Flooding throughout crop growth (3 +/- 2cm)	M1	3.73	12.13	206	180	3.39	24.95
	M2	4.24	11.77	267	212	3.46	25.40
	M3	2.53	7.96	205	162	3.69	24.45
	M4	2.23	7.13	201	133	3.46	24.60
	M5	2.68	8.70	178	118	3.26	24.72
I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI	M1	4.38	13.82	199	180	3.71	25.25
	M2	5.44	14.67	298	274	3.38	26.15
	M3	3.62	11.48	213	171	3.63	25.35
	M4	3.40	10.52	227	165	3.46	25.40
	M5	3.54	11.14	207	143	3.49	25.02
I 3- Alternate wetting and drying	M1	4.27	12.90	225	178	3.57	24.33
	M2	4.26	13.42	294	210	3.53	24.97
	M3	2.92	9.10	198	175	3.16	24.13
	M4	3.68	9.26	208	139	3.56	24.17
	M5	3.79	10.44	185	140	3.36	24.40
Interaction	I and M	0.26	NS	16.47	12.29	NS	NS
	M and I	0.29	NS	16.58	11.96	NS	NS
Mean of Irrigation	l1	3.08	9.53	216	161	3.45	24.42
	l2	4.07	12.33	229	186	3.53	25.44
	l3	3.79	11.02	222	168	3.44	34.40
C.D. (0.05)		0.22	0.39	9.81	6.04	NS	NS
C.V. (%)		7.73	4.59	5.71	4.54	6.27	90.56
Method of Methods	M1	4.12	12.96	211	179	3.56	24.84
	M2	4.65	13.29	293	232	3.46	24.17
	M3	3.02	9.51	205	169	3.50	24.64
	M4	3.10	8.97	212	146	3.49	24.72
	M5	3.33	10.09	190	133	3.37	24.72
C.D. (0.05)		0.15	0.60	9.51	7.10	NS	NS
C.V. (%)		5.05	6.60	5.19	5.01	8.14	91.75
Experimental Mean		3.65	10.96	222	172	3.47	28.22

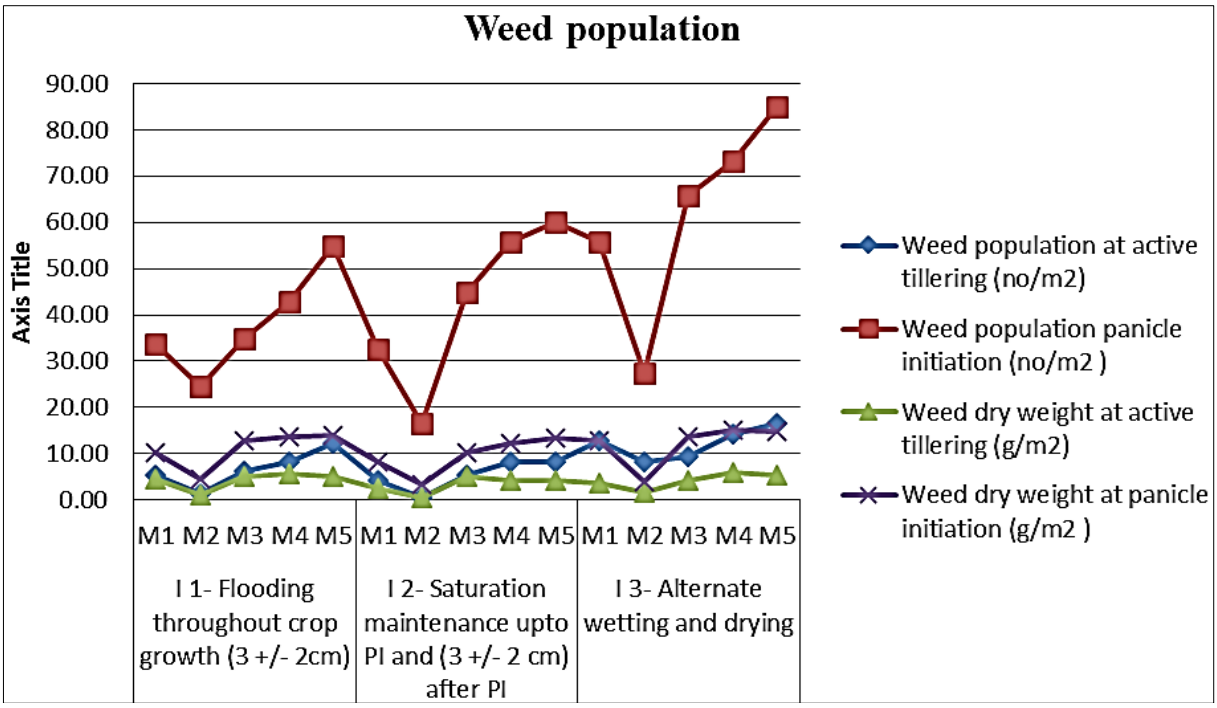

Fig 1: Evaluation of water management for enhancing water use efficiency and weed control efficiency in different rice establishment methods (Yield and yield attributing character)

Table 2: Evaluation of water management for enhancing water use efficiency and weed control efficiency in different rice establishment methods (Weed population)

