Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(2): 369-373
Received: 16-12-2020
Accepted: 05-02-2021

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Effect of irrigation frequency and weed management practices on yield, yield attributes and water productivity of rice

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Abstract
A field experiment was conducted to evaluate the effect of Irrigation frequency and weed management practices on performance of transplanted rice at Crop Research Centre, Chirori of Sardar Vallabhbhai Patel University of Agriculture & Technology. Meerut (U.P.), during *kharif* season 2018. The experiment was laid out in Split plot design with three replications. The experiment consisted of three Irrigation frequency *viz*: (I1) Irrigation at 2 day interval, (I2) Irrigation at 5 days interval, and (I3) Irrigation at 7 days interval in main plot and four weed management practice *viz*.: Bispyribac sodium 25 g ai.ha PoE, Cono weeder (at 25 & 45 DAT), two hand weeding (at 25 & 45 DAT) and weedy check in sub plot. Pusa basmati-1 was used as test variety.
The findings revealed that among the different Irrigation frequencies, the application of (I_2) Irrigation at 5 days interval recorded significantly better Yield and yield attributes. The highest yield attributes, grain yield (45.39 q ha^{-1}) and straw yield (55.59 4 q ha^{-1}) was recorded with (I_2) Irrigation at 5 days interval, closely followed by (I_1) Irrigation at 2 days interval. Whereas In case of weed management treatments two hand weeding recorded significantly higher growth parameters, yield attributes, grain yield (45.39 q ha^{-1}) and straw yield (55.59 q ha') than weedy check. Successive increase in irrigation frequency has increased in moisture content at harvest, being highest at (I_2) Irrigation at 5 days interval, (17.3). Maximum water productivity (3.74 kg grain m^{-3}) was recorded under I_3 (Irrigation at 7 days interval) followed by I_1 (Irrigation at 2-day interval) and I_2 (Irrigation at 5 days interval). Although, mean water productivity was 1.95 kg grams/m^3. Whereas In case of weed management practices combined application of two hand weeding stored the highest moisture content of 16.1%. Water productivity in weed management practices varied from 1.17 to 1.62 kg grams/m^3, being highest under treatment receiving weedy check, respectively. Therefore, it can be concluded that application of Irrigation at 5 days interval with cono weeder was best management option to get higher yield as well as profit from rice.

Keywords: Irrigation, yield, rice, weed management

Introduction
Rice is major staple food crop of the world to diet of 2.7 billion people and it contains 7-8% protein, 3% fat and 3% fiber. In India, rice occupies 44.50 mha area with production and productivity of 115.63 mt and 2.59 t/ha, respectively (Anonymous, 2018-19) [1]. Rice is the single largest user of fresh water consuming about 30 per cent and more than 45 per cent of total fresh water in World and Asia, respectively (Barker *et al.*, 1999) [3]. However, the increasing scarcity of fresh water for agriculture and competing demand from the non-agricultural sector threaten the sustainability of irrigated rice ecosystem. By 2025, 15 out of 75 million of Asia's irrigated rice may experience severe water shortage (Tuong and Bouman, 2003) [12]. Hence, the major challenges are to produce more rice, increase water productivity and reduce water input in the fields.
Researchers are developing water-saving technologies such as alternate wetting and drying, continuous soil saturation (Borell *et al.*, 1997), direct dry seeding, ground cover systems (Lin *et al.*, 2003) [7] and system of rice intensification (Stoop *et al.*, 2002) [11] but all these systems use prolonged periods of flooding and hence water losses still remain high. Shifting from conventional flooded system or alternate water saving option of irrigation by pressurized irrigation system *viz*., sprinkler, surface drip and micro-sprinkler irrigation in non-puddled, non-flooded conditions can reduce more water 50 per cent of the water requirements for rice production by reducing seepage, percolation and evaporation losses (Medley and Wilson, 2008) [8].

