Evaluation of Sequential Application of Herbicides in Rice-fallow Maize (*Zea mays*)

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ABSTRACT

In Odisha, rice-relay pulse cropping has been a traditional practice, but delayed monsoons have made pulse cultivation increasingly difficult. In this context, rice-fallow maize is gaining prominence. Despite its potential, this system poses unique challenges such as regeneration of rice stubble and enhanced weed growth. Thus, identifying an optimal herbicide sequence for the rice-fallow maize system becomes vital, forming the basis of the present research. The current study was carried out during the *rabi* season of 2023-24 at the P.G. Research Farm of Centurion University of Technology and Management, Odisha. The investigated treatments encompassed the nine treatments *viz.,* one unweeded check, one hand weeding and seven sequential herbicide treatments which were allocated in randomized block design with three replications. The results indicated that the experimental field was infested with grassy and broad-leaved weeds, while no sedges were observed. At 80 DAS, weed density and weed dry matter were highest in the weedy check (H9), whereas pendimethalin @ 1 kg *a.i.* ha^{-1} as PE *fb* Topramezone + Atrazine (1:10) @ 25.2 *a.i.* ha^{-1} as PoE at 20 and 40 DAS (H6) recorded the lowest, resulting in a weed control efficiency of 94.64%. The H6 treatment significantly improved dry matter accumulation, grain, stover and biological yield of fallow maize. Therefore, recommended for effective weed control in rice-fallow maize systems.

Key words: Grain yield, Maize, Weed control efficiency, Weed density, Weed dry matter.

Due to growing food demand by the rapidly expanding population, utilizing the fallow period for a second crop has become essential. In Odisha, rice-relay pulse cropping is a commonly practiced sequence (Kumar *et al.*, 2018). Yet, over the past decade, cultivation pulse crops in the region was ought to be challenging. In addition, delayed monsoons have postponed the transplanting of *kharif* rice, thereby negatively affecting the sowing window for pulses (Jena *et al.*, 2020). In this context, maize cultivation during the fallow period is gaining attention due to its adaptability to challenging conditions. In India maize covers an area of approximately 10.04 million hectares, with a production of 33.62 million tonnes and an average productivity of 3349 kg ha^{-1} (GoI, 2023). Similarly, in Odisha, maize occupies about 272.15 thousand hectares, producing 869 thousand tonnes with a productivity of 3194 kg ha^{-1} (GoO, 2023).

In rice-maize cropping sequence 25-30% of energy is consumed during conventional field preparation (Kadiyala *et al.,* 2012). This not only reduces farm profitability but also delays maize sowing, ultimately lowering productivity. To overcome this, the rice-fallow maize system is emerging as an efficient and promising alternative. Despite its potential, this system poses unique challenges such as regeneration of rice stubble and enhanced weed growth. In maize, the critical period for weed competition is typically the first 45 days after sowing (DAS), beyond which weeds have minimal impact on yield (Kumar *et al.*, 2015; Hussen, 2021). Yield losses due to weed in maize varies from 28 to 93%, depending on the type of weed flora and intensity and duration of crop weed competition (Mhlanga *et al.,* 2016). As a result, effective weed management within the first 8 weeks after sowing is essential to reduce competition and ensure optimal maize growth and yield (Ullah *et al.*, 2008; Singh *et al.,* 2023).

However, despite the importance of managing weeds during this period, timely weeding is often hampered by labour shortages and the unavailability of suitable equipment for efficient weed management in the rice-fallow maize system. In this context, determining the most effective herbicide sequence (Pre and post-emergence application of herbicides) for maize cultivation in the rice-fallow system became crucial. To address this research gap the present research was conducted.

A field experiment was carried out at Post-Graduation Research Farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Odisha (18.80° N latitude, 84.18° E longitude and at an altitude of 89 meters above mean sea level) during *rabi* season of 2023-24. During the period of experimentation,

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the total amount of rainfall received was 188.5 mm with the maximum temperature ranged between 28.7°C to 42.2°C and the minimum temperature ranged between 14.5°C to 27.9 °C. In the morning, the relative humidity ranged between 77% to 87.4% and in the afternoon, the relative humidity ranged between 38.3% to 70.3% during the crop growing period. Moreover, the weekly sunshine hours, pan evaporation and wind velocity during the crop growing period ranged from 5.7 hrs day^{-1} to 9 hrs day^{-1}, 1.6 mm to 4.8 mm and 3.6 km hr^{-1} to 7.1 km hr^{-1}, respectively.

The soil in the experimental field was sandy loam in texture, slightly acidic in reaction (6.4), low in organic carbon (0.35%) and available nitrogen (194.5 kg ha^{-1}) but medium in available phosphorus (14.5 kg ha^{-1}) and available potassium (126.4 kg ha^{-1}) with an electrical conductivity at a safer range (0.7 dSm^{-1}). The present study was conducted on Maize hybrid *viz.,* NMH 8352 (Winner) with a recommended dose of fertilizer of 120-60-60 kg N-P_2O_5-K_2O ha^{-1}.

