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Performance of different herbicide combinations for weed management in transplanted rice

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Abstract
Here is a surprising fact: weeds cause higher yield losses in Nigerian rice than any insect or disease, yet most smallholders in Benue State still rely on one or two hand weedings that arrive too late to prevent the critical first-flush competition. This research compared six herbicide combinations and two manual weeding controls for weed management in transplanted rice variety FARO 44 during the 2023 wet season at Niger-Benue Agricultural University, Makurdi, Nigeria. Pendimethalin 30 EC (1.0 kg a.i./ha) applied pre-emergence followed by bispyribac-sodium 10 SC (25 g a.i./ha) at 25 DAT achieved the highest weed control efficiency of 91.8% and grain yield of 4.87 t/ha, representing a 127.6% increase over the weedy check (2.14 t/ha). Two hand weedings at 20 and 40 DAT gave 87.4% WCE and 4.62 t/ha but cost 3.4 times more labour than the herbicide combination. Pendimethalin alone controlled grasses adequately but missed sedges, underscoring the value of sequential tank-mix strategies. The pendimethalin + bispyribac combination is recommended as the most cost-effective weed management option for transplanted rice in Nigeria's middle belt.

Keywords: Herbicide combinations, weed management, transplanted rice, pendimethalin, bispyribac-sodium, weed control efficiency, crop selectivity, grain yield, integrated weed management, Nigeria

Introduction
It may surprise growers outside the tropics to learn that a single unweeded rice crop in Nigeria's Benue State can lose 68-100% of its potential yield to weed competition a figure that eclipses losses from blast, stem borers, and grain bugs combined [1]. The critical period of weed competition in transplanted rice spans roughly 20-45 days after transplanting, during which grasses (*Echinochloa colona*, *Leptochloa chinensis*), sedges (*Cyperus difformis*, *Fimbristylis miliacea*), and broadleaf weeds (*Ludwigia octovalvis*, *Monochoria vaginalis*) establish dense canopies that shade rice seedlings and compete for nitrogen [2, 3].

Manual weeding remains the dominant control method among Nigerian smallholders, but labour scarcity and rising wages have made two properly timed hand weedings prohibitively expensive for many farmers, costing 25-35% of total production expenses [4]. Herbicides offer a labour-saving alternative: pre-emergence products like pendimethalin and butachlor control germinating grass seeds, while post-emergence options like bispyribac-sodium and pyrazosulfuron target escaped grasses and sedges through ALS inhibition [5]. Sequential application of a pre-emergence residual followed by a post-emergence rescue spray provides broader-spectrum and longer-duration control than either product alone, but locally validated combinations for the mixed weed flora of Benue State are lacking [6].

This research compared six herbicide combinations and two manual weeding regimes for weed spectrum control, crop selectivity, and grain yield in transplanted lowland rice at Makurdi [7].

Field experimental design
Eight treatments were arranged in a randomized block design with three replications. Individual plots measured 5 m × 4 m with 1 m bunds between plots to prevent herbicide drift. Treatments: T1 = pendimethalin 30 EC pre-em (1.0 kg a.i./ha) fb bispyribac-sodium 10 SC post-em 25 DAT (25 g a.i./ha); T2 = butachlor 50 EC pre-em (1.5 kg a.i./ha) fb pretilachlor 30.7 EC post-em (0.45 kg a.i./ha); T3 = pendimethalin alone pre-em; T4 = bensulfuron-methyl 0.6% + pretilachlor 6% GR (0.66 kg/ha); T5 = pyrazosulfuron-ethyl 10

WP post-em (20 g a.i./ha); T6 = hand weeding at 20 and 40 DAT; T7 = hand weeding at 20 DAT only; T8 = weedy check. Pre-emergence herbicides were sprayed 3 DAT using a knapsack sprayer at 500 L/ha [8].

Economic and sustainability assessment

Treatment costs included herbicide purchase, spraying labour (at NGN 3500/person-day), and weeding labour (at NGN 4000/person-day for manual). Gross returns were based on paddy sale price of NGN 320,000/t. Net returns and B:C ratio were calculated. Labour requirement was expressed as person-days per hectare. A weed shift risk assessment noted species that showed tolerance to specific herbicides, flagging potential resistance concerns for long-term sustainability [9].