Therefore, cost effective and consistent weed management system and appropriate irrigation water management needs to be identified of rice modified as per the temperate valley situations. Effective weed control in transplanted rice is one of the major limitations hindering its wide spread cultivation. Manual removal of weeds is labor intensive, tedious, back-breaking and does not ensure weed removal at critical stage of crop weed competition bring heavy reduction in growth and yield of the crop. Hence for transplanted rice, the chemical method of weed management is best suited as it takes care of weeds right from beginning of crop growth and is also cost effective. Most of the herbicide recommended for rice is generally applied as pre-emergence to take care of weed during initial period. However, to minimize the competition between weeds and rice, the weeds population need to be kept below threshold level especially during critical weed competition period.

Herbicides which give excellent control when applied into water may perform poorly in the absence of standing water (Kumar *et al*. 2009) [6]. The herbicide pyrazosulfuron-ethyl at 40 DAT along with closer planting was effective for reducing weed population and dry weight (Gogoi *et al*., 2005).Conventional methods of weed control such as hand weeding may not be possible because of labour scarcity, time consuming, possible damage to rice plant, problem in differentiating grassy weeds and relatively less effectiveness (Singh and Singh, 2006) [10]. One way to reduce weeding efforts is by transplanting in rows which allows the use of simple tools for weeding like rotator weeder which on one hand control weeds and one the other hand this also increase soil aeration, which is an important aspect in SRI management. Weeding is necessary with SRI and can actively enhance yield through soil aeration which stimulates root growth and soil biological activity.

The yield loss due to poor weed management may vary from 10% to complete failure (Singh *et al.* 2008) [9]. The removal of competitive effect of weeds by weeding reduces interspecific competition for resources more efficiently and enables the plants to utilize available resources more efficiently throughout the growth cycle, which in turn positively influences crop yield and biomass production. Thus, effective weed management is crucial for higher yield of crop. Hand weeding is very easy and environment-friendly but tedious and highly labour intensive. At present, farmers very often fail to remove weeds due to unavailability of labours, especially at peak period. Moreover, the labour cost is increasing day by day which increases production cost making rice production as highly non-profitable business venture. In such conditions, herbicides offer the most practical and economic means of weed management. Herbicide controls weeds very effectively and increases the yield of rice. Bispyribac-sodium is a post emergence herbicide, used as broad spectrum to control the grasses, broad leaves and annual sedges, with excellent control of *Echinochloa species*. Reduction in weed density due to application of bispyribac-sodium at 15 and 25 DAT in transplanted rice were reported by Yadav *et al*. (2009) [13].

Materials and Methods

The field experiment was carried out at the Crop Research Center Chirodi of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) at latitude of 29^0 40′ North and longitude of 77^0 42′ East and at an altitude of 237 meter above mean sea level. Meerut lies in the heart of Western Uttar Pradesh and has sub-tropical climate. The experimental field had an even topography with good drainage system. Meerut has a semi-arid and sub-tropical climate characterized by hot summers and severe cold winters. The mean maximum weakly temperature was varied from 30.9 to 39.4^0C, whereas the lowest 11.1 to 28.3^0C. The annual rainfall is about 960.7 mm and mean relative humidity attains the maximum value 96.1 per cent and the minimum 45.4 per cent during the whole crop season. The soil of experimental field was sandy loam in texture, bulk density (1.37 Mg/m3), pH 7.50, EC (1.55 dS/m), low is organic carbon (0.46%) and available N (202.50 kg/ha), medium in available P (14.56 kg/ha) and available K (196.72 kg/ha). The experiment was laid out in Split plot design with three replications. The experiment consisted of three Irrigation frequency *viz*: (I1) Irrigation at 2 day interval, (I2) Irrigation at 5 days interval, and (I3) Irrigation at 7 days interval in main plot and four weed management practice *viz*.: Bispyribac sodium 25 g ai.ha PoE, Cono weeder (at 25 & 45 DAT),two hand weeding (at 25 & 45 DAT) and weedy check in sub plot. Pusa basmati-1 was used as test variety.