The present study consisted of nine treatments with three replications laid out in randomized block design (Table 1). The data observed was analyzed statistically using analysis of variance (ANOVA). The statistical analysis mainly involved the calculation of standard error of means (SEm±) and critical difference at 5 per cent level of significance (Gomez and Gomez, 1984). Further, the data was presented with alphabets superscripting the integers and the same letters as a superscript indicate that those treatments did not vary significantly at 5 per cent level of significance.

The experimental field was infested with grasses and broad-leaved weeds, while no sedges were detected throughout the investigation. The weed species identified during the study included *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Cynodon dactylon*, *Echinochloa colona*, *Eragrostis unioloides* and *Chloris radiata* among the grasses, as well as *Phyllanthus amarus*, *Parthenium hysterophorus*, *Euphorbia hirta*, *Amaranthus viridis* and *Diger amuricata* among the broad-leaved weeds.

The perusal of data in Table 2 revealed that at 80 DAS, the weed density and weed dry matter were significantly influenced by sequential application of herbicides. The highest weed density and weed dry matter was noted by H9. It was attributed to the adoption of no weed control measures that allowed weeds to grow unchecked throughout the study period resulting in higher weed dry matter. On the other hand, the lowest weed density was noted by H6 which was on par with H2. It was attributed to the pre-emergence application of pendimethalin at 1 kg a.i. ha^{-1} created a soil barrier that inhibited the germination and emergence of weed seeds, ensuring lower weed density during early crop establishment. This was followed

Table 1: Treatment details.

Treatments	Treatment details
H1	Atrazine @ 1 kg a.i./ha as PE (Pre emergence)
H2	Atrazine @ 1 kg a.i/ha as PE *fb* Tembotrione + Atrazine(1:10) 750 g a.i/ha as PoE (Post emergence) at 20 and 40 DAS
H3	Atrazine @ 1 kg a.i./ha as PE *fb* Topramezone + Atrazine (1:10) 25.2 g a.i/ha as PoE at 20 and 40 DAS
H4	Atrazine @ 1 kg a.i./ha as PE *fb* Mesotrione + Atrazine (Ready mix) @ 750 gm a.i/ha as PoE at 20 and 40 DAS
H5	Pendimethalin @ 1 kg a.i./ha as PE *fb* Tembotrione + Atrazine(1:10) 750 g a.i/ha as PoE at 20 and 40 DAS
H6	Pendimethalin @ 1 kg a.i./ha as PE *fb* Topramezone + Atrazine (1:10) 25.2 g a.i/ha as PoE at 20 and 40 DAS
H7	Pendimethalin @ 1 kg a.i./ha as PE *fb* Topramezone + Atrazine (1:10) 25.2 g a.i/ha as PoE at 20 and 40 DAS
H8	Hand weeding at 20 and 40 DAS
H9	Weedy check

Table 2: Effect of sequential application of herbicides on weed and growth parameters of rice-fallow maize during summer season, 2024.

Treatments	Weed density	Weed dry matter (g 0.25 m^{-2})	Weed control efficiency (%)	Plant height (cm)	Dry matter accumulation (g m^{-2})
H1	4.26^{b} (14.66)	3.95^{b} (12.51)	60.73	253^{a}	528^{ab}
H2	1.64^{ef} (2.0)	1.84^{de} (2.06)	94.64	257^{a}	592^{a}
H3	2.23^{cde} (3.0)	1.25^{e} (0.84)	91.96	258^{a}	496^{b}
H4	2.18^{de} (5.66)	3.18^{bc} (7.77)	84.84	262^{a}	492^{b}
H5	2.63^{cd} (5.0)	1.87^{de} (2.33)	86.61	262^{a}	497^{b}
H6	1.31^{f} (2.0)	1.19^{e} (0.57)	94.64	259^{a}	598^{a}
H7	2.88^{c} (5.66)	2.51^{cd} (4.38)	84.84	255^{a}	461^{b}
H8	2.57^{cd} (4.33)	1.72^{de} (1.56)	88.40	262^{a}	482^{b}
H9	6.60^{a} (37.33)	16.74^{a} (19.63)	-	246^{a}	517^{b}
S.Em,±	0.22	0.30	-	11.1	24
CD (P=0.05)	0.66	0.90	-	NS	71

*Figures in parentheses are original values. The data on weed density are of square root transformation values (√X ± 0.5).

by the post-emergence application of topramezone + atrazine (1:10) at 25.2 kg a.i. ha^{-1}, which might have provided effective control of both grassy and broadleaf weeds at later growth stages. The combined action of these herbicides resulted in significantly reduced weed density. Further, lower weed density by the former treatment might have attributed to significantly lower weed dry matter because fewer weeds mean less overall biomass accumulation which was on par with H2, H3 and H5 Ultimately, the former treatment exhibited the highest weed control efficiency. This discussion was in close conformity with Gupta *et al.* (2018); Akhtar *et al*. (2015); Rani *et al.* (2022) and Mitra *et al.* (2018) in maize.

