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Alternate wetting and drying (Pani Pipe) irrigation (AWDI) and green manuring technique for sustainable rice production

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ABSTRACT

A study was conducted in Karaipottanar sub-basin area of Namakkal district of Tamil Nadu in rice crop in 35.0 ha (25 demonstrations). The results showed that the adoption of alternate wetting and drying irrigation (AWDI) and green manure technique resulted in higher grain yield as compared to farmers' practice. The net return (Rs 39,208.30/ha) and B-C ratio (2.10) were observed in demonstration plots which were higher than farmers' practice (Rs 28,569.40/ha and 1.74 respectively). The water productivity was higher (5.14 kg/m^3) in demonstration plots as compared to the control plots (3.37 kg/m^3) and the average water saving was 26 per cent in demonstration plots. The green manure application resulted in increased available nutrients like organic carbon, nitrogen, phosphorus and potassium content in the soil. From this study it was concluded that AWDI with field water tube was the better water management technique not only in increasing rice yield but also in saving water.

Keywords: Rice; AWDI; Pani Pipe; green manure; water saving; yield; soil nutrients

INTRODUCTION

Rice is one of the most important staple foods for more than half of the world's population particularly in Asia. India is the largest producer of rice after China. India produced 130.29 MT rice in an area of 46.38 million hectares with a productivity of 280.9 tonnes per ha (Anon 2022). The production of rice must increase with the ever-increasing need for food of the growing population. The increasing demand and production of rice grain has to be achieved by using an intensive approach, like improved rice varieties, best agronomic management practices, improved nutrient management practices, better plant protection measures etc.

Water is a key driver of agricultural production and is considered as most precious input in rice cultivation. About sixty per cent of the rice cultivated areas in India are irrigated and more than fifty per cent of the total water in irrigation is used in rice cultivation. Because rice is the largest user of water, water is the single most important component for sustainable rice production (Surendran et al 2021). It is very important to utilize irrigation water wisely and efficiently to achieve rice production. Alternate wetting and drying irrigation (AWDI) with field water tube is one of the best water management technologies developed by International Rice Research Institute for irrigated lowland rice where rice fields are not kept continuously submerged but are allowed to dry intermittently during growing stages that saves water and reduces greenhouse gases (GHG) emissions, number of irrigations and pests and diseases while maintaining yields (Ayyadurai et al 2020, Hiya et al 2020).

Sustaining soil and crop productivity is a challenging issue due to depletion of organic carbon matter (OCM), deficiency of macro as well as micronutrients under intensive agriculture. Since the nutrient supply in soil to the plant system plays a vital role in intensive rice cultivation, neither the chemical fertilizers nor the organic manures alone can help achieve sustainable food production. Fertilizer application is believed to have been responsible for at least 50 per cent increase in crop yield in the 20th century (Yousaf et al 2017). On account of the continuous world energy crisis with increasing prices of chemical fertilizers, the use of organic manures as renewable sources of plant nutrients is gaining importance. Therefore, more efforts are needed to identify an improved nutrient management strategy for a particular target ecosystem. Green manuring is the process of turning green plants into the soil either by raising them in the same field or in plants grown elsewhere at the green stage before flowering and being incorporated into the soil. It is a good management practice in agricultural production, because it can improve soil fertility and quality (Lee et al 2010) and also supply N, a primary limiting nutrient for crops (Pypers et al 2005). In this context, KVK, Tiruchirappalli, Tamil Nadu demonstrated the importance of water management through AWDI technique with green manure incorporation in combination with rice cultivation in Namakkal region of Tamil Nadu to create awareness among the farming community to achieve increased rice production through efficient utilization of water and effective cultivation through integrated nutrient management.

MATERIAL and METHODS

The study was conducted at Singalakombai, Pallipalayam and Periyakombai of Erumaipatti block in Karaipottanar sub-basin area of Namakkal district of Tamil Nadu (Fig 1) under Tamil Nadu Irrigated Agriculture Modernization Project sanctioned during 2020-21 in rice crop in 35.0 ha (25 demonstrations). The Cauvery main river is one of the perennial rivers of Tamil Nadu. Karaipottanar, also called as Karuvettar, is one part of Cauvery basin (Fig 2). Karuvattar river originates from Koli hills in the northern part of Namakkal district. The total length of Karaipottanar river is about 54 km. In this sub-basin, there are 28 tanks and 54 anicuts with a total ayacut of 4,055.87 ha. The sub-basin receives rain mainly in southwest monsoon period with average annual rainfall of 401.50 mm.

