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Economic evaluation of pruning intensities and herbicidal treatments on weed management and wheat productivity under *Dalbergia sissoo* based agroforestry system

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Abstract

Agroforestry improves farm productivity, yet wheat yield often declines due to shading and heavy weed infestation. This study evaluated the agronomic and economic effects of four pruning intensities (0, 25, 50, 75%) and four weed-management practices (pendimethalin, hand weeding, metribuzin, and weedy check) under a *Dalbergia sissoo*-based agroforestry system during Rabi 2019-20 using a strip-plot design. Pruning significantly enhanced test weight, grain yield, straw yield, and harvest index, with open conditions recording the highest yield (3302.58 kg ha^{-1}). Hand weeding (2798.60 kg ha^{-1}) and pendimethalin (2604 kg ha^{-1}) outperformed the weedy check. Economic analysis showed maximum gross (₹ 1,63,039 ha^{-1}) and net returns (₹ 1,22,271 ha^{-1}) under 25% pruning with hand weeding, while the highest B:C ratio (3.16) occurred with 25% pruning plus pendimethalin. The study concludes that moderate pruning (25-50%) combined with efficient herbicide use offers the most productive and economically viable strategy for wheat cultivation under *D. sissoo* agroforestry.

Keywords: Agroforestry, *Dalbergia sissoo*, pruning intensity, weed management, herbicides, wheat productivity, economic analysis, benefit cost ratio

Introduction

Agroforestry has emerged as a highly productive and economically sustainable land-use system, particularly after India became the first country in the world to adopt a National Agroforestry Policy in 2014 under the Ministry of Agriculture and Farmers Welfare. The policy emphasizes expansion of tree cover, livelihood improvement, employment generation, and diversification of farm income through integration of trees with crops and livestock. It also highlights agroforestry as a strategy to meet the increasing domestic and industrial demand for timber and wood products, thereby strengthening farm-level economic resilience (Verma *et al*., 2017) [24]. Agroforestry systems have long been recognized for their capacity to provide fuelwood, timber, fodder, and additional cash income, making them an economically viable option for small and marginal farmers (Solanki *et al*., 1998) [23]. Despite these benefits, a key economic challenge in agroforestry is the reduction in crop yield due to shading from tree canopies. Shading decreases light availability one of the most critical factors for crop photosynthesis and yield, leading to productivity losses, especially under dense tree stands (Acciaresi *et al*., 1994) [1]. Therefore, management of tree canopy becomes essential to maintain crop productivity and profitability.

Dalbergia sissoo (shisham) is widely cultivated because of its fast growth, nitrogen-fixing ability, multipurpose uses, and high timber value. It is traditionally planted on field boundaries, farms, and riverine areas across the Indo-Gangetic plains and Himalayan foothills (Singh and Sharma *et al*., 2007) [21]. However, *D. sissoo* can significantly influence the economic performance of intercrops through its canopy characteristics. Pruning has been reported as an effective canopy-management practice that enhances light penetration, reduces competition, and thereby improves growth and yield of associated crops, ultimately enhancing system profitability (Fownes and Anderson *et al*., 1991) [9].

Wheat (*Triticum aestivum* L.) is India's second largest staple food crop, grown on 31.45 million hectares with a production of 109.52 million tonnes and a productivity of 3507 kg ha^{-1} (IASRI *et al*., 2021) [12]. In Madhya Pradesh, wheat occupies 3.03 million hectares with an average yield of 2802 kg ha^{-1} (Agricultural Statistics *et al*., 2020) [2]. Because wheat contributes substantially to household food security and farm income, any reduction in wheat yield under agroforestry directly affects economic returns. However, the slow early growth of wheat, combined with fertilizer use and frequent irrigation, enhances weed pressure, making weed management a major cost component in wheat production. Weeds contribute to nearly

37% of total agricultural production losses in India (Yaduraju *et al*., 2006) [26]. Under agroforestry conditions, altered light and moisture conditions further encourage diverse and aggressive weed flora, complicating management. Manual weeding, although effective, is labour-intensive, costly, and often impractical in closely spaced wheat systems. The rising cost and shortage of agricultural labour further increase production costs and reduce profitability. As a result, chemical weed management has become a more economically viable option (Mishra *et al*., 2002) [16]. Herbicides such as pendimethalin, clodinafop, mesosulfuron, sulfosulfuron, and metribuzin have demonstrated high efficacy in controlling major grassy and broadleaf weeds in wheat (Chhokar *et al*., 2012) [6].

Pendimethalin, a widely used pre-emergence herbicide, is recommended for controlling annual grasses and broadleaf weeds in wheat and other field crops (Hossain and Da Silva *et al*., 2012) [11]. However, higher application rates or improper use may affect crop safety, making economic evaluation essential. Metribuzin, another effective herbicide, controls *Phalaris minor* and broadleaf weeds but is sensitive to soil moisture and application accuracy (Malik *et al*., 2005) [15]. Several studies highlight that combining or sequencing herbicides enhances weed suppression, reduces labour requirements, and increases economic returns (Baghestani *et al*., 2008) [3]. Uncontrolled infestations of major weeds like *Phalaris minor*, *Avena ludoviciana*, *Chenopodium album*, *Medicago denticulata*, *Cyperus rotundus*, and *Cynodon dactylon* can reduce wheat grain yield by more than 54% (Singh *et al*., 2002) [22].

Thus, both pruning intensity and herbicide application directly influence the economic output of wheat under *Dalbergia sissoo*-based agroforestry. While pruning increases light availability and enhances yield, herbicidal weed control reduces labour cost and prevents yield losses - together contributing to higher profitability. However, existing studies have evaluated these components mostly in isolation. Limited scientific evidence is available on their combined impact on wheat productivity, cost of cultivation, net returns, and benefit-cost ratios under *D. sissoo* agroforestry. Therefore, this study aims to quantitatively assess the economic effects of different pruning intensities and herbicidal treatments on weed suppression, wheat yield, production costs, and overall economic viability in *Dalbergia sissoo*-based agroforestry systems.