The seedling of rice was raised in nursery by 'Wet bed method'. Seed beds of 8 x 1.25 m size were prepared in dry condition. On sowing date, the beds were flooded with water and puddled. After levelling a mixture of 135 g urea (60 kg ha^{-1}), 187.5 g single super phosphate (30 kg ha^{-1}) and 25 g zinc sulphate per bed was broadcasted and incorporated in to the soil. Sprouted seed were sown then beds kept saturated initially up to a week and then submerged with a thin layer of water throughout nursery period. The recommended dose of N P K & Zn (120: 60: 40: 5.5 kg/ha) were applied through urea, DAP, MOP and $ZnSO_4$, respectively in all the plots uniformly. The half of nitrogen and full dose of phosphorus, potassium and Zn were applied as basal at the time of last harrowing during field preparation /final puddling. Remaining half nitrogen was top dressed in two equal splits, at tillering and panicle initiation stage, respectively. About 25 days old seedlings was used for transplanting. Transplanting was done manually in third week of the July as per treatments keeping two seedlings $hill^{-1}$. The irrigation was applied as per treatments. After dough stage, water was gradually drained out to facilitate easy harvesting of the crop. Bispyribac sodium are applied as post emergence at 25 DAT sprayed on crop with a knapsack sprayer using a spray volume of 500 liters of water ha^{-1}. Care was taken to ensure uniform application of herbicides in each plot as per treatments. The crop was harvested at full physiological maturity. Threshing was done plot wise and grain were cleaned, dried and weighed separately for each net plot and computed to q ha^{-1} at 14% moisture level. The straw yield was also recorded plot wise after sun drying and computed to q ha^{-1}. Fallow the standard procedures and observations were recorded on yield and yield attributes and water productivity of rice.

Result &Discussion

Yield attributes: The Table -1 shows that the highest panicle length (22.32 cm) was recorded under I_2 (Irrigation at 5 days interval), which was significantly higher than the other irrigation levels treatments. The lowest panicle length (20.90 cm) was recorded under I_3 (Irrigation at 7 days interval). The weed management practices had significant effect on panicle length. The highest panicle length (24.23 cm) of rice was recorded under two hand weeding. Whereas the lowest in weedy check. Use of herbicidal bispyribac sodium produced significantly higher panicle length than the weedy. The use of cono weeder was recorded significantly longer panicle length

(22.60 cm) than bispyribac sodium and weedy check treatments. The lowest panicle length (18.35 cm) was recorded with weedy check. The interaction effect between irrigation levels and weed management practices was found non-significant.

The highest number of panicles was recorded with I_2 (Irrigation at 5 days interval) *i.e.* (134.62), which were significantly higher than the other treatments. The lowest number of panicle (130.60) was recorded with I_3 (Irrigation at 7 days interval). The weed management practices had also significant effect on number of panicle. The highest number of panicle of rice was recorded under two hand weeding (139.01), which was significantly higher than the rest of the treatments at all the stages except cono weeder treatment, which remained at par in number of panicles. The use of cono weeder and Bispyribac sodium @ 25 g a.i ha^{-1} were also remained at par in number of panicles. The lowest number of panicle recorded with weedy check (118.23). The interaction effect between irrigation levels and weed management practices was found to be non-significant.

The highest number of grain $panicle^{-1}$was recorded with I_2 (Irrigation at 5 days interval) (129.54), which was significantly higher than rest of the irrigation treatments. The lowest number of grain $panicle^{-1}$ (123.74) was recorded under I_3 (Irrigation at 7 days interval), which was statistically at par to I_1 (Irrigation at 2 day interval).The weed management practices had significant effect on number of grain $panicle^{-1}$ The highest number of grain $panicle^{-1}$ of rice (129.62) was recorded under two hand weeding, which was significantly higher than rest of the treatments. The use of cono weeder also recorded significantly higher number of grain $panicle^{-1}$ (127.28) than weedy check only. Whereas the lowest number of grain $panicle^{-1}$ recorded with weedy check (121.0).The interaction effect between irrigation levels and weed management practices was found to be non-significant.