Details of green manure-AWDI (Pani Pipe) technique adopted

The green manure crop Dhaincha (*Sesbania aculeata*) was grown in main field and incorporated into the soil at 50 per cent flowering stage. Alternate wetting and drying irrigation (AWDI) was completely based on the depletion of water level below the surface. For adopting AWDI, three field water tube Pani Pipes were used, which were made of 40 cm long plastic pipe having a diameter of 15 cm, perforated with holes on all sides. The tube was dug in the soil such that 15 cm part of it protruded above the soil surface and the soil from inside was removed so that the bottom of the tube was visible. The water table inside the tube was kept the same as outside the tube. Continuous observations were made and depth of water level inside PVC pipe was measured. When it reached below 15 cm, the field was irrigated up to the height of 5 cm above ground level.

The data on number of irrigations, growth and yield parameters of paddy were collected for interpretation. The benefit-cost ratio (BCR) was calculated by finding the ratio between the gross return and gross cost of production as given below:

$$\text{BCR} = \frac{\text{Gross return}}{\text{Gross cost of production}}$$

Water productivity was calculated by using the following formula:

$$\text{Water productivity} = \frac{\text{Grain yield (kg)}}{\text{Quantity of water used for irrigation (mm)}}$$

RESULTS and DISCUSSION

Climate variations

Data given in Table 1 show that minimum and maximum sunshine in 2019, 2020 and 2021 was 360.1 cal/cm^2 (December) and 657.2 cal/cm^2 (April), 311.8 cal/cm^2 (December) and 638.0 cal/cm^2 (April) and 306.8 cal/cm^2 (January) and 657.2 cal/cm^2 (April) respectively. The maximum temperature in 2019, 2020 and 2021 was 39.0°C (May), 41.1°C (May) and 39.0°C (May) respectively, whereas, the minimum was 18.8°C (January), 19.4°C (February) and 21.7°C (February) respectively. Minimum and maximum relative humidity in 2019, 2020 and 2021 was 55.7 per cent (July) and 80.1 per cent (October),

