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Effect of integrated weed management on growth and green fodder yield of multicut fodder sorghum (CO 31)

C Nithya, V Ramesh, S Ramakrishnan, V Boopathi and M Sathiyabarathi

C Nithya
Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India

V Ramesh
Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India

S Ramakrishnan
Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India

V Boopathi
Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India

M Sathiyabarathi
Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India

Corresponding Author:
C Nithya
Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu, India

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Abstract
A field experiment was conducted during 2024 - 2025 at the Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, to evaluate suitable and effective integrated weed management practices for multicut fodder sorghum. The study was laid out in a randomized block design with seven treatments of integrated weed management practices, replicated thrice. Observations were recorded on weed density, weed dry weight, crop growth parameters and green fodder yield. Results indicated that all weed management practices significantly reduced weed density and dry weight, leading to marked improvements in crop growth and green fodder yield. Among the treatments, pre-emergence application of atrazine at 0.50 kg a.i./ha followed by one hand weeding at 30 days after sowing proved to be the most effective and economical practice for weed control and yield enhancement. This was closely followed by hand weeding twice, at 30 and 60 days after sowing, which also provided effective weed control and higher green fodder yield.

Keywords: Multicut fodder sorghum, integrated weed management, weed control, green fodder yield

Introduction
Fodder availability is a critical determinant of livestock productivity, particularly in developing countries such as India, where the livestock sector plays a significant role in rural livelihoods and food security. Among forage crops, multicut fodder sorghum (*Sorghum bicolor* L. Moench) has become a preferred choice due to its high biomass yield, superior nutritive value, and ability to regenerate after successive harvests (Rani *et al*., 2017) [11]. The hybrid variety CO 31, developed by Tamil Nadu Agricultural University, has gained prominence for its suitability in multicut systems, offering high green fodder yield potential, palatability, and tolerance to abiotic stresses (Karthikeyan *et al*., 2020) [8].

However, fodder sorghum productivity is significantly constrained by weed competition, particularly during the early stages of crop establishment. Weeds compete with crops for essential resources such as light, moisture, nutrients, and space, resulting in reduced growth, poor tillering, and lower biomass accumulation. Yield losses in fodder sorghum due to weed infestation can range from 30% to 60%, depending on weed species composition and management practices (Gharde *et al*., 2018) [5]. Additionally, the presence of toxic or invasive weeds can deteriorate forage quality and pose health risks to livestock.

Conventional weed management practices in fodder sorghum typically involve manual weeding and chemical herbicide application. While herbicides are effective, their continuous use has led to several ecological and agronomic concerns, including herbicide-resistant weed biotypes, soil and water contamination, and potential health hazards from herbicide residues in fodder (Choudhary and Kumar, 2019) [3]. Manual weeding, though environmentally safe, is labor-intensive, costly, and often impractical in large-scale operations or during periods of peak labor demand.

To address these challenges, Integrated Weed Management (IWM) has emerged as a sustainable and ecologically sound strategy for weed control. IWM involves the integration of cultural, mechanical, biological, and chemical approaches to manage weed populations in an economically viable and environmentally safe manner (Rao, 2011) [10]. In fodder sorghum, IWM practices may include the use of competitive varieties such as CO 31, timely sowing, optimal seeding rates, inter-row cultivation, and selective pre- and post-emergence herbicide applications to achieve effective weed suppression and improved crop performance.

Adoption of IWM not only enhances weed control efficiency but also promotes better crop growth by improving physiological traits such as plant height, tiller number, leaf area index, and total dry matter accumulation (Yadav *et al*., 2021) [15]. Improved crop vigor translates into higher green fodder yield, better forage quality, and enhanced sustainability of production systems. Furthermore, IWM aligns with climate-smart agricultural principles by reducing chemical dependence and supporting biodiversity and soil health (Bhullar and Chauhan, 2015) [1].

