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Bio-efficacy of pretilachlor with varying irrigation regimes in furrow transplanted and furrow irrigated rice (*Oryza sativa* L.) in Punjab

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Rice (*Oryza sativa* L.) is the most important staple food of India contributing 45 % of the total food grain production. Rice is the highest water-requiring crop in the *kharif* season. To economize irrigation water, the concept of reduced water supply per irrigation through furrow irrigated rows and bed or furrow transplanted rice was evaluated for its effect on rice productivity and irrigation water savings. These studies revealed 30 to 40 per cent saving in irrigation. Paddy yields were either statistically same or slightly reduced particularly in years when the rains were about 50 % below normal (Mahey *et al*, 2003; Kaur, 2004). However, in these studies the authors reported severe problem of weeds because of comparatively unsaturated conditions on the raised portion of beds where even if herbicide is applied, its activity is reduced and also prevalence of oxygenated conditions favoured the growth of both narrow and broadleaf weeds. Thus, once again the physiological basis of *Echinochloa* seed germination and its control with herbicides' use under just saturation conditions were thought of, as has been the case in flat puddled transplanted rice (Sandhu *et al.,* 1992) with the hypothesis that even if some water saving is sacrificed to maintain the saturated conditions on the raised portion of bed by just inundating them while applying irrigation water during the first two weeks after transplanting to get optimum control of weeds through herbicide even then a saving of about 50-60 cm (20-25%) in irrigation water can be achieved by furrow/bed transplanting system over conventional method. Thus keeping in the view the physiology of *Echinochloa* seed germination and its control with herbicide use under saturated conditions the present investigation was undertaken to evaluate the effect of furrow and bed transplanting and varying irrigation management on crop growth and crop-weed competition.

The field investigation was carried out at student's farm, Punjab Agricultural University, Ludhiana (30^0 56' N latitude with 75^0 52' E longitude, 247 m mean sea level). The soil of the experimental field was sandy loam, low in organic carbon (0.27 and 0.21 %) and available N (210 and 182 kg ha^{-1}) and medium in available P (18.9 and 17.8 kg ha^{-1}) and K (185 and 140 kg ha^{-1}) in 0-15 and 15-30 cm soil depth, respectively. The soil reaction (pH) and electrical conductivity were in the normal range. The experiment was laid out in a randomized block design with four replications. The experiment comprising of 14 treatment combinations from seven planting methods × (irrigation treatments) viz. (i) Transplanting puddled flat × (Border method of irrigation) [Flat (BM)]; (ii) Transplanting 2 rows/furrow × (Irrigation inundating beds during establishment phase and in furrows thereafter) [2R/F (Inun. B+F)]; (iii) Transplanting 2 rows/bed × (Irrigation inundating beds during establishment phase and in furrows thereafter) [2R/B (Inun. B+F)]; (iv) Transplanting 2 rows/furrow × (Irrigation inundating beds throughout after transplanting) [2R/F (Inun. B)]; (v) Transplanting 2 rows/bed × (Irrigation inundating beds throughout after transplanting) [2R/B (Inun. B)]; (vi) Transplanting 2 rows/furrow × (Irrigation in furrows throughout after transplanting) [2R/F (F)]; (vii) Transplanting 2 rows/bed × (Irrigation in furrows throughout after transplanting) [2R/B (F)] and two weed control treatments i.e. (i) Unweeded control [UWC] (ii) Use of pretilachlor @ 0.75 kg ha^{-1} and metsulfuron @ 0.015 kg ha^{-1} [Herbicide]. Pretilachlor was mixed with sand and applied at 2 days after transplanting and Metsulfuron was sprayed 22 days after transplanting while nitrogen, phosphorus, potassium at the rate of 125, 30 and 30 kg ha^{-1} were applied through urea, di-ammonium phosphate and murate of potash. The weed population was recorded species wise from each plot at given interval. The samples for dry matter accumulation were taken periodically from unit area i.e. 0.3375 m^2 (50 cm × 67.5 cm) from furrow and bed transplanted plots and 0.2 m^2 (100 cm × 20 cm) from flat transplanted plots. In order to test the significance of results, the data were subjected to statistical analysis of variance according to method given by Cochran and Cox (1967).

A. Observation on weeds

Weed flora

Echinochloa crusgalli (33.2% and 11.7%) [per cent of narrow / broadleaf / sedge spp. and per cent of total weed population], *E. colonum* (51.0% and 18.0%) and *Eleusine* spp. (15.8% and 5.6%) were the narrow leaf weeds and *Eclipta alba* (32.8% and 10.6%), *Trianthema monogyna* (36.1% and 11.7%) and *P. niruri* (31.1% and 10.1%) were the broadleaf

Short Communication

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species while *Cyperus iria* (100% and 32.3%) was the lone sedge type species prevalent in the experiment.

