Oryza Vol. 55 No. 1, 2018 (179-184)
DOI 10.5958/2249-5266.2018.00021.8

Effect of fertilizer levels and supplementary irrigation on late maturing transplanted paddy under rainfed medium land situations

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Received : 15 November 2016 Accepted : 18 March 2018 Published : 21 March 2018

ABSTRACT

A field experiment was conducted at the Research Farm of Indian Institute of Water Management (IIWM), Bhubaneswar in the kharif season for two years (2012 and 2013) to study the effect of supplementary irrigation and fertilizer levels on long duration paddy variety 'Swarna' grown in a medium land having dyke height of 20 cm around the plots. Dry spells of 18 to 21 days duration occurred at panicle initiation and flowering stage in the first year, and at active tillering and panicle initiation stage in the second year. The results revealed that as compared to the rainfed situation, two supplementary irrigations (5 cm each using flexi pipe) during the dry spells (at active tillering, panicle initiation and flowering stages) improved rice grain and straw yield by 15.7% and 10.3%, respectively. Recommended fertilizer dose (80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}) increased rice grain and straw yields by 18.2% and 16.1%, respectively, as compared to the 60% of the recommended dose.

Key words: *Rainfed paddy, dry spell, supplementary irrigation, yield attributes, crop growth attributes*

INTRODUCTION

Eastern India receives an average annual rainfall of about 1500 mm which is quite adequate for successful crop production of wet season rice. However, wide variation regarding distribution of rainfall often results in periods of dry spell or excess rainfall (Subash, 2014). This aberration is more pronounced in recent years, possibly due to climate change effects. Rice is sensitive to water deficit stress at different growth stages (Kumar et al., 2016, 2017); water deficit stress at early stage may reduce vegetative growth, and at reproductive stage may directly affect the crop yield and its attributes. However, rice crop is most sensitive to water deficit during the reproductive stage (Pawar and Dongarwar, 2007). Transplanting as the method of crop establishment is often practiced under the topographically medium lands with favourable water regimes. In uplands and medium lands, weeds are severe biological constraints for growth and yield of rice. Puddling is mostly done in medium lands for controlling the weed flora, minimizing the percolation loss of water and associated nutrients, easy stand establishment, and high yield. However, transplanted rice is very prone to drought stress due to limited root proliferation within the puddled soil. Mid and late maturing rice varieties are usually grown under such conditions to get high yield. However, dry spell often coincides with the reproductive phase (Singh et al., 2010), especially, in late maturing rice varieties. Even mid or early maturing varieties encounter such stress under late planted conditions. The problem of yield reduction in paddy due to dry spell is overcome by providing supplementary irrigation(s) during this period (Pawar and Dongarwar, 2007). One supplementary irrigation of 6 cm depth improved rice yield in wet season in Bangladesh by 58% (Islam et al., 1991). Education of the farmer for adopting modern scientific cropping sequence (Roy et al., 2011) and supplementary irrigation provided during the water-stress days were identified as the factors which could enhance the technical efficiency of paddy production (Suresh and Reddy, 2006). Crops receiving balanced fertilizers can better overcome the adverse soil physical conditions including deficit moisture (Tisdale et al., 1985; Rautaray, 2002). Imbalanced use of chemical fertilizers has led to sharp decline not only in the crop yield but also in soil organic carbon content (Nayak et al., 2012). A crop could recover fast from drought when fertilized with nitrogen as it ensures deep root system reaching the sub-surface stored soil moisture (Vittal et al., 2005). Keeping these points in view, effects of graded doses of fertilizer and number of protective irrigations during dry spell was evaluated on growth and yield of rainfed rice.