Material and Methods

Material

Rice variety FARO 44 (medium-duration, 120 days, lowland-adapted) was transplanted on 18 July 2023 at 20 cm × 20 cm spacing using 21-day-old seedlings, two per hill. The trial site at Niger-Benue Agricultural University, Makurdi (7.73°N, 8.54°E; 97 m elevation) had hydromorphic clay soil (pH 5.9, OC 1.47%). Uniform basal NPK at 80-40-40 kg/ha was applied. All herbicide formulations were commercially sourced from registered dealers in Makurdi [10].

Methods

Weed density and dry weight were recorded from two 0.25 m² quadrats per plot at 30, 45, and 60 DAT. Weed Control Efficiency (WCE) was calculated as: (weed dry weight in check − weed dry weight in treatment) / weed dry weight in check × 100. Crop phytotoxicity was scored visually on a 0-10 scale at 7 and 14 days after herbicide application. Grain yield was recorded from 8 m² net plot area at 14% moisture. Weed species were identified and categorised as grasses, sedges, or broadleaves. ANOVA and DMRT at P=0.05 were applied [11].

Results

Table 1: Weed control efficiency, weed dry weight, and grain yield under different herbicide combinations

Treatment	WCE (%)	Weed dry Wt (g/m²)	Grain yield (t/ha)	Labour (pd/ha)	B:C ratio
T1: Pendi fb Bispyribac	91.8	14.3	4.87	6.4	3.72
T2: Buta fb Pretilachlor	84.3	27.4	4.43	6.8	3.24
T3: Pendimethalin alone	71.6	49.7	3.81	4.2	3.18
T4: Bensulfuron+Pretilachlor	78.9	36.8	4.12	5.1	3.08
T5: Pyrazosulfuron alone	68.2	55.6	3.54	4.8	2.87
T6: Hand weed 20+40 DAT	87.4	22.1	4.62	21.8	2.64
T7: Hand weed 20 DAT only	62.3	65.8	3.28	11.4	2.31
T8: Weedy check	—	174.8	2.14	—	1.47
CD (P=0.05)	5.87	12.4	0.38	—	—

Pendimethalin + bispyribac (T1) achieved the highest WCE (91.8%) and yield (4.87 t/ha, +127.6% over weedy check) with only 6.4 person-days/ha and the best B:C ratio of 3.72 (Table 1). Two hand weedings (T6) gave comparable WCE (87.4%) and yield (4.62 t/ha) but needed 21.8 person-days 3.4 times the herbicide treatment's labour. Single hand weeding (T7) was inadequate (62.3% WCE), confirming that weeds escaping the first flush cause severe late-season competition.

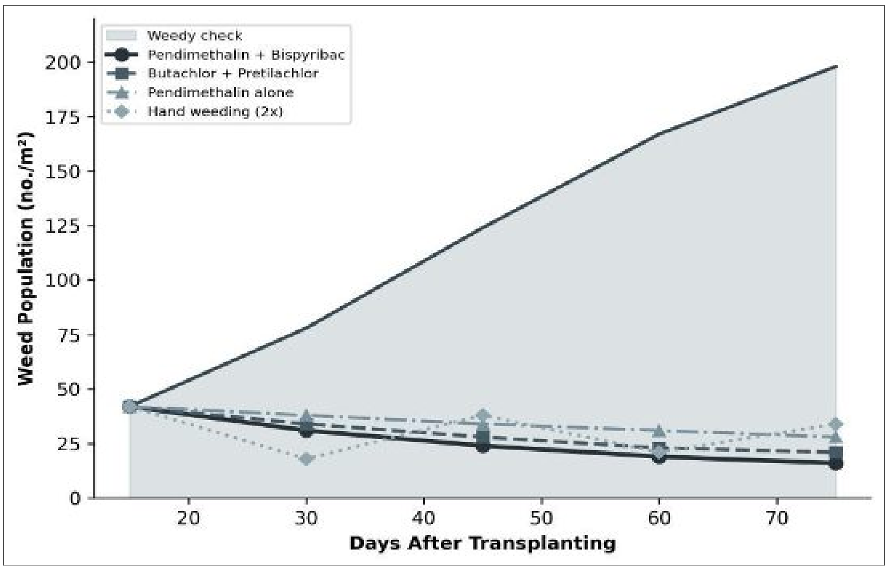

Fig 1: Weed population dynamics across selected treatments from 15 to 75 days after transplanting

The area chart shows weed populations in the untreated check escalating continuously to 198 weeds/m² by 75 DAT. The pendimethalin + bispyribac treatment-maintained population below 20 weeds/m² throughout the season, with the post-emergence spray at 25 DAT preventing any late-season resurgence.