The highest 1000-grain weight did not significantly influence by irrigation frequency. However, highest (23.76g) and lowest (22.02g) 1000- grain weight was observed in I_2 (Irrigation at 5 days interval) and I_3 (Irrigation at 7 days interval), respectively. The weed management practices had significant effect on 1000-grain weight. The highest 1000-grain weight of rice was recorded under two hand weeding (25.2 g), which was significantly higher than other treatments. The lowest 1000-grain weight recorded with weedy check (21.13 g).The interaction effect between irrigation levels and weed management practices was found to be non-significant.

Similar results were noted by Singh *et al.* (2014) also confirmed the same.

Table 1: Effect of irrigation levels and weed management practices on yield attributes of rice crop

Treatments	Panicle length (cm)	No. of panicle (m^2)	No. of grain/ panicle	1000 grain weight (g)
Irrigation frequency				
I_1 (Irrigation at 2 day interval)	21.74	131.50	125.37	23.58
I_2 (Irrigation at 5 days interval)	22.32	134.62	129.54	23.76
I_3 (Irrigation at 7 days interval)	20.90	130.60	123.74	22.02
SEm±	0.08	0.53	0.57	0.39
CD (P=0.05)	0.30	2.06	2.20	NS
Weed management practices				
W_1 (Weedy check)	18.35	118.23	121.00	21.13
W_2 (Two hand weeding (At 25 & 45 DAT)	24.23	139.01	129.62	25.22
W_3 (Bispyribac sodium @ 25 g a.i ha^{-1})	21.45	135.50	126.95	22.93
W_4 (Cono weeder (At 25 & 45 DAT)	22.60	136.22	127.28	23.21
SEm±	0.23	1.22	0.66	0.33
CD (P=0.05)	0.68	3.65	1.95	0.98

Yield studies: The Table -2 shows that, the highest grain yield (41.62 q ha^{-1}) was recorded with I_2 (Irrigation at 5 days interval) which was significantly higher than I_3 (Irrigation at 7 days interval) but at par to I_1 (Irrigation at 2 day interval). Whereas the lowest grain yield (39.32 q ha^{-1}) was recorded under I_3 (Irrigation at 7 days interval).The weed management practices had also a significant effect on grain yield. The highest grain yield (45.39 q ha^{-1}) of rice was recorded with two hand weeding, which was significantly higher than rest of the treatments. Whereas the lowest grain yield (30.31 q ha^{-1}) recorded in weedy check. Application of bispyribac sodium and cono weeder produced similar grain yield but significantly higher than weedy check. The interaction effect between irrigation levels and weed management practices was found non-significant. Finding of present investigation are in agreement with finding of Yadav *et al.*, 2009 [13].

The highest straw yield (51.83 q ha^{-1}) was recorded with I_2 (Irrigation at 5 days interval), which was significantly higher than I_3 (Irrigation at 7 days interval) but at par to I_1 (Irrigation at 2-day interval). Whereas the lowest straw yield (48.23 q ha^{-1}) was recorded under I_3 (Irrigation at 7 days interval). Among the weed management practices, the highest straw yield (55.59 q ha^{-1}) of rice was recorded with two hand weeding. Whereas the lowest straw yield (41.70 q ha^{-1}) recorded in weedy check. Bispyribac sodium and cono weeder treatments produced significantly higher straw yield than the weedy check. The use of cono weeder and bispyribac sodium treatment produced similar straw yield. The interaction effect between irrigation levels and weed management practices was found to non-significant. This finding confirms the results of Chauhan *et al.* (2012) [4].

The highest biological yield (93.45 q ha^{-1}) was recorded with I_2 (Irrigation at 5 days interval), which was significantly higher than the other irrigation frequency treatments. Whereas the lowest biological yield (87.55 q ha^{-1}) was recorded under I_3 (Irrigation at 7 days interval) treatment. The weed management practices, the significantly highest biological yield (100.98 q ha^{-1}) of rice was recorded with two hand weeding than rest of the treatments. Whereas the lowest biological yield (72.01 q ha^{-1}) recorded in weedy check. The cono weeder treatment was also recorded significantly more biological yield (95.73 q ha^{-1}) over weedy check, but remained at par to the Bispyribac sodium @ 25 g a.i ha^{-1}. The interaction effect between irrigation frequency and weed management practices was found to non-significant.