MATERIALS AND METHODS

A field experiment was conducted at the Research Farm of Indian Institute of Water Management, Mendhasal for two years during wet seasons (*kharif*) of 2012 and 2013 to find out the effect of fertility level and supplementary irrigation on paddy yield attributes and yield. The soil of the experimental field was Aeric Haplaquepts with sandy clay loam in texture (61% sand, 17% silt, and 22% clay), pH (5.4), organic carbon (0.52), available N (224 kg ha^{-1}), P_2O_5 (20.4 kg ha^{-1}) and K_2O (250 kg ha^{-1}). The experiment was laid out in split plot design with supplementary irrigation schedules in the main plot and fertilizer doses in the sub-plot. The main plot treatments were rainfed paddy (I_1), rainfed paddy with one supplementary irrigation (I_2) and rainfed paddy with two supplementary irrigations (I_3). The fertilizer levels were 100% of the recommended dose at 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} (F_1), 80% of recommended dose (F_2), and 60% of recommended dose (F_3). The fertilizers were applied in the form of DAP, urea and MOP. The full dose of P and K and 50% of N were applied as basal at the last ploughing. The remaining N was applied in two equal splits at tillering and panicle initiation stage of the crop. A bund height of 20 cm was maintained around each sub-plot using puddled soil for in-situ water harvesting. Daily rainfall was recorded using raingauge in the meteorological observatory at IIWM research farm. Measuring scales were fixed in each plot for recording ponding water depth in different treatments during crop growth period.

Late maturing (150 days) rice variety Swarna with high yield potential was used for this experiment under moderately delayed planting with the anticipation that it may encounter soil moisture deficit needing supplemental irrigation. The experiment was conducted in a medium land with the history of rice-groundnut cropping system. The crop was established under the transplantation method. The dates of transplanting were 28th and 25th July for the first and second year, respectively. Supplementary irrigation of 5 cm depth each was applied using flexi pipe during dry spell. In the first year, the irrigation treatment I_2 was provided irrigation on 25th September 2012. The I_3 was provided the first irrigation on 25th September and the second one on 20th October. In the second year, I2 received irrigation on 17th August 2013. The I3 received first irrigation on 17th August and the second one on 12th September.

Grain and straw yield (t ha^{-1}) of rice along with other yield attributing characters *viz.,* plant height (cm), tillers hill^{-1}, days to 50% flowering, panicles m^{-2}, grains panicle^{-1}, 1000 grain weight (g) were recorded as per the standard procedure (Kumar et al., 2017). Leaf area index was measured using LI-3000C leaf area meter at heading stage to know the highest value. The chlorophyll meter (SPAD 502) was used for measuring the SPAD value at heading stage using the youngest fully developed leaf at midway between the leaf base and tip. The grain and straw were sun-dried and subsequently, yields were recorded at 14% and 10% moisture, respectively. However, the biomass yield was obtained after oven drying at 70^{0}C to constant weight (Kumar et al., 2016, 2017). The data related to growth and yield parameters were analyzed applying analysis of variance. Significance of treatments was tested by F-test (Gomez and Gomez, 1984) and the Least Significant Difference (LSD) was calculated at 5% probability.

RESULTS AND DISCISSION

Dry spell occurrence and water regime

The analysis of dry spell occurrence showed that in the year 2012, a dry spell of 21 days duration occurred between 10th September to 30th September with a rainfall of 3.1 mm only on 20th September. The second dry spell of another 21 days duration occurred during the period 11th October to 31st October. Incidentally, the dry spells coincided with the panicle initiation and flowering stage of the crop. In the year 2013, one dry spell of 19 days duration occurred at the beginning stage of the experiment *i.e.,* 30th July to 17th August. The

Table 1. Crop growth attributes of rice as influenced by fertilizer dose and irrigation (Mean of 2012 and 2013).