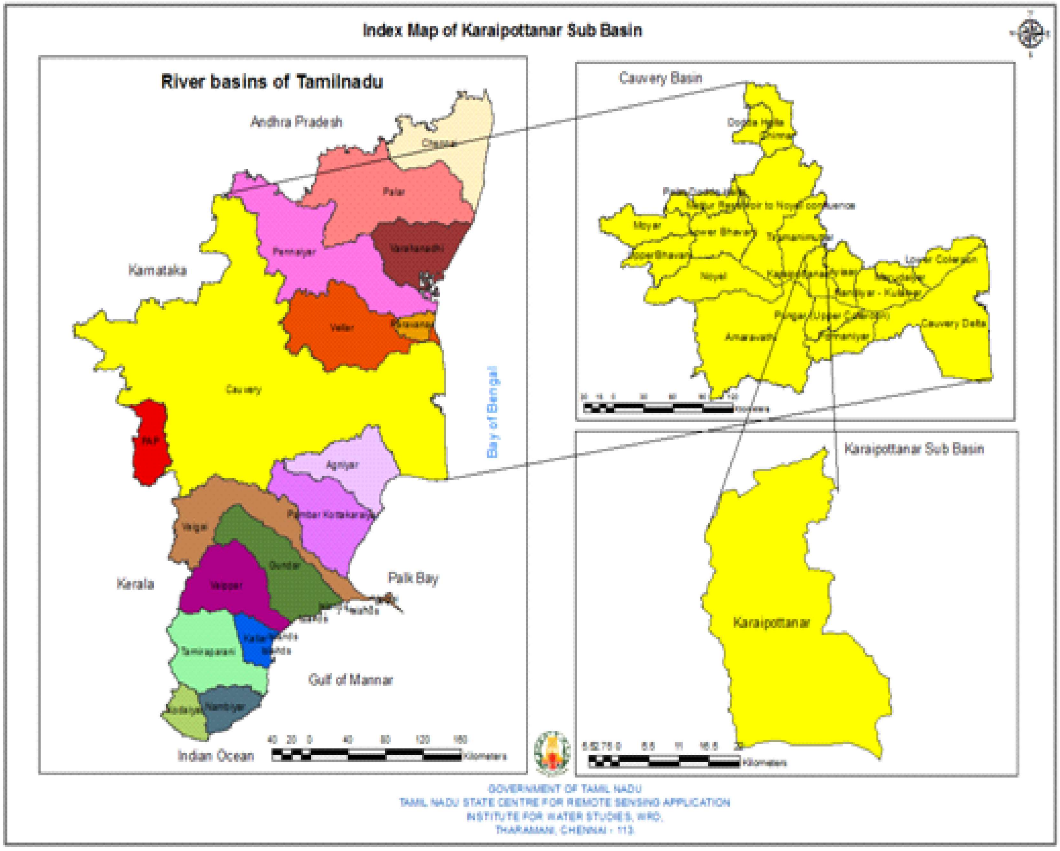

Fig 1. Index map of Karaipottanar sub-basin

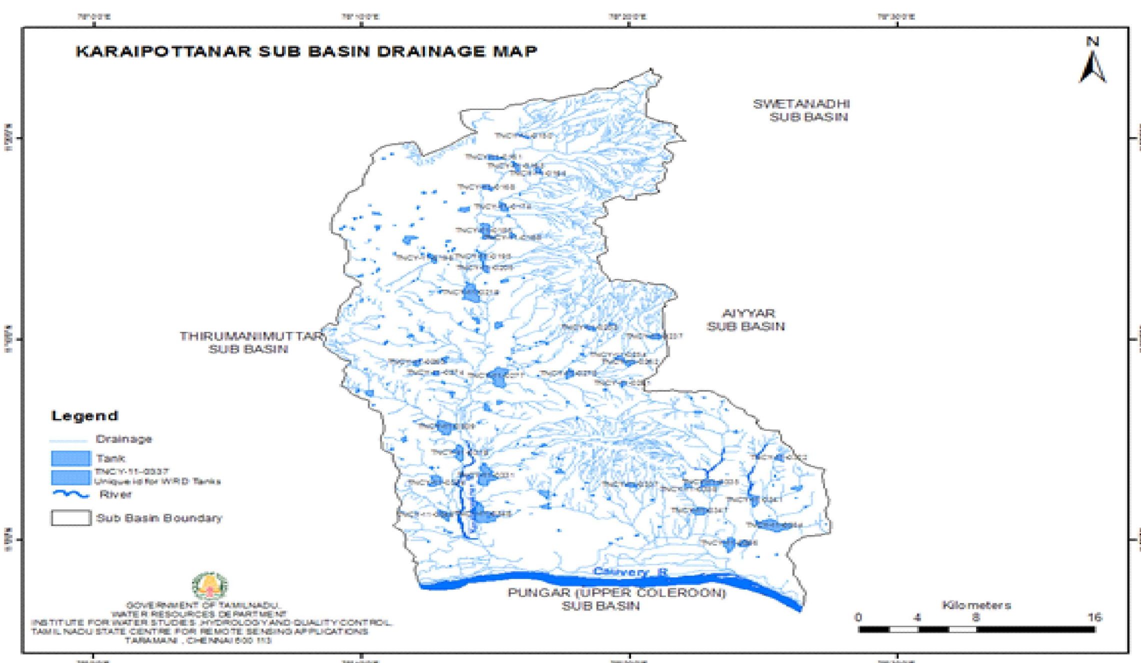

Fig 2. Karaipottanar sub-basin drainage map

56.4 per cent (June) and 84.6 per cent (December) and 56.0 per cent (June) and 85.6 per cent (January) respectively. Minimum and maximum wind speed in 2019, 2020 and 2021 was 3.9 kmph (January) and 10.9 kmph (August), 3.2 kmph (December) and 10.2 kmph (August) and 3.5 kmph (January) and 11.1 kmph (July) respectively. In 2019, there was no rain from January to April and maximum 5.0 mm in September. In 2020, there was no rain in January and February and 5.4 mm in September. In 2021, no rain was observed in February and March, whereas maximum 10.8 mm was observed in November.

Effect of green manure – AWDI (Pani Pipe) techniques on growth, yield and economics of rice

The results show that the adoption of AWDI and green manure techniques resulted in higher grain yield as compared to farmers' practice. The grain yield (48.90 q/ha) increased substantially in demonstration plots compared to control plots (43.90 q/ha) (Table 2).

The increase in grain yield might be due to increased available soil nutrients and the overall positive effect of adoption of AWDI and green manure on soil health and the ecosystem in and around the rhizosphere of the crop. Adoption of the AWDI and green manuring improved vegetative growth, number of productive tillers and number of grains per panicle which in turn favourably influenced the grain yield.

Suryavanshi and Singh (2019) and Sarwar et al (2017) also expressed that the addition of green manure was associated with enhancement in nutrient availability after decomposition and improvement in soil structure, leaving more air into the soil and improving drainage, thus finally improving the water holding capacity of soil that favoured the grain and straw yield. Adoption of AWDI influenced the depth of rice roots that absorbed more nutrients from different soil layers which ultimately produced more tillers and thus the yield of rice.

