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Role of Planting Patterns and Weed Control Treatments on Growth and Yield of Unpuddled Transplanted Rice (*Oryza sativa* L.)

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ABSTRACT

Background: Weeds pose a significant biotic threat to the production of rice, hindering its growth and yield. An experimental study was carried out at Lovely Professional University, Phagwara, Punjab, India during the 2023 *kharif* season to investigate the impact of different planting patterns in relation to weed control treatments on weed dynamics and paddy yield of transplanted rice under unpuddled conditions.

Methods: The experiment was laid out in Split Plot Design comprising of four planting patterns, *viz.* transplanting two rows/ridge, transplanting two rows/ridge + one in furrow, flat transplanting (unpuddled), flat transplanting (puddled) in main plots and four weed control treatments, *viz.* pendimethalin 0.75 kg/ha as pre-em. *f.b.* bispyribac 10 SC at 25 g/ha as post-em., pendimethalin 0.75 kg/ha as pre-em. *f.b.* penoxsulam 240 SC at 24 g/ha as post-em., pendimethalin 0.75 kg/ha as pre-em. *f.b.* fenoxaprop 6.7 EC at 67 g/ha, post-em., unweeded (control) in sub-plots with four replications.

Result: The investigation's outcomes revealed that the highest paddy yield (67.6 q/ha) was achieved by transplanting two rows per ridge and one in the furrow, significantly outperforming other planting patterns. Conversely, the paddy yields from flat unpuddled (60.2 q/ha) and flat puddled (59 q/ha) treatments were statistically at par. Among the weed control treatments, the sequential application of pendimethalin (0.75 kg/ha) as a pre-emergence and bispyribac sodium 10 SC (25 g/ha) as a post-emergence significantly inhibited the growth and biomass accumulation of diverse weed types, such as grasses, sedges and broad-leaved weeds resulting in significantly higher paddy yield (77.9 q/ha) in comparison to all other weed control treatments.

Key words: Planting patterns, Rice, Unpuddled conditions, Weed control treatments.

INTRODUCTION

Rice (*Oryza sativa* L.) serves as a primary food source for over 50% of the world's inhabitants. During 2024, paddy cultivation in Punjab covered 31.68 lakh hectares with total paddy production of 20.5 million tons and an average yield of 64.79 quintals per hectare, yielding over 13 million metric tons of rice (Anonymous, 2024). In Asia, the primary method of rice cultivation is the manual transplantation of seedlings into puddled soil. The process of soil puddling in paddy rice cultivation involves manipulating water-saturated or near-saturated soil to create a soft, homogeneous mud layer (Kirchhof *et al.*, 2011). The disintegration of soil aggregates and deterioration of soil structure caused by puddling makes it challenging to restore suitable soil conditions for crops following rice cultivation (Sharma *et al.*, 2005). Transplanting in non-puddled conditions emerges as a promising alternative, addressing various challenges while reducing rice production costs, with conservation agriculture practices demonstrating decreased water usage, enhanced productivity and profitability and improved soil physical properties compared to conventional puddling methods (Jat *et al.*, 2009). Planting patterns in rice cultivation has a substantial effect on weed dynamics, crop growth and overall productivity. Ridge transplanting of rice can potentially increase yields and WUE and furrow-bed planting provides additional advantages like improved soil aeration, reduced lodging, higher WUE and minimal soil surface cracking and crusting, which helps conserve moisture by reducing evaporation (Hussain *et al.*, 2019).

Weed control stands as the primary challenge under unpuddled conditions, as these systems face significantly higher weed pressure compared to puddled transplanting, which naturally suppresses weeds during the puddling process (Chaudhary *et al.*, 2023). Uncontrolled weed proliferation in rice cultivation can result in substantial yield reductions, with losses varying from 30% to 90% (Duary *et al.*, 2015). Chemical weed control stands out as the most practical, efficient and economical method in situations where labour is limited and weeding overlaps with other important agricultural activities. Application of pre-emergence

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herbicides like pendimethalin were shown to effectively suppress weeds and enhance crop yield compared to untreated control plots (Onwuchekwa-Henry *et al*., 2023). Farmers commonly use post-emergence herbicides such as bispyribac-sodium, penoxsulam and fenoxaprop-p-ethyl for weed control. These herbicides are selective in their action; for example, bispyribac is particularly effective against *Cyperus iria* L., *Echinochloa colona* L. In the past, fenoxaprop without a safener was applied in DSR to manage *Leptochloa chinensis* L. Nees and *Dactyloctenium aegyptium* L. Willd. (Mahajan and Chauhan, 2015). The sequential application of pre- and post-emergence herbicides can effectively control weeds and enhance yields in rice across various tillage systems, including minimum tillage (Singh *et al*., 2016). This study was conducted to evaluate the influence of planting patterns and various weed control treatments on yield of transplanted rice and growth of weeds.