	Plant height (cm)	Tillers hill^{-1}	Leaf area index	SPAD value	Days to 50% flowering	Biomass yield (t ha^{-1})
% of recommended fertilizer dose						
100%	83.7	11.41	5.1	42.3	85.1	10.30
80%	82.7	11.22	4.9	41.6	83.8	9.54
60%	81.1	10.68	4.6	39.8	81.2	8.73
CD *(p=0.05)*	0.9	0.67	0.29	1.3	1.8	0.33
Irrigation schedule						
Rainfed	81.3	8.40	4.1	38.2	80.4	8.89
1 irrigation*	82.4	9.37	4.5	40.5	82.7	9.50
2 irrigations**	83.7	10.09	4.7	41.9	83.8	10.16
CD *(p=0.05)*	1.3	0.64	0.25	1.1	2.1	0.29

* One irrigation was provided at panicle initiation stage and active tillering stage for first and second year, respectively.
**First irrigation was provided at panicle initiation and active tillering stage for first and second year, respectively. Second irrigation was provided at flowering and panicle initiation stage for first and second year, respectively.

second dry spell of 18 days duration occurred during the period 30th August to 16th September. In this year, the dry spells coincided with active tillering and panicle initiation stage of the crop. It is noteworthy to mention that the supplemental irrigations were applied during the dry spells in respective years.

Fig. 1 and Fig. 2 show the average ponding depth in different irrigation treatments along with weekly rainfall and irrigation in the years 2012 and 2013, respectively. The rainfall amounts in the figure indicate the weekly rainfall in the preceding week of the date of recording of the ponding depth. The rainfall values indicate that in the year 2012, good rainfall occurred in the initial stages of the cropping period and dry spells occurred towards the latter period. On the contrary in the year 2013, dry spells occurred in the initial stages of the cropping period and sufficient rainfall was received in latter stage. The maximum ponding depth in any irrigation treatment was as high as 170 mm in the year 2012 and 195 mm in the year 2013. Thus, a dyke height of 20 cm was sufficient to harvest in-situ rain water. Higher ponding depths were associated with higher rainfall events. However, there was not much difference in the ponding depth in different treatments except at the time of irrigation events. As the irrigation was applied during the dry spells, the supplementary irrigations resulted in higher ponding depth in comparison to no irrigation treatments.

Effect of fertilizer dose and supplementary irrigation on crop growth

Plant height and tillers hill^{-1} recorded at maturity stage, and leaf area index and SPAD (Soil-Plant Analyses Development) value recorded at heading stage were similar under 80% and 100% of the recommended fertilizer dose *viz.,* 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} (Table 1). The cropping history of the experimental field was rice-groundnut system. Groundnut being a legume crop might have beneficial effect on residual fertility and soil health. Thus, a lower fertilizer dose by 20% did not adversely affect these plant growth parameters. However, further reduction in fertilizer dose to 60% of the recommended dose resulted in reduced plant height, tillers, leaf area index and SPAD value. Rice being a cereal crop has high nutrient demand, especially for N and K; and hence reducing fertilizer dose by 40% resulted in poor plant growth. Reduced SPAD value indicating less chlorophyll synthesis might have resulted in less leaf area index, plant height and tillers per plant. Crop growth duration judged from the observation on days to 50% flowering revealed that at 60% of the recommended fertilizer dose, it was less by 3.9 days. Early flowering may be due to less availability of plant nutrients, especially N and P, under 60% fertilizer dose. It was observed that the biomass yield increased with the increased dose of fertilizer which can be attributed to increased leaf area index, plant height and tillers per plant.

Regarding the effect of irrigation treatments, plant growth parameters were the lowest under the rainfed crop. In rainfed crop, dry spell during active tillering as in the second year of experimentation is harmful by restricting root growth due to soil hardening in the experimental soil. This might have adverse effect

Table 2. Yield and yield attributes of rice as influenced by fertilizer dose and irrigation (Mean of 2012 and 2013).

	Panicles m^{-2}	Filled grains $Panicle^{-1}$	1000 Grain weight(g)	Grain filling (%)	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)	Harvest Index
% of recommended fertilizer dose							
100%	340.9	83.4	17.6	76.4	4.49	6.92	0.39
80%	323.2	79.5	17.1	74.4	4.25	6.41	0.40
60%	292.3	76.9	16.8	73.2	3.80	5.96	0.39
CD *(p=0.05)*	22.9	3.2	0.5	1.6	0.23	0.22	NS
Irrigation schedule							
Rainfed	296.4	77.4	17.1	73.5	3.89	6.33	0.39
1 irrigation*	322.8	80.2	17.1	74.8	4.15	6.70	0.39
2 irrigations**	337.2	82.1	17.2	75.6	4.50	6.98	0.40
CD *(p=0.05)*	22.7	3.3	0.4	1.3	0.26	0.21	NS