Similar observations were made by Hiya et al (2020) through the adoption of AWDI. Similar results were obtained by Yang et al (2016).

The net return of Rs 39,208.30 per ha was observed in demonstration plots which was higher than farmers' practice (Rs 28,569.40/ha). The B-C ratio was higher (2.10) in demonstration plots as compared to farmers' practice (1.74). The increase in net return and B-C ratio could be due to the higher grain yield of rice in demonstration plots. From the present investigations, it was concluded that adoption of green manure and AWDI resulted in improvement in physiological traits, productivity and the profitability of rice.

Effect of green manure-AWDI (Pani Pipe) technique on water productivity and water saving

Production of any crop highly depends on soil health and fertility. The positive impact of AWDI and green manure application on water productivity and water saving is shown in Table 2 (Fig 3). The results showed that the adoption of AWDI and green manure technique positively increased water productivity as compared to farmers' practice. In demonstration plots, the water productivity was higher (5.14 kg/m^3) as compared to the control plots (3.37 kg/m^3) and the average water saving was 26 per cent in demonstration plots.

Effect of green manure-AWDI (Pani Pipe) technique on soil fertility

The green manure application resulted in increased available nutrients like organic carbon, nitrogen, phosphorus and potassium content in the soil (Table 3).

There was an increase of 0.03 per cent of organic carbon, 33.0 per cent available nitrogen, 2.1 per cent available phosphorus and 20.0 per cent available potassium in the soil. However, pH and EC got decreased by 0.1 and 0.14 per cent respectively. Increased levels of organic carbon might be due to the organic materials added through incorporation and decomposition of green manure. Similarly, increased nitrogen could be due to the build-up of nitrogen by nitrogen-fixing bacteria present in the root nodules.

van Noordwijk et al (2015) observed that green manure application added N in soil profile, which might be due to the uptake of N from deep soil profile to top soil due to its downward root growth. Similar trends by the application of green manure on enrichment of available nutrients in soil were observed by Xie et al (2017), Adekiya et al (2019) and Lu et al (2011).

Decreased levels of pH and EC could be due to organic acid production as well as the partial pressure of CO_2 released during decomposition of green manure. Addition of organic matter through green manure favourably helped in the mineralization of soil nitrogen, leading to buildup of higher availability of N.

Similarly, an increased level of available phosphorus could be possibly ascribed to the organic acids produced during decomposition of green manure which would have reduced the activity of chelation and reduced P fixation of applied P.

Table 1. Month-wise meteorological parameters recorded during the study

Month	Sunshine (cal/cm^2)	T_{max} (°C)	T_{min}(°C)	RH (%)	Wind speed (kmph)	Rainfall (mm)
Jan'19	531.7	30.9	18.8	71.9	3.9	0.0
Feb'19	577.4	33.8	21.7	69.4	4.9	0.0
Mar'19	643.7	36.0	22.1	63.2	4.3	0.0
Apr'19	657.2	37.9	24.8	60.4	4.3	0.0
May'19	644.7	39.0	29.2	57.4	6.7	0.5
Jun'19	611.2	37.4	27.6	56.0	10.1	0.2
Jul'19	569.1	36.2	26.7	55.7	10.8	0.7
Aug'19	512.7	35.2	26.4	60.0	10.9	0.9
Sep'19	540.8	34.6	25.7	70.9	8.1	5.0
Oct'19	481.9	34.1	24.9	80.1	4.0	3.9
Nov'19	431.8	36.4	23.7	76.4	4.1	2.5
Dec'19	360.1	32.7	22.0	78.8	4.6	2.5
Jan'20	490.5	34.0	21.5	73.2	4.1	0.0
Feb'20	541.7	39.5	19.4	66.3	4.9	0.0
Mar'20	613.1	40.2	22.5	64.6	4.9	0.3
Apr'20	638.0	38.7	24.6	63.6	4.4	1.7
May'20	592.0	41.1	26.0	59.6	5.6	0.5
Jun'20	580.3	38.5	26.7	56.4	8.8	0.8
Jul'20	532.5	36.2	25.3	63.5	7.2	1.0
Aug'20	547.1	36.5	25.4	62.0	10.2	2.7
Sep'20	503.2	35.1	24.9	69.1	7.5	5.4
Oct'20	504.8	35.6	24.7	68.1	6.4	3.0
Nov'20	397.2	31.6	23.7	81.5	3.4	3.3
Dec'20	311.8	29.3	22.0	84.6	3.2	2.9
Jan'21	306.8	29.8	22.2	85.6	3.5	3.0
Feb'21	577.4	33.8	21.7	69.4	4.9	0.0
Mar'21	643.7	36.0	22.1	63.2	4.3	0.0
Apr'21	657.2	37.8	24.8	60.4	4.3	0.1
May'21	644.7	39.0	27.6	57.4	6.7	0.3
Jun'21	611.2	37.4	27.6	56.0	10.1	1.1
Jul'21	577.7	36.2	26.6	56.3	11.1	1.9
Aug'21	523.8	34.2	25.5	68.4	8.2	2.6
Sep'21	544.8	34.2	25.1	70.9	7.4	4.0
Oct'21	481.9	33.3	24.6	82.9	5.4	6.6
Nov'21	431.8	36.4	23.7	76.4	4.1	10.8
Dec'21	408.8	30.0	21.9	84.9	3.8	1.7