The harvest index was not significantly influenced by irrigation frequencies, however maximum and minimum values of harvest index were associated with I_3 (Irrigation at 7

days interval) and I_1 (Irrigation at 2-day interval), respectively. The weed management practices had significant effect on harvest index. The highest harvest index of rice was recorded with use of cono weeder (45.69%), which was significantly higher than weedy check and statistically at par with cono weeder and Bispyribac treatment. The lowest harvest index recorded under weedy check (42.01%).

Table 2: Effect of irrigation levels and weed management on grains, straw, biological yield (q ha^{-1}) and harvest index (%) of rice crop

Treatment	Yield (q ha^{-1})			Harvest index (%)
	Grains	Straw	Biological	
Irrigation frequency				
I_1 (Irrigation at 2 day interval)	40.54	50.54	91.09	44.30
I_2 (Irrigation at 5 days interval)	41.62	51.83	93.45	44.40
I_3 (Irrigation at 7 days interval)	39.32	48.23	87.55	44.72
SEm±	0.34	0.42	0.59	0.32
CD (P=0.05)	1.32	1.62	2.30	NS
Weed management				
W_1 (Weedy check)	30.31	41.70	72.01	42.01
W_2 (Two hand weeding (At 25 & 45 DAT)	45.39	55.59	100.98	44.99
W_3 (Bispyribac sodium @ 25 g a.i ha^{-1})	42.51	51.55	94.06	45.20
W_4 (Cono weeder (At 25 & 45 DAT)	43.74	51.99	95.73	45.69
SEm±	0.43	0.74	1.02	0.43
CD (P=0.05)	1.28	2.19	3.04	1.28

Soil moisture content at harvest and water productivity (kg m^{-3}) of rice: The Table -3 represent that the average highest moisture content at the time of sowing (21%) and it was lowest at the time of crop maturity in all the treatments. Successive increase in irrigation frequency has increased in moisture content at harvest, being highest at I_2 (Irrigation at 5 days interval), 17.3, respectively. Though, the respective mean values were 15.7%. Similarly, combined application of two hand weeding stored the highest moisture content of 16.1%, respectively. The next in the order were cono weeder (At 25 & 45 DAT and Bispyribac sodium @ 25 g a.i ha^{-1} treatments.

The crop water use increased markedly in I_2 (Irrigation at 5 days interval) than I_1 (Irrigation at 2 day interval) and I_3 (Irrigation at 7 days interval) during year of study. Water productivity varied inversely with irrigation frequency. Maximum water productivity was recorded under I_3 (Irrigation at 7 days interval) followed by I_1 (Irrigation at 2-day interval) and I_2 (Irrigation at 5 days interval). Although, mean water productivity was 1.95 kg grams/m^3, respectively. Among weed management practices, water productivity varied from 1.17 to 1.62 kg grams/m^3, being highest under treatment receiving weedy check, respectively.

Table 3: Effect of irrigation frequency and weed management practices on soil moisture content at harvest and water productivity (kg m^{-3}) of rice

Treatments	Water productivity		
	Soil moisture content (%)	Total water applied (cm)	Water productivity (kg grain m^{-3})
Irrigation levels			
I_1 (Irrigation at 2 day interval)	15.4	44.32	0.92
I_2 (Irrigation at 5 days interval)	17.3	34.36	1.21
I_3 (Irrigation at 7 days interval)	14.3	10.52	3.74
Mean	15.7	29.73	1.95
Moisture conservation practices			
W_1 (Weedy check)	13.8	18.69	1.62
W_2 (Two hand weeding (At 25 & 45 DAT)	16.1	38.59	1.17
W_3 (Bispyribac sodium @ 25 g a.i ha^{-1})	14.2	32.61	1.30
W_4 (Cono weeder (At 25 & 45 DAT)	15.6	35.74	1.22
Mean	14.9	31.39	1.36

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