Despite its potential, research on IWM in fodder production systems, particularly in multicut sorghum, remains limited. Most studies have focused on grain crops, while the specific requirements and outcomes of IWM in forage systems are less documented. Therefore, the present study was undertaken to evaluate the impact of integrated weed management practices on the growth attributes and green fodder yield of multicut fodder sorghum (CO 31), with the objective of identifying economically feasible and environmentally sustainable weed management strategies.

Materials and Methods

Experimental Site and Season

A field experiment was conducted during 2024–2025 at the Livestock Farm Complex, Veterinary College and Research Institute, Namakkal, Tamil Nadu. The site is located at 11.22°N latitude and 78.17°E longitude, with an altitude of 218 m above mean sea level. The soil was alkaline (pH 7.54), high in organic carbon (0.97%), low in available nitrogen (245 kg ha^{-1}), high in available phosphorus (31.25 kg ha^{-1}) and medium in available potassium (182 kg ha^{-1}). The experiment was laid out in a Randomized Block Design (RBD) with seven integrated weed management treatments, replicated three times. The treatments are, T_1 - Atrazine @ 0.50 kg a.i./ha as pre-emergence (PE) + one hand weeding at 30 days after sowing (DAS), T_2 - Pendimethalin @ 0.50 kg a.i./ha as PE + one hand weeding at 30 DAS, T_3 - Atrazine @ 0.50 kg a.i./ha as PE + twin wheel hoe weeding at 30 DAS, T_4 - Pendimethalin @ 0.50 kg a.i./ha as PE + twin wheel hoe weeding at 30 DAS, T_5 - Hand weeding at 30 and 60 DAS, T_6 - Twin wheel hoe weeding at 30 and 60 DAS and T_7 - Weedy check (Unweeded control). Each plot measured 6 m × 4 m. The multicut fodder sorghum variety CO 31 was used as the test crop and sown at a row spacing of 30 cm using a seed rate of 5 kg ha^{-1}.

Weed Parameters

Weed Density

Weed density was assessed using a 0.5 m × 0.5 m (0.25 m²) quadrat placed at four randomly selected spots in each plot. All weeds within the quadrat were counted, and mean values were expressed as number of weeds m^{-2} following the procedure of Burnside and Wicks (1965) [2]. Observations were recorded at 30 and 60 days after sowing (DAS).

Weed Dry Weight

Weeds sampled within the quadrat were shade-dried and then oven-dried at 80°C for 72 hours to determine dry weight. Values were recorded at 30 and 60 DAS and expressed as g m^{-2}.

Weed control efficiency

Weed control efficiency (WCE) was calculated as per the procedure given by Mani *et al.* (1973) [9] and expressed in percentage.

$$WCE = \frac{WDC - WDT}{WDC} \times 100$$

Where, WDC - Weed dry weight in unweeded control plot (kg ha^{-1})

WDT - Weed dry weight in treated plot (kg ha^{-1})

Statistical Analysis

Data were analyzed using the standard procedures for Randomized Block Design as outlined by Gomez and Gomez (2010) [6]. Weed density and germination data were square-root transformed before analysis. Treatment means were compared using the critical difference (CD) at the 5% probability level whenever significant differences were observed.

Results and Discussion

Weed Flora of the Experimental Field

The experimental field was infested with a mixed population of broadleaved, grassy, and sedge weeds. Broadleaved weeds predominated, with five major species like *Boerhaavia diffusa*, *Trianthema portulacastrum*, *Cleome gynandra*, *Digera arvensis*, and *Abutilon indicum*. Among the grassy weeds, *Cynodon dactylon* and *Dactyloctenium aegyptium* were dominant. The sedge species *Cyperus rotundus* was also present and represented the only sedge weed in the experimental area.