* One irrigation was provided at panicle initiation stage and active tillering stage for first and second year, respectively.
**First irrigation was provided at panicle initiation and active tillering stage for first and second year, respectively. Second irrigation was provided at grain filling and panicle initiation stage for first and second year, respectively.

on nutrient uptake and subsequently on crop growth. Dry spell at tillering stage reduces tiller number by reducing the nutrient content of the mother culm. Water deficit at panicle initiation stage (encountered in both the years) may reduce the leaf and panicle elongation rate leading to less plant height and leaf area index. Providing supplementary irrigation during the dry spell, improved the plant height, tillers $hill^{-1}$, leaf area index, SPAD value and biomass yield. This was due to avoidance of adverse soil physical condition and improved nutrient uptake by plant.

Effect of fertilizer dose and supplementary irrigation on yield attributes and yield

Panicle number, filled grains $panicle^{-1}$, test weight of grains and grain filling% were highest under the 100% of recommended fertilizer dose leading to highest grain and straw yields (Table 2). Highest tiller number, leaf area index and SPAD value at vegetative stage and subsequently high nutrient availability at reproductive stage was responsible for highest yield. The lowest yield attributes and yield were recorded under the 60% of recommended fertilizer dose which was due the less availability of plant nutrients with the drastic reduction in fertilizer dose by 40%. Grain and straw yields were higher by 18.2% and 16.1%, respectively, under the recommended fertilizer dose as compared to the 60% of the dose. Use of 80% of the recommended fertilizer also resulted in higher grain yield by 11.8 %, and straw yield by 7.6 % as compared to the 60% fertilizers dose. Comparison for yield attributes between the 100% and 80% of the recommended fertilizer dose revealed that

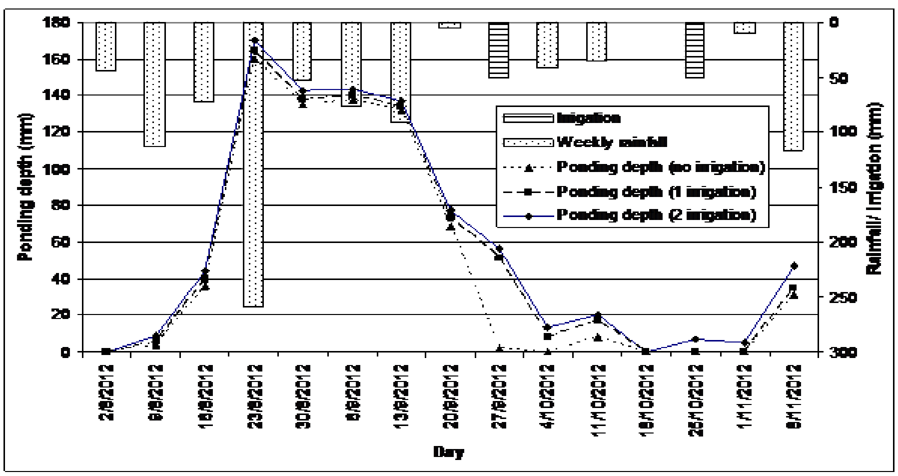

Fig.1. Average ponding depth in different irrigation treatments along with weekly rainfall and irrigation in the year 2012.