MATERIALS AND METHODS

The field experiment was conducted during the *kharif* season of 2023 at agriculture research farm of Lovely Professional University located in Phagwara, Punjab. The experimental site is located in the central plain zone of the state's agro-climatic region (31°14′43.8″N, 75°41′44.1″E), at an elevation of 252 m above mean sea level and experiences a warm and hot climate, with an average annual temperature of 23.9°C and an average annual rainfall of 600 mm. The experiment was executed using a Split-Plot Design with four replicates. The main plots comprised of four planting patterns, *viz.* M_1-transplanting two rows/ridge, M_2-transplanting two rows/ridge + one in furrow, M_3-flat transplanting (unpuddled), M_4-flat transplanting (puddled) and sub-plots comprised of four weed control treatments, *viz.* T_1-pendimethalin 0.75 kg/ha as pre-em. *f.b.* bispyribac 10 SC at 25 g/ha as post-em. (20-25 DAT), T_2-pendimethalin 0.75 kg/ha as pre-em. *f.b.* penoxsulam 240 SC at 24 g/ha as post-em. (10-12 DAT), T_3-pendimethalin 0.75 kg/ha as pre-em. *f.b.* fenoxaprop 6.7 EC at 67 g/ha, post-em. (20-25 DAT), T_4-control (unweeded).

Thirty days old seedlings of PR-126 variety of rice were used for transplanting, ridges were made 60 cm apart as per treatment in dry well prepared field. Row to row spacing was 20 cm in flat sown and in two rows per ridge and one in furrow with plant to plant spacing of 15 cm. In two rows per ridge, row to row spacing was 30 cm with plant to plant spacing of 10 cm in order to maintain uniform plant population in all planting patterns. Prior to transplanting, all treatments were supplemented with a basal fertilizer application of 30 kg/ha phosphorus (single super phosphate), 30 kg/ha potassium (muriate of potash) and 15 kg/ha zinc (zinc sulphate). The application of nitrogen at the rate of 120 kg/ha, in the form of urea, was done in three split doses. Pendimethalin, mixed with 150 kg of sand per hectare, was applied in standing water within two days after transplanting as per treatment. The application of all post-emergence herbicides was carried out using a knapsack sprayer equipped with a flat-fan nozzle, with water as the carrier solution at a volume of 375 lit/ha. Plant height was measured using five randomly selected plants from each experimental plot. To assess crop dry matter accumulation and weed biomass, two 30 cm² quadrats were randomly placed in each plot. Weed densities and biomass were recorded separately for grassy and broadleaf weeds, including sedges in the broadleaf category. Both rice and weed samples were sun-dried, followed by oven-drying at 60°C for 48 hours till complete dryness before weighing. At crop maturity, crop was harvested from a 4 m² plot, followed by threshing and cleaning. The grain weight was recorded and yield was subsequently converted to quintals per hectare (q/ha) for consistent analysis. The data were statistically analysed with the aid of OPSTAT software using ANOVA to determine the significance of differences among treatments, while the F-test was used to compare means and critical difference values were calculated at a 5% significance level. Also, to meet the assumptions of the analysis, weed density and weed biomass data were transformed using a square-foot transformation after adding one to original values.

RESULTS AND DISCUSSION

Weed dynamics

An assessment of the weed dynamics data of grassy and broadleaf weeds presented in Table 1 suggested that among the main plot treatments, significantly lower weed count and dry matter were observed with two rows per ridge and one in the furrow along with maximum weed control efficiency, compared to other planting methods, likely because this method enhances the crop's competitiveness against weeds and faster canopy closure that limits light penetration to the soil (Mahajan and Chauhan, 2011). The density of both grassy and broadleaf weeds, as well as dry matter, was signifcantly higher in the unpuddled flat method and exhibited lower weed control efficiency compared to the puddled flat transplanting technique.

Among weed control treatments, pendimethalin 0.75 kg/ha as pre-em. *f.b.* bispyribac 10 SC at 25 g/ha as post-em. demonstrated superior control of both grassy and broadleaf weeds, while achieving maximum weed control efficiency with the lowest count/m² and biomass when compared to other treatments. It may be due to the broad-spectrum efficacy of bispyribac, which effectively targets a wide range of weed species. The findings align with those reported by (Mahajan and Chauhan, 2013; Verma *et al.,* 2022). Conversely, the unweeded control showed significantly higher weed count/m² and dry matter accumulation by weeds as compared to other weed control treatments (Mullaivendhan *et al*., 2024). The interaction between the planting patterns and weed control treatments had no significant effect on the weed density and biomass of the grassy and broadleaf weeds.