Weeds density and dry matter accumulation

Inundating the beds while applying irrigation water during the first two weeks after transplanting (15 DAT) significantly improved the efficacy of herbicide (pretilachlor) as is revealed by statistically lower total weed population in treatments 2R/F (Inun. B+F) over 2R/F (F) as well as statistically the same weed population as observed in the recommended practice [Flat (BM)]. This gets support from the work reported by Singh and Tiwari (2005) and Kumar *et al* (2004) while working with FIRBS system for transplanting rice. At 30 DAT complete control of broadleaf weeds was ovserved due to post-emergence application of metsulfuron at 22 DAT. Total weed population decreased a bit at 60 and 90 DAT because of self competition as well as crop-weed competition. Rest of the trends in total weed population almost remained statistically the same as observed at 15 and 30 DAT except that the irrigation methods 'Inun. B' (as expected) and 'Inun. B+F' which were statistically at par irrespective of bed and furrow transplanting up to 15 DAT because irrigation regime in both the treatments was same, at 30 DAT 'Inun. B' started exerting statistically more pressure on the total weed population due to continuation of inundation as compared to 'Inun. B+F' where the irrigation was shifted to furrows only. This statistical superiority of 'Inun. B' system over 'Inun. B+F' was reflected in total weed population data recorded at 90 DAT.

The data on total dry matter accumulated by weeds is presented in Table 1. At 30 DAT, 'F' method of irrigation recorded significantly higher total weed dry matter as compared with all the combinations of bed and furrow transplanting with 'Inun. B+F' and 'Inun. B' which were further at par with recommended practice [Flat (BM)] in reducing the weed dry matter. This was due to significantly reduced total weed population and improved moisture regime with inundation of beds during the establishment phase in treatment 2R/F (Inun. B + F). The trends in weed dry matter remained same up to harvest stage except the treatment 2R/F (Inun. B + F) which was statistically at par with recommended practice at 30 DAT, from 60 DAT onwards recorded significantly higher weed dry matter than recommended practice. At 60 DAT herbicide application under recommended practice as well as in combination with 'Inun. B + F' and 'Inun. B' maintained its superiority over 'F' method of irrigation as is evident from significantly lower weed dry matter under the former combinations in comparison to 'F' method. Improved moisture also improved herbicide activity, which resulted in reduced weed population and thus the reduced weed dry matter accumulation. The findings get support from the work published Kumar *et al.* (2004) and Singh and Tiwari (2005).

B. Observations on crop

Dry matter accumulation by crop

The data on total dry matter accumulation at harvest given in Table 2 reveal that irrespective of planting technique the irrigation method 'F' proved significantly inferior to 'Inun. B+F' and 'Inun. B'. These differences are explained on the basis of improvement of soil moisture regime from 'F' < 'Inun. B+F' < 'Inun. B' < 'BM' which is positively correlated to the crop growth and negatively to the weed population. Under unweeded control conditions irrespective of planting technique all the irrigation methods recorded crop dry matter, which was significantly lower than recorded under recommended practice [Flat (BM)]. However, under herbicide use conditions, only 'F' irrigation method proved significantly inferior than 'BM' while all other methods were statistically at par with 'BM'.

Number of effective tillers m^{-2}

A perusal of the data in Table 2 indicates that the effective number of tillers increased with increase in extent and duration of inundation in the order that 'F' < 'Inun. B+F' < 'Inun. B'. Similar results were reported by Kumar *et al* (2004) from Haryana. Number of effective tillers m^{-2} increased significantly when the weeds were kept under control through use of herbicides. Number of effective tillers under unweeded control conditions increased as the extent and duration of inundation was increased. Whereas under herbicide use conditions combinations of planting technique and irrigation method were statistically at par with recommended practice except in treatments 2R/F (F) and 2R/B (F) which are significantly inferior to the recommended practice with respect to the number of effective tillers m^{-2}.

Number of filled grains per panicle

The data on number of filled grains per panicle given in Table 2 reveal that, irrespective of planting technique, the 'F' irrigation method recorded significantly less number of grains per panicle in comparison to other two irrigation methods i.e. 'Inun. B' and 'Inun. B + F' tested and the recommended practice 'BM'. Vories *et al* (2002) from USA also reported significantly greater number of grains per panicle in flood irrigated than under furrow irrigated treatment. Controlling weeds with herbicide use significantly increased the number of filled grains per panicle over unweeded control conditions. However, all the interaction effects were non-significant.