The perusal of data in Table 2 revealed that apart from plant height of rice-fallow maize all other growth parameters *viz.,* dry matter accumulation were significantly influenced by sequential application of herbicides in rice-fallow maize. Among the treatments, the H6, effectively controlled weeds, reducing competition for nutrients, water and light. This might have led to better crop growth, enhanced photosynthesis and higher dry matter accumulation in rice-fallow maize at 80 DAS. The former treatment was statistically comparable with H2. However, the plant height was not influenced by the treatments applied in the present investigation since, maize plant height is largely governed by genetic factors and herbicides used in the experiment might not have plant growth-promoting effect. This discussion was in strong corroboration with the findings of Acharya *et al.* (2022), Verma *et al.* (2009) and Wiqar *et al.* (2021) in maize.

The significant influence in cob length and the number of grains per row (Table 3), leading to maximum grain yield in rice-fallow maize, could be attributed to reduced weed competition for nutrients and moisture due to H6. This treatment allowed maize plants to utilize more nutrients, water and sunlight, promoting better cob development and grain filling. Compared to other treatments, including the H1and H9, this strategy was superior because pendimethalin provided broader and longer-lasting weed suppression. As a result, H6 recorded (Table 4) was significantly higher grain yield of 19.00% over H3, 15.84% over H1 and 29.16% over H9 demonstrating the effectiveness of this herbicide sequence in optimizing maize productivity. The discussion was in close conformity with Triveni *et al.* (2017), Agrawal *et al.* (2019) and Chopra *et al.* (2008) in maize. However, cob girth, number of rows per cob and 100 seed weight (Table 3) recorded no significant variation with sequential application of pre and post emergence herbicides because these traits are relative stable genetic characteristics of maize variety which were significantly not influenced by agronomic management. Similarly, results are observed in Sairam

Table 3: Effect of sequential application of herbicides on yield attributes of rice-fallow maize during summer season, 2024.

Treatments	Cob length (cm)	Cob girth (cm)	No. of rows/cob	No. of grains/Row	100 seed weight (g)
H1	18.73^{ab}	14.57^{b}	14.20^{ab}	38.27^{c}	27^{a}
H2	17.50^{b}	16.03^{a}	14.23^{ab}	39.43^{c}	29.33^{a}
H3	19.37^{a}	15.91^{a}	14.50^{ab}	40.40^{bc}	26.50^{a}
H4	19.37^{a}	16.30^{a}	14.47^{ab}	42.47^{ab}	29.00^{a}
H5	20.00^{a}	14.57^{b}	14.60^{a}	39.50^{c}	28.50^{a}
H6	20.13^{a}	16.53^{a}	13.87^{b}	43.20^{a}	29.50^{a}
H7	18.83^{ab}	15.70^{ab}	13.90^{b}	40.60^{abc}	28.50^{a}
H8	18.70^{ab}	16.07^{a}	13.83^{b}	40.60^{abc}	27.50^{a}
H9	17.43^{b}	15.58^{ab}	13.93^{ab}	35.50^{d}	25.83^{a}
S.Em,±	1.39	0.7	0.50	1.40	1.57
CD (P=0.05)	4.18	NS	NS	4.18	NS

Table 4: Effect of sequential application of herbicides on yield and harvest index of rice-fallow maize during summer season, 2024.

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
H1	8556^{bcd}	11514^{bc}	20070^{b}	42.79^{ab}
H2	9768^{ab}	14462^{a}	24230^{a}	40.27^{ab}
H3	8329^{cd}	11438^{bc}	19767^{b}	42.02^{ab}
H4	9693^{ab}	11978^{b}	21671^{b}	44.99^{a}
H5	9002^{abcd}	10502^{bc}	19504^{bc}	46.17^{a}
H6	9912^{a}	16324^{a}	26237^{a}	37.71^{b}
H7	9358^{abc}	11753^{b}	21111^{b}	44.33^{a}
H8	8890^{abcd}	10878^{bc}	19768^{b}	44.94^{a}
H9	7674^{d}	9578^{c}	17252^{c}	44.70^{a}
S.Em,±	449.6	697.3	793.1	2.01
CD (P=0.05)	1348	2091	2378	NS

et al. (2023); Jadhav *et al.* (2022) in maize and Reddy *et al.* (2012) in rice. Moreover, due to cumulative effect of plant height and dry matter accumulation and ultimately enhanced the grain yield of rice-fallow maize further attributed H6 to attribute the highest stover yield and biological yield.

CONCLUSION

Based on the findings, the pre-emergence application of pendimethalin @ 1 kg a.i./ha followed by post-emergence application of topramezone + atrazine @ 25.2 a.i ha^{-1} at 20 and 40 DAS is recommended for effective weed control, enhanced crop growth and productivity in rice-fallow maize systems.

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Disclaimers

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Informed consent

None.

Conflict of interest

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