However, for broadleaf weeds, the unweeded control and sequential application of pendimethalin (0.75 kg/ha, pre-emergence) and fenoxaprop-p-ethyl (6.7 EC at 67 g/ha, post-emergence) showed statistically at par weed density and biomass, which also demonstrated lowest weed control efficiency when compared to other herbicidal treatments. This outcome can be attributed to fenoxaprop's selective action on grassy weeds, leaving broadleaf weeds and sedges largely uncontrolled (Mahajan and Chauhan, 2015).

Crop growth parameters

Data pertaining to the growth parameters presented in Table 2 reveals that among the main plot treatments there was no significant impact of planting patterns on the plant height of rice, However, among the sub-plots, pre-em. pendimethalin 0.75 kg/ha as. *f.b.* bispyribac 10 SC at 25 g/ha as post-em was found to have a significantly higher plant height in comparison to other weed control treatments. Plant height in pre-em. pendimethalin *f.b.* post-em. fenoxprop-p-ethyl was significantly less than other herbicidal treatments.

No. of tillers/m^2 were significantly higher in two rows per ridge and one in furrow compared to other planting patterns. Similarly, among sub-plots, the sequential application of pendimethalin (0.75 kg/ha, pre-emergence) and bispyribac 10 SC (25 g/ha, post-emergence) in significantly surpassed other treatments in total no. of tillers/m^2 whereas significantly lower no. of tillers/m2 were observed in unweeded (control) in comparison to all herbicidal treatments (Sanodiya and Singh, 2022).

The planting pattern consisting of two rows per ridge and one in the furrow resulted in significantly superior dry matter accumulation by crop compared to other main plot treatments, Amongst the weed control treatments, the herbicide treatment combining pendimethalin (pre-emergence) with bispyribac (post-emergence) significantly outperformed other treatments, whereas the unweeded control exhibited significantly less dry matter accumulation than other treatments, whereas the interactive effect of planting patterns and weed control treatments was found to be non-significant on all the growth parameters. The superior results in this treatment can be attributed to the synergistic action of pendimethalin which controlled non-paddy weeds and bispyribac, which effectively controlled nearly all paddy weeds (Parihar *et al*., 2019). The findings are in conformity with Kashyap *et al.,* 2022 and Sai *et al.,* 2024.

Yield parameters

Evaluation of the crop yield data presented in Table 3 indicates that among the planting patterns two rows per ridge and one in the furrow demonstrated superior performance, producing significantly higher paddy yield (67.6 q/ha) and straw yield (128.2 q/ha) compared to flat unpuddled, flat puddled and two rows/ ridge. Higher yield in two rows per ridge and one in furrow may be due to better weed control and better growth and yield attributes compared to other planting patterns. The results are similar with previous research findings that zero-tillage unpuddled transplanted rice (ZT UPTR) can produce yields equal to or greater than puddled transplanted rice (PTR) under fully irrigated conditions (Islam *et al.,* 2019).

Amongst the weed control treatments, sequential application of pendimethalin (0.75 kg/ha, pre-emergence) and bispyribac sodium 10 SC (25 g/ha, post-emergence)

Table 1: Effect of planting patterns and weed control treatments on weed density, biomass and weed control efficiency of grassy and broadleaf weeds (60 DAT).

Treatments	Grassy weeds		Broadleaf weeds		Weed control efficiency (%)
	Weed density/m^2	Weed biomass (q/ha)	Weed density/m^2	Weed biomass (q/ha)	
Main plots (Planting patterns)					
Two rows/ridge	7.58 (76.4)	2.99 (10.1)	4.97 (29.9)	1.57 (1.6)	58.0
Two rows/ridge + One in furrow	7.04 (65.9)	2.80 (8.6)	4.43 (23.6)	1.46 (1.2)	64.7
Flat unpuddled	8.72 (102.0)	3.42 (13.2)	5.96 (44.2)	1.75 (2.3)	44.4
Flat puddled	8.19 (89.8)	3.22 (11.6)	5.45 (36.8)	1.66 (1.96)	51.6
S.Em(±)	0.13	0.05	0.15	0.02	-
C.D. (5%)	0.41	0.16	0.47	0.06	-
Sub plots (Weed control treatments)					
Pendi., pre-em *f.b.* bispyribac sodium	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	100.0
Pendi., pre-em *f.b.* penoxsulam	7.66 (59.1)	2.83 (7.1)	5.16 (27.5)	1.43 (1.0)	70.8
Pendi., pre-em *f.b.* fenoxaprop-p-ethyl	8.91(80.1)	3.51 (11.5)	7.41 (54.5)	2.00 (2.9)	48.3
Control (unweeded)	13.95 (195.0)	5.09 (24.9)	7.24 (52.6)	2.03 (3.1)	-
S.Em(±)	0.23	0.07	0.21	0.04	-
C.D (5%)	0.67	0.20	0.60	0.10	-
C.D (5%) Interaction	NS	NS	NS	NS	-