Treatment					
Main plot irrigation management practices	**Crop establishment methods**	**Weed population at active tillering (no/m2)**	**Weed population panicle initiation (no/m2)**	**Weed dry weight at active tillering (g/m2)**	**Weed dry weight at panicle initiation (g/m2)**
I 1- Flooding throughout crop growth (3 +/- 2cm)	M1	5.25 (2.39)	33.75 (5.85)	4.38	10.10
	M2	1.50 (1.40)	24.50 (4.99)	1.17	4.65
	M3	6.25 (2.59)	35.00 (4.95)	5.22	12.75
	M4	8.25 (2.96)	42.75 (6.57)	5.63	13.55
	M5	12.25 (3.56)	55.00 (7.43)	5.02	14.10
I 2- Saturation maintenance up to PI and (3 +/- 2 cm) after PI	M1	4.25 (2.17)	32.50 (5.60)	2.57	8.23
	M2	0.50 (0.97)	16.50 (4.12)	0.47	3.45
	M3	5.50 (2.44)	45.00 (6.74)	5.02	10.30
	M4	8.25 (2.95)	55.75 (7.50)	4.25	12.20
	M5	8.25 (2.95)	60.00 (7.77)	4.10	13.32
I 3- Alternate wetting and drying	M1	12.75 (3.63)	55.75 (7.50)	3.73	12.80
	M2	8.25 (2.95)	27.50 (5.26)	1.70	3.88
	M3	9.50 (3.15)	65.75 (8.14)	4.13	13.77
	M4	14.25 (3.84)	73.25 (8.58)	5.85	15.10
	M5	16.50 (4.12)	85.00 (9.24)	5.47	14.92
Interaction	I and M	0.26	0.72	NS	NS
	M and I	0.27	0.73	NS	NS
Mean of Irrigation	l1	6.70 (2.58)	38.20 (6.16)	4.28	11.03
	l2	5.35 (2.29)	41.95 (6.35)	3.28	9.50
	l3	12.25 (3.54)	61.45 (7.74)	4.18	12.09
C.D. (0.05)		0.17	0.46	NS	0.75
C.V. (%)		7.80	8.77	40.34	8.88
Method of Methods	M1	7.42 (2.73)	40.67 (6.32)	3.56	10.38
	M2	3.42 (1.77)	22.83 (4.79)	1.12	3.99
	M3	7.08 (2.73)	48.58 (6.94)	4.79	12.27
	M4	10.25 (3.25)	57.25 (7.55)	5.24	13.62
	M5	12.33 (3.54)	66.67 (8.15)	4.87	14.12
C.D. (0.05)		0.15	0.14	0.74	0.93
C.V. (%)		6.49	7.43	22.91	10.35
Experimental Mean		2.80	6.75	3.92	10.88

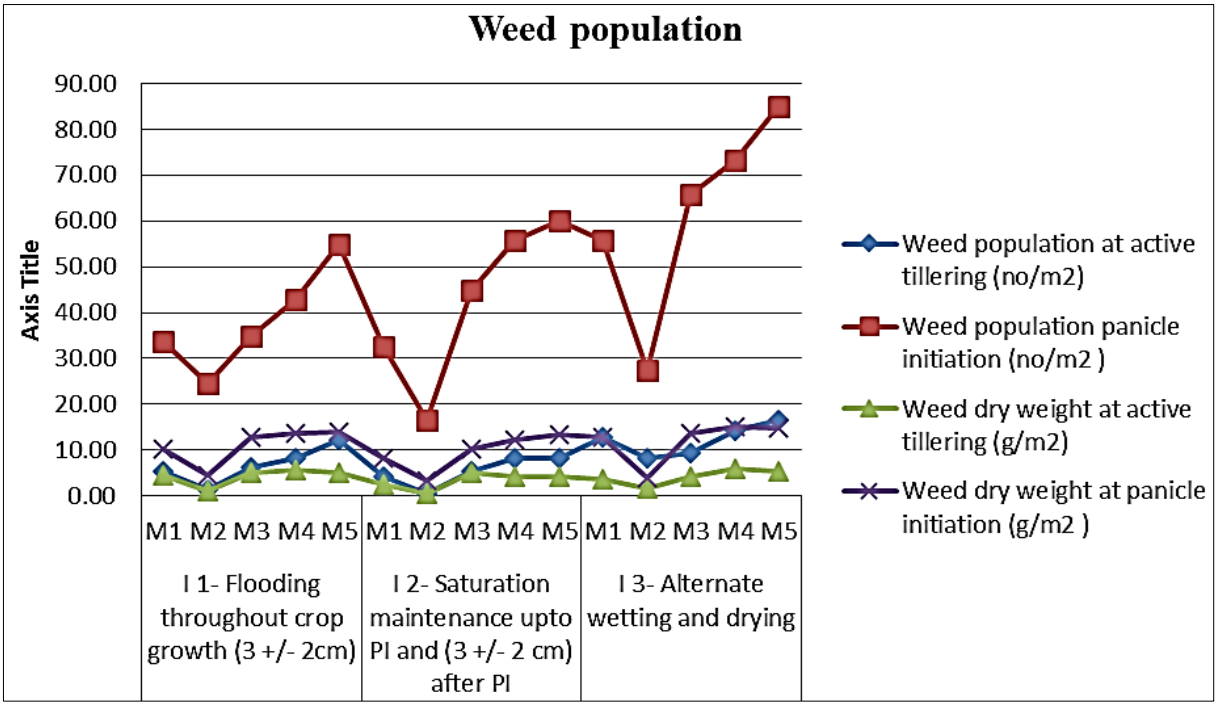

Fig 2: Evaluation of water management for enhancing water use efficiency and weed control efficiency in different rice establishment methods (Weed population)

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