Table 2. Effect of green manure-AWDI (Pani Pipe) technique on growth, yield and economics of rice

Component	Farmer' practice	Demonstration plots
Plant height (cm)	112.8	118.8
Root volume (cc)	106.5	112.9
Number of productive tillers	19.6	22.1
Number of filled grains/panicle	120.8	132.5
Grain yield (q/ha)	43.90	48.90
Straw yield (tonnes/ha)	76.90	78.70
Net income (Rs/ha)	28,569.40	39,208.30
B-C ratio	1.74	2.10
Water productivity (kg/m^3)	3.37	5.14
Water saving (%)	-	26

Table 3. Effect of green manure-AWDI (Pani Pipe) technique on soil fertility

Soil property	Initial value	Farmers' practice	Demonstration plots	Per cent difference
Organic carbon	0.44	0.44	0.47	0.03
pH	7.8	7.9	7.7	– 0.1
EC	1.87	1.86	1.73	– 0.14
Available nitrogen	275	289	308	33.0
Available phosphorus	7.2	8.5	9.3	2.1
Available potassium	419	425	439	20.0

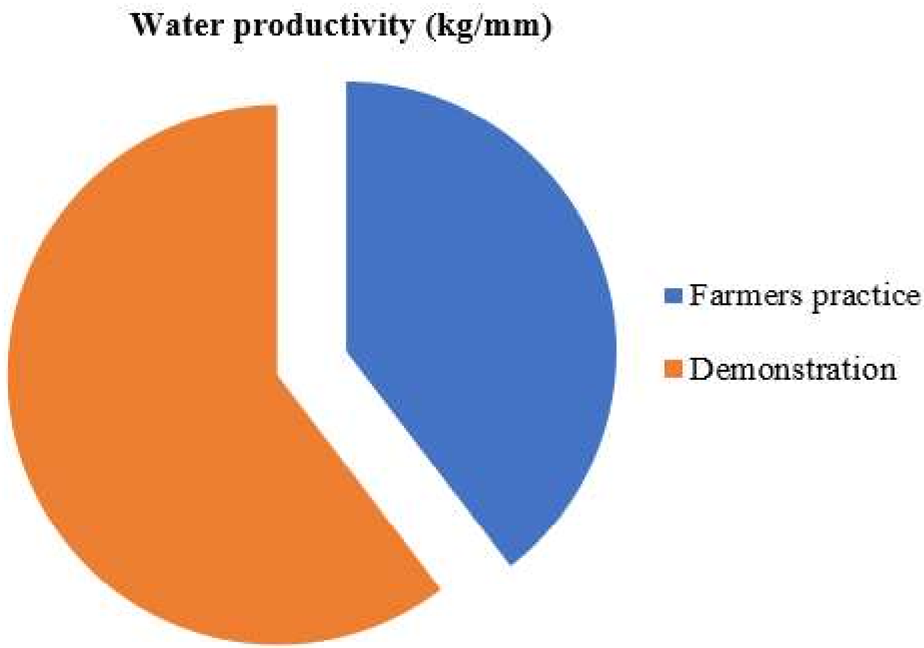

Fig 3. Effect of green manure-AWDI (Pani Pipe) technique on water productivity

CONCLUSION

Alternate wetting and drying irrigation (AWDI) with Pani Pipe is the best water-saving technology for increasing rice yield and also for saving water in paddy growing areas; adopting of this technology can reduce the number of irrigations and increase the area under rice.

Green manures play an important role in sustainable rice production by improving soil nutrient status and indirectly helping in saving water through moisture retention in the soil. The alternate wetting and drying irrigation (AWDI) with Pani Pipe and green manure increases yield of rice, reduces irrigation water requirement and increases soil fertility. Farmers can reduce their irrigation water consumption in rice fields without decreasing its yield.

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