Table 1: Details of weed species found in the experimental field

Botanical Name	Common Name	Habit	Family
A. Broadleaved weeds			
Boerhaavia diffusa (L)	Hog weed	Perennial	Nyctaginaceae
Trianthema portulacastrum	Giant pig weed	Annual	Aizoaceae
Cleome gynandra.	African cabbage	Annual	Cleomaceae
Digera arvensis	False amaranth	Annual	Amaranthaceae
Abutilon indicum	Country mallow	Annual	Malvaceae
B. Grassy weeds			
Cynodon dactylon	Bermuda grass	Perennial	Poaceae
Dactyloctenium aegyptium	Egyptian crowfoot grass	Annual	Poaceae
B. Sedge weed			
Cyperus rotundus	Purple nut sedge	Perennial	Cyperaceae

Weed Density

Weed control treatments significantly influenced total weed density at 45 days after sowing (DAS) (Table 2). The lowest weed density (27.35 plants m^{-2}) was recorded under hand weeding at 30 and 60 DAS, which was statistically comparable to atrazine @ 0.50 kg a.i. ha^{-1} applied as pre-emergence (PE) followed by one hand weeding at 30 DAS (30.52 plants m^{-2}) and pendimethalin @ 0.50 kg a.i. ha^{-1} as PE followed by one hand weeding at 30 DAS. These treatments effectively suppressed weed emergence through timely mechanical and/or chemical interventions, thereby reducing weed density significantly. Similar findings have been reported by Vijayakumar *et al*. (2014) [14] and Galon *et al*. (2016) [4], who observed lower weed densities with atrazine and pendimethalin or alachlor in combination.

Treatments involving twin wheel hoe weeding (T_3, T_4, and T_6) were comparatively less effective, with weed densities ranging from 42 to 68 plants m^{-2}. The higher weed density was observed in the unweeded control (T_7), which recorded 155 plants m^{-2}, indicating severe weed infestation under unmanaged conditions.

Weed Dry Matter

Weed dry matter accumulation exhibited a trend similar to weed density (Table 2). The lowest weed dry matter was obtained with hand weeding at 30 and 60 DAS (5.8 g m^{-2}), followed by atrazine @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS (9.5 g m^{-2}) and pendimethalin @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS (12.0 g m^{-2}). These treatments were statistically on par and effective in minimizing weed biomass through efficient suppression facilitated by integrated chemical and manual weed control.

In contrast, the unweeded control (T_7) recorded the maximum weed dry matter (85.0 g m^{-2}), reflecting unchecked weed growth and intense competition with the crop. Twin wheel hoe weeding treatments (T_3, T_4, and T_6) recorded intermediate weed dry matter values (14.5 - 20.0 g m^{-2}), indicating moderate weed suppression. These findings reinforce the advantage of combining chemical and mechanical methods for effective weed management. Ishaya *et al.* (2007) [7] similarly emphasized that integrating pre and post-emergence herbicides with cultural and mechanical practices enhances weed suppression and reduces weed biomass.

Table 2: Effect of integrated weed management practices on weed density (No./m^2), weed dry weight (gm/m^2) and weed control efficiency (%) at 45 DAS in multicut fodder sorghum

Treatments	Weed Density (No./m^2)	Weed Dry Matter (gm/m^2)	Weed Control Efficiency (%)
T_1 - Atrazine + HW @ 30 DAS	5.70 (30.52)	3.39 (9.50)	83
T_2 - Pendimethalin + HW @ 30 DAS	6.36 (38.46)	3.74 (12.0)	79
T_3 - Atrazine + Twin WHW @ 30 DAS	6.65 (42.23)	4.06 (14.5)	75
T_4 - Pendimethalin + Twin WHW @ 30 DAS	7.18 (49.6)	4.42 (17.5)	69
T_5 - HW at 30 & 60 DAS	5.42 (27.35)	2.79 (5.8)	90
T_6 - Twin WHW @ 30 & 60 DAS	8.39 (68.34)	4.69 (20.0)	65
T_7 - Weedy check	12.54 (155.23)	9.33 (85.0)	0.0
SEd	0.52	0.31	-
CD (P = 0.05)	1.06	0.64	-