Figures without parenthesis are square root transformed values $\sqrt{\chi + 1}$.
Figures with parenthesis are original values.

Table 2: Effect of planting patterns and weed control treatments on plant height, no. of tillers/m^2 and crop dry matter (60 DAT).

Treatments	Plant height (cm)	No. of tillers/ m^2	Dry matter accumulation (q/ha)
Main plots (Planting patterns)			
Two rows/ridge	73.9	338.7	165.0
Two rows/ridge + One in furrow	72.2	382.5	171.0
Flat unpuddled	73.4	290.6	158.3
Flat puddled	73.3	299.1	160.7
S.Em(±)	0.4	6.9	0.9
C.D. (5%)	NS	22.4	2.8
Sub plots (Weed control treatments)			
Pendi., pre-em *f.b.* bispyribac sodium	78.1	392.6	189.0
Pendi., pre-em *f.b.* penoxsulam	76.1	350.2	174.9
Pendi., pre-em *f.b.* fenoxaprop-p-ethyl	73.4	317.2	157.0
Control (unweeded)	65.1	250.9	134.1
S.Em(±)	0.7	11.8	1.2
C.D (5%)	2.0	34.1	3.3
C.D (5%) Interaction	NS	NS	NS

Table 3: Effect of planting patterns and weed control treatments on the paddy and straw yield (q/ha) of rice.

Treatments	Paddy yield (q/ha)	Straw yield (q/ha)
Main plots (Planting patterns)		
Two rows/ridge	63.6	120.3
Two rows/ridge + One in furrow	67.6	128.2
Flat unpuddled	60.2	112.8
Flat puddled	59.0	108.9
S.Em(±)	0.6	2.2
C.D. (5%)	1.9	7.2
Sub plots (Weed control treatments)		
Pendi., pre-em *f.b.* bispyribac sodium	77.9	147.4
Pendi., pre-em *f.b.* penoxsulam	72.7	132.4
Pendi., pre-em *f.b.* fenoxaprop-p-ethyl	68.3	124.0
Control (unweeded)	31.5	66.4
S.Em (±)	0.7	2.5
C.D (5%)	2.1	7.3
C.D (5%) Interaction	NS	NS

resulted in significantly superior paddy (77.9 q/ha) and straw (147.4 q/ha) yields relative to all herbicidal treatments and unweeded control (31.3 q/ha paddy, 66.4 q/ha straw respectively). Paddy yield in post-em. fenoxaprop-p-ethyl was significantly less than bispyribac sodium and penoxsulam treatments. The interaction between different planting patterns and weed control treatments showed no significant impact on paddy yield. The superior outcomes may be due to the sequential application throughout the critical period of crop-weed competition by effectively controlling weeds, this treatment reduces competition for nutrients, water and light, allowing rice plants to utilize resources more efficiently for growth and yield formation. The results of current research align with those reported by Walia *et al.,* 2008 and Saravanane (2020).

CONCLUSION

The outcomes of research suggest that in unpuddled rice cultivation, implementing minor land configuration changes, adopting a specific planting pattern of two rows per ridge and one in the furrow, supported by proper weed control measures (pendimethalin *f.b.* bispyribac sodium) have the capacity to maximize the paddy yields when compared to that of conventional puddled transplanted rice cultivation. Moreover, integrated herbicide approach with the application of pendimethalin (0.75 kg/ha, pre-emergence) and bispyribac10 SC (25 g/ha, post-emergence) proved highly effective in controlling diverse weed populations by targeting both grassy and broadleaved weeds at different growth stages, this herbicide combination significantly reduced weed pressure, resulting in notably increased crop yield, whereas the performance of penoxsulam and fenoxaprop-p-ethyl was inferior to bispyribac sodium.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

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