Table 1: Density and dry matter of weeds as influenced by various treatments

Treatments	Number of weeds (m^{-2})				Total dry matter of weeds (q ha^{-1})			
	15 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	At harvest
Unweeded control								
Flat (BM)	27.5	34.3	25.0	17.9	3.3	10.3	16.7	17.8
2R/F (Inun. B+F)	47.2	59.9	47.4	33.2	4.3	14.3	23.0	24.2
2R/B (Inun. B+F)	47.0	64.7	51.9	36.0	4.8	15.2	25.4	25.9
2R/F (Inun. B)	46.8	52.0	38.6	26.9	3.9	13.7	22.0	22.8
2R/B (Inun. B)	47.0	54.2	41.7	29.4	4.6	14.5	23.7	24.9
2R/F (F)	84.8	96.3	79.9	61.9	11.9	36.1	56.2	56.5
2R/B (F)	88.3	98.9	81.5	64.0	12.6	37.1	58.5	59.3
Herbicides								
Flat (BM)	5.6	5.0	3.7	1.8	0.6	4.5	7.2	7.9
2R/F (Inun. B+F)	7.3	5.4	3.7	2.2	0.8	4.8	7.1	8.0
2R/B (Inun. B+F)	7.2	5.4	3.9	2.4	0.9	4.8	7.5	8.0
2R/F (Inun. B)	6.9	5.2	3.4	1.8	0.6	4.4	6.8	7.6
2R/B (Inun. B)	6.8	5.5	3.6	2.2	0.9	4.8	7.3	8.0
2R/F (F)	13.9	16.8	11.8	8.3	1.7	10.5	17.1	17.6
2R/B (F)	14.3	17.3	12.4	8.5	1.8	11.0	17.7	18.4
Interaction LSD (0.05)	**2.8**	**3.5**	**3.0**	**2.4**	**1.2**	**2.3**	**2.8**	**3.0**

Table 2: Total dry matter, effective tillers, filled grains per panicle and grain yield as influenced by various treatments

Treatments	Total Dry matter (q.ha^{-1})	Effective tillers (m^{-2})	No. of filled grains per panicle	Grain yield (q.ha^{-1})
Unweeded control				
Flat (BM)	132.4	315	128.3	50.3
2R/F (Inun. B+F)	90.4	204	121.7	28.5
2R/B (Inun. B+F)	85.9	189	120.0	26.1
2R/F (Inun. B)	105.3	214	123.4	39.4
2R/B (Inun. B)	101.3	222	122.5	35.8
2R/F (F)	64.7	158	116.0	21.9
2R/B (F)	61.4	151	114.8	21.4
Herbicides				
Flat (BM)	152.6	357	132.6	55.7
2R/F (Inun. B+F)	152.2	352	132.4	54.1
2R/B (Inun. B+F)	152.5	357	131.5	54.5
2R/F (Inun. B)	153.4	370	133.2	56.9
2R/B (Inun. B)	152.7	357	132.6	54.9
2R/F (F)	119.5	304	124.4	45.1
2R/B (F)	118.9	304	123.8	44.7
Interaction LSD (0.05)	**7.7**	**37**	**NS**	**3.5**

Grain yield

The data on grain yield given in table 2 reveal that among the three modified irrigation systems tested in this study, the irrigation systems 'Inun. B' proved statistically better over 'Inun. B + F' and 'F' for grain yield. These differences are explained on the basis of the degree of favourable moisture regimes, which existed under the various irrigation methods. 'F' method of irrigation offered comparatively the driest environment throughout the crop growth period particularly on the top of the beds. The irrigation systems 'Inun. B+F' and 'Inun. B' were the same during the crop establishment phase but after two weeks of transplanting 'Inun. B+F' was the next system where moisture regime was less favourable as compared to 'Inun. B'. Thus, comparatively better oxygenated conditions are expected to prevail under 'F' which along with warm temperature and moist conditions provided the best situation for weed germination and their growth (Table 1) and thus the intense crop-weed competition. In the 'Inun. B+F' system comparatively inundated conditions (may be short lived) as compared to recommended practice created changes in physico-chemical properties of soil which inhibited weed seed germination (Table 1) to some good extent and comparatively better moisture regime helped the crop plant to accumulate significantly more dry matter (Table 2) and channelize the photosynthates to develop more number of effective tillers (Table 2), filled grains per panicle (Table 2) and significantly higher yield over 'F' system of irrigation. The increase in yield and decreased weed seed germination with increased soil moisture regime have also been reported by Reddy and Reddy (1999) and Mishra *et al*. (2001).

Grain yield was significantly influenced by the interaction of planting technique × (irrigation method) and weed management levels. Weed management through herbicide use significantly increased the grain yield in all the combinations of planting technique × (irrigation method). The per cent increase in grain yield under recommended practice [Flat (BM)] with herbicide use was 11.0 while this increase in rest of the six treatment combinations ranged between 44.4 to 109.0 per cent over unweeded control conditions. Irrespective of the planting technique, under unweeded control conditions, the grain yield was significantly superior under different irrigation systems in the order that 'F' < 'Inun. B + F' < 'Inun. B' < 'BM' whereas under herbicide use conditions the order of statistical superiority, with regards to grain yield under different irrigation system was 'F' < 'Inun. B+F' = 'Inun. B' = 'BM'. This has clearly demonstrated significant improvement in the bioefficacy of pretilachlor with improved moisture conditions.

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