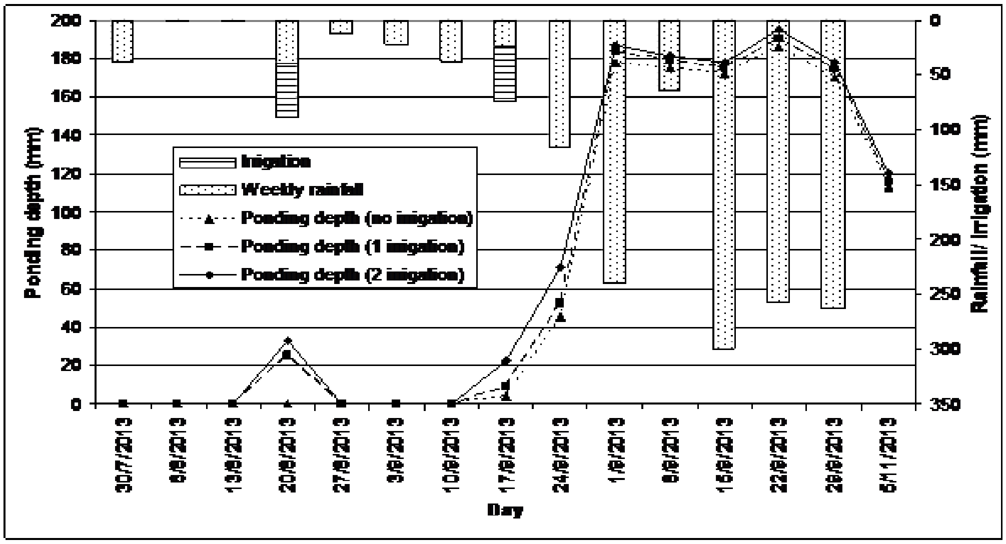

Fig. 2. Average ponding depth in different irrigation treatments along with weekly rainfall and irrigation in the year 2013.

the two treatments were at par regarding panicle number. However, filled grains panicle^{-1}, test weight of grains, grain filling%, grain and straw yields were higher under the 100% of recommended fertilizer dose vis-à-vis 80% of the recommended fertilizer dose. Thus, recommended fertilizer dose should be used for getting high yield. Board and Peterson (1980) have reported that grain filling percentage below 85% need management intervention. Low grain filling % reported in this experiment was due to the test variety Swarna with Mahsuri background which are known for their high basal and total sterility.

Lowest panicle number, grain filling %, and grain and straw yields were recorded under the rainfed crop. This was due to the lowest tiller number, leaf area index and SPAD value at vegetative stage for this treatment. Providing two supplementary irrigations during the two dry spells improved the yield attributes and yield. Grain and straw yields were higher by 15.7% and 10.3%, respectively, under the treatment with two supplementary irrigations as compared to the rainfed situation. This can be attributed to avoidance of soil hardening and improved nutrient availability due to provision of supplementary irrigation. Islam et al. (1991) reported 58% rice yield increase in wet season due to supplementary irrigation of 6 cm depth. A low yield improvement of 15.7% in this experiment can be attributed to the provision of field dyke of 20 cm height around each plot for enough water harvesting and subsequently mitigating water stress during dry spell (Rautaray, 2011). Comparison between one and two supplementary irrigations revealed that higher grain and straw yields were recorded under the latter treatment. Thus, two supplementary irrigations were beneficial when rainfed medium land rice encountered two dry spells.

The field experimental results can be used in developing crop growth models which can simulate crop growth and yield for different scenarios. Detailed monitoring of crop growth and yield attributes are very essential for calibration and validation of crop growth models. The calibrated model can be useful for studies on simulation of different scenarios for climate change and its effect on growth and yield of paddy.

CONCLUSION

Two dry spells of approximately 20 days duration each were encountered during panicle initiation and flowering stages in long duration paddy variety Swarna in rainfed medium land situation in the year 2012. In the year 2013, the two dry spells of approximately 18 days duration each occurred during the active tillering and panicle initiation stages. The effect of supplementary irrigation and fertilizer application revealed that there was increase in paddy grain and biomass yield with each supplementary irrigation. Similarly, there was increase in yield with increase in each level of fertilizer application. Thus, a fertilizer dose of 80 kg N, 40 kg

P_2O_5 and 40 kg K_2O ha^{-1} and supplementary irrigations during dry spells at active tillering, panicle initiation and flowering stages is recommended for getting optimum yield. The detailed measurement of crop growth and yield attributes will be helpful in crop growth modeling and thereby simulating different scenarios of climate change.

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