*Figures in parenthesis are original values

Weed Control Efficiency

Weed control efficiency (WCE) varied significantly among treatments (Table 2). The highest WCE (90%) was recorded under hand weeding at 30 and 60 DAS (T_5), closely followed by atrazine @ 0.50 kg a.i. ha^{-1} as pre-emergence (PE) + one hand weeding at 30 DAS (T_1). These treatments demonstrated superior weed suppression through timely interventions combining manual and chemical methods. Similar results were reported by Sukhpreet Singh *et al.* (2019) [12], who observed maximum WCE with hand weeding at 20 and 30 DAS. Treatments T_2, T_3, and T_4 also achieved reasonably good WCE, ranging from 69% to 79%. In contrast, the unweeded control (T_7) recorded 0% WCE, highlighting the extent of weed competition in the absence of management. The superior performance of T_1 and T_5 was consistent with their reduced weed density and dry matter, underscoring the effectiveness of integrated weed management (IWM).

Plant Height

Plant height was significantly influenced by weed management practices (Table 3). The tallest plants were observed in hand weeding at 30 and 60 DAS (T_5), statistically on par with atrazine @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS (T_1), which recorded 238 cm. These treatments minimized weed competition during the critical early growth stages, facilitating enhanced plant vigor. Conversely, the shortest plants (147 cm) were recorded in the weedy check (T_7), where nutrient and moisture competition from weeds severely restricted crop growth. Similar findings were reported by Thakur *et al.* (2016) [13], who observed maximum plant height and dry matter with integrated chemical and manual weed control in rainy season sorghum.

Number of Tillers per Plant

Tillering, a key determinant of biomass production, was significantly affected by weed management (Table 3). The highest number of tillers (14.5) was recorded in hand weeding at 30 and 60 DAS (T_5), followed by atrazine @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS (T_1) with 13.2 tillers per plant. These treatments provided effective weed suppression, allowing optimal nutrient uptake and promoting tiller development. In contrast, the weedy check (T_7) produced the lowest number of tillers (7.0), indicating severe suppression due to weed interference. Sukhpreet Singh *et al.* (2019) [12] also reported similar improvements in tillering under integrated weed management.

Number of Leaves per Plant

The number of leaves per plant followed a trend similar to plant height and tillering (Table 3). The maximum leaf count (97 leaves per plant) was recorded under hand weeding at 30 and 60 DAS (T_5), followed by atrazine @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS (T_1) with 91 leaves per plant. Treatments involving twin wheel hoe weeding recorded intermediate values, whereas the lowest leaf count (55 leaves per plant) occurred in the weedy check (T_7). Superior leaf production under effective weed control treatments can be attributed to improved light interception and reduced competition during early crop growth.

Green Fodder Yield

Green fodder yield was markedly influenced by integrated weed management (Table 3). Hand weeding at 30 and 60 DAS (T_5) produced the highest yield (141.3 t ha^{-1} $year^{-1}$), significantly surpassing all other treatments. Atrazine @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS (T_1) recorded a comparable yield of 134.2 t ha^{-1} $year^{-1}$. Yield declined progressively in treatments involving twin wheel hoe weeding and in the unweeded control, reflecting the adverse impact of weed competition. These results corroborate the findings of Sukhpreet Singh *et al.* (2019) [12], who reported that intensive manual weeding or a combination of pre-emergence herbicides with manual methods maximized fodder yield.

Overall, the study highlights that integrated weed management, particularly hand weeding at 30 and 60 DAS and atrazine @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS, effectively minimized weed competition, enhanced crop growth parameters and substantially increased green fodder yield in multicut sorghum.