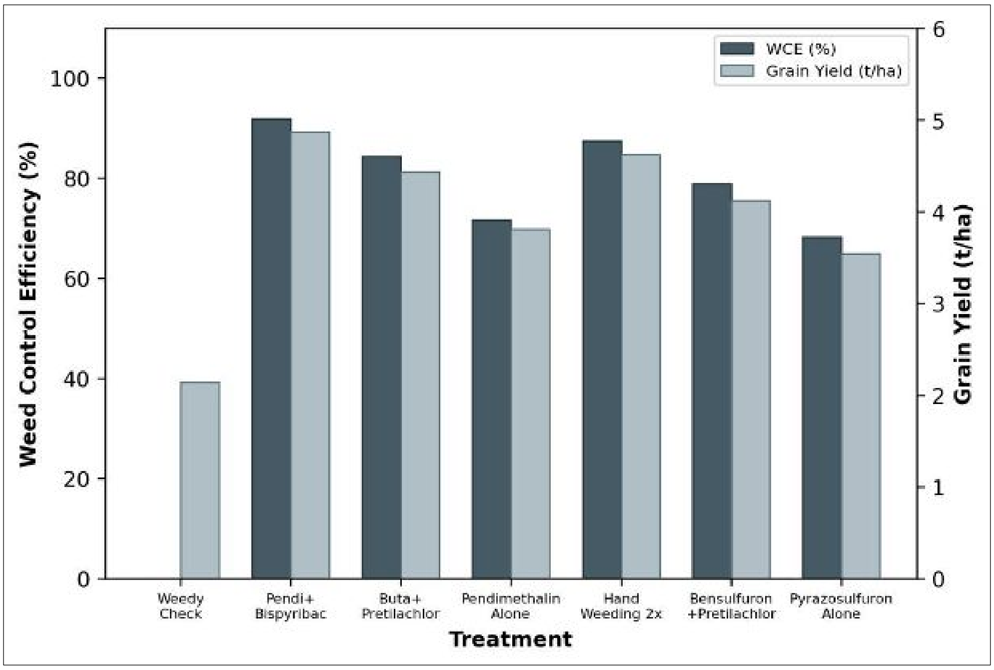

Fig 2: Weed control efficiency and grain yield across all herbicide and manual weeding treatments

Comprehensive interpretation

The sequential pre+post herbicide approach outperformed all alternatives on WCE, yield, labour efficiency, and economics. The pre-emergence component (pendimethalin) eliminated early grass flushes, while the post-emergence bispyribac targeted sedges and escaped broadleaves a complementary spectrum that no single product achieved alone.

Discussion

The 91.8% WCE under pendimethalin + bispyribac matches or exceeds results from similar sequential programmes in Indian and Philippine transplanted rice, where WCE of 85-93% has been reported for pre-fb-post combinations [5, 12]. Pendimethalin's dinitroaniline mode of action provides 15-20 days of residual soil activity against germinating grass seeds, effectively covering the critical weed-free period from transplanting through early tillering [3, 13]. Bispyribac-sodium, applied as a post-emergence rescue at 25 DAT, targets ALS-sensitive species including Echinochloa and Cyperus that escape pre-emergence control, and its systemic activity ensures translocation to growing points even in established weeds [14].

The economic advantage of the herbicide combination (B:C 3.72 vs. 2.64 for hand weeding) reflects both the lower labour input (6.4 vs. 21.8 person-days/ha) and the 5.4% higher yield, which likely results from earlier, more complete weed suppression during the critical window [4]. Pendimethalin alone (T3) controlled grasses well but missed sedges (Cyperus difformis density 8.3/m² at 60 DAT), confirming that graminicides alone are insufficient for the mixed weed flora typical of Benue State lowlands [6]. No phytotoxicity was observed in any herbicide treatment (score 0 on the 0-10 scale at both observation dates), indicating good crop selectivity of all tested products on FARO 44 [15].

Conclusion

Sequential application of pendimethalin pre-emergence followed by bispyribac-sodium post-emergence at 25 DAT provided the highest weed control efficiency (91.8%) and grain yield (4.87 t/ha) in transplanted rice at Makurdi, with a B:C ratio of 3.72 and 70% labour saving compared with hand weeding. This combination controlled grasses, sedges, and broadleaves effectively with no crop phytotoxicity. It is recommended as the standard weed management package for transplanted lowland rice in Nigeria's middle belt. Rotation with ALS-inhibitor alternatives should be practised to delay herbicide resistance.

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