Table 3: Effect of integrated weed management practices on Plant height (cm), No. of tillers/plant, No. of leaves/plant at first harvest and green fodder yield (t/ha/year) in multicut fodder sorghum

Treatments	Plant height (cm)	No. of tillers/plant	No. of leaves /plant	Green Fodder Yield (t/ha/yr)
T_1 - Atrazine + HW @ 30 DAS	238	13.2	91	134.2
T_2 - Pendimethalin + HW @ 30 DAS	228	12.7	88	128.6
T_3 - Atrazine + Twin WHW @ 30 DAS	221	12.0	85	107.5
T_4 - Pendimethalin + Twin WHW @ 30 DAS	215	11.2	80	103.8
T_5 - HW at 20 & 40 DAS	242	14.5	97	141.3
T_6 - Twin WHW @ 30 & 60 DAS	208	10.8	77	113.6
T_7 - Weedy check	147	7.0	55	67.2
SEd	6.8	0.42	2.9	4.27
CD (P = 0.05)	13.2	0.88	6.1	8.5

Economics of Integrated Weed Management

Economic analysis revealed significant differences in cost of cultivation, gross returns, net returns, and benefit cost (B:C) ratio among the treatments. The cost of cultivation ranged from ₹85,000 to ₹1,03,000 per hectare, depending on the type and intensity of weed management adopted. The highest cost (₹1,03,000/ha) was recorded under hand weeding at 30 and 60 DAS (T_5) due to additional labor requirements, whereas the lowest cost (₹85,000/ha) occurred in the weedy check (T_7), which lacked any weed control measures.

Gross returns closely reflected the green fodder yield. The highest gross return (₹2,11,950/ha) was obtained from T_5, followed by atrazine @ 0.50 kg a.i. ha^{-1} as PE + one hand weeding at 30 DAS (T_1), which recorded ₹2,01,300/ha. The lowest gross return (₹1,00,800/ha) was observed in T_7, underscoring the detrimental impact of weed competition on fodder productivity.

Net returns followed a similar trend. Despite its higher cost of cultivation, T_5 produced the maximum net return (₹1,08,950/ha), slightly higher than T_1 (₹1,02,300/ha), indicating that intensive manual weeding, while costlier, yielded excellent economic benefits.

The B:C ratio, a measure of economic efficiency, was highest in T_1 (2.03), followed by T_5 (2.03) and T_2 (1.94). Although T_5 provided the highest yield and net return, its B:C ratio was slightly lower due to higher labor costs. The lowest B:C ratio was observed in T_7, confirming that unweeded conditions are uneconomical and unsustainable**.**

Table 4: Effect of integrated weed management practices on economics in multicut fodder sorghum

Treatments	Cost of Cultivation (₹/ha/yr)	Gross Return (₹/ha/yr)*	Net Return (₹/ha/yr)	B:C Ratio
T_1 - Atrazine + 1 HW @ 30 DAS	99,000	2,01,300	1,02,300	2.03
T_2 - Pendimethalin + 1 HW @ 30 DAS	99,500	1,92,900	93,400	1.94
T_3 - Atrazine + Twin WH @ 30 DAS	93,000	1,61,250	68,250	1.73
T_4 - Pendimethalin + Twin WH @ 30 DAS	93,500	1,55,700	62,200	1.67
T_5 - HW at 20 & 40 DAS	1,05,000	2,11,950	1,06,950	2.02
T_6 - Twin WH @ 30 & 60 DAS	97,500	1,70,400	72,900	1.75
T_7 - Weedy check	85,000	1,00,800	15,800	1.19

*Gross return calculated assuming an average market price of ₹1500 per tonne of green fodder

Conclusion

Integrated weed management practices significantly influenced weed suppression, crop growth, fodder yield, and economic returns in multicut fodder sorghum (CO 31). Among the treatments, hand weeding at 30 and 60 DAS (T_5) and atrazine @ 0.50 kg a.i. ha^{-1} as pre-emergence followed by one hand weeding at 30 DAS (T_1) were the most effective. These treatments recorded the lowest weed density and weed dry matter, along with the highest weed control efficiency, which translated into superior growth parameters such as plant height, number of tillers, and number of leaves per plant. Consequently, they achieved the highest green fodder yields and provided greater economic returns compared to the other treatments. In contrast, the untreated control (T_7) exhibited severe weed infestation, poor growth, reduced yield, and was economically unviable. Overall, integrating herbicides with timely manual or mechanical weeding proved most effective for optimizing both productivity and profitability in multicut fodder sorghum.

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