Materials and Methods

The present investigation was conducted during Rabi 2019 - 20 at the Agroforestry Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur (M.P.). The experimental site is characterized by varying tree canopy density, heterogeneous soil fertility, and modified agro-microclimatic conditions, all of which influence crop yield, labour utilization, production cost and, ultimately, the economic viability of agroforestry systems. The economic methodology adopted for the present study followed standard farm management procedures suggested by CACP (2008) [4], Gittinger (1982) [10], and CIMMYT (1988) [7]. All cost components associated with wheat cultivation and pruning operations were quantified. The cost of cultivation was computed by separating variable and fixed costs following the functional economic approach of Kochar (2011) [13] and Sharma and Prasad (2014) [19]. Variable costs included the procurement of certified seed (JW-3288 @ 100 kg ha^{-1}), fertilizer application at the recommended dose of 100:60:40 NPK kg ha^{-1}, herbicides such as pendimethalin (1.0 L ha^{-1}, pre-emergence) and metribuzin (250 g ha^{-1}, post-emergence), labour charges for hand-weeding at 30 DAS, irrigation, sowing, harvesting, threshing, and other intercultural operations. Fixed costs consisted of rental value of land, land revenue, depreciation on implements, and interest on working capital.

Tree-management costs were also incorporated, particularly labour wages associated with executing 25%, 50%, and 75% pruning intensities and handling the biomass. All tree-related cost estimations adhered to established agroforestry economic guidelines recommended by Nair (1993) [17] and FAO (2015) [8]. Yield attributes included grain yield, straw yield, and pruned biomass. Economic output was calculated by multiplying yield components with their MSP values.

Gross Return (GR) was computed using the formula**:**

GR=Value of grain + Value of straw

Net Return (NR) was estimated as:

NR=GR−Cost of Cultivation

Profitability assessment was carried out through the Benefit-Cost Ratio (B:C Ratio):

B:C= Gross Return (GR)/Cost of Cultivation

These indicators collectively provided an integrated understanding of absolute profitability, cost efficiency, and economic competitiveness under different levels of pruning and weed-management interventions. The experiment was conducted using a strip-plot design. Pruning intensities constituted the main plots, while weed-management treatments formed the subplots. Pruning treatments included no pruning, 25% pruning, 50% pruning, and 75% pruning, with an open field (no-tree) plot serving as the baseline control. Weed-management interventions included pendimethalin (pre-emergence), hand-weeding at 30 DAS, metribuzin (post-emergence), and an untreated weedy check.

All treatment combinations were evaluated not only for agronomic performance but also for their economic implications in terms of cost structure, yield stability, weed-suppression efficiency, and profitability of wheat grown under Dalbergia sissoo-based agroforestry conditions. This integrated methodological approach enabled the study to capture real production economics, incorporating cost variability, yield advantages, weed-control efficiency, and financial sustainability across all treatment interactions. The findings derived from this framework contribute to identifying economically viable and resource-efficient management options for wheat cultivation in tree-based production systems.

Results and Discussion

The test weight of wheat grains exhibited a clear and significant response to varying pruning intensities and herbicidal treatments (Table 1 and Fig 1). Under the main

treatment effects, test weight increased consistently with higher levels of pruning. The absence of pruning resulted in the lowest test weight (32.46 g), whereas 75% pruning produced a substantially higher value (35.03 g). The maximum test weight (38.22 g) was recorded in the open area without trees, indicating that complete absence of shading ensures optimal grain filling (Table 1 and Fig 1). This trend supports earlier findings suggesting that increased light availability enhances photosynthetic activity and facilitates assimilate translocation to developing grains (Kumar *et al*., 2020; Singh *et al*., 2018) [14, 27].

The improvement in test weight with increased pruning intensity can be attributed to reduced canopy shading, favourable microclimatic modifications, and increased solar radiation reaching the crop. Previous researchers have also highlighted that pruning helps optimize the light regime in agroforestry systems, thereby improving grain development (Sharma *et al*., 2016) [20].

Herbicidal treatments also had a notable impact on test weight (Table 1 and Fig 1). Hand weeding yielded the highest test weight (36.30 g), followed by pendimethalin at 1.0 L ha^{-1} (35.07 g), whereas the weedy check recorded the lowest value (33.05 g). This indicates that weed competition significantly affects nutrient availability and grain filling. These findings align with those of Chhokar *et al*. (2012) [6] and Yadav *et al*. (2023) [25], who reported the importance of effective weed management in improving grain size and overall wheat productivity.

The combined influence of pruning and weed control contributed to improved test weight by reducing canopy competition and minimizing weed pressure, two major constraints in tree-based wheat cultivation. Higher test weight generally enhances grain quality and market value, improving economic returns in agroforestry systems.

Table 1: Test weight as influenced by different intensities of pruning and herbicidal treatments.

Treatments	Test weight (g)
Pruning intensities	
P_0: No pruning	32.46
P_1: 25% pruning	33.05
P_2: 50% pruning	34.90
P_3: 75% pruning	35.03
Open area no tree	38.22
SEm ±	0.51
CD (P = 0.05)	1.52
Herbicidal treatments	
T_1: Pendimethalin @ 1.0 lit./ha as Pre-emergence	35.07
T_2: Hand weeding at 30 DAS	36.30
T_3: Metribuzin @ 250 g/ha as post - emergence	34.51
T_4: Weedy check (control)	33.05
SEm ±	0.35
CD (P=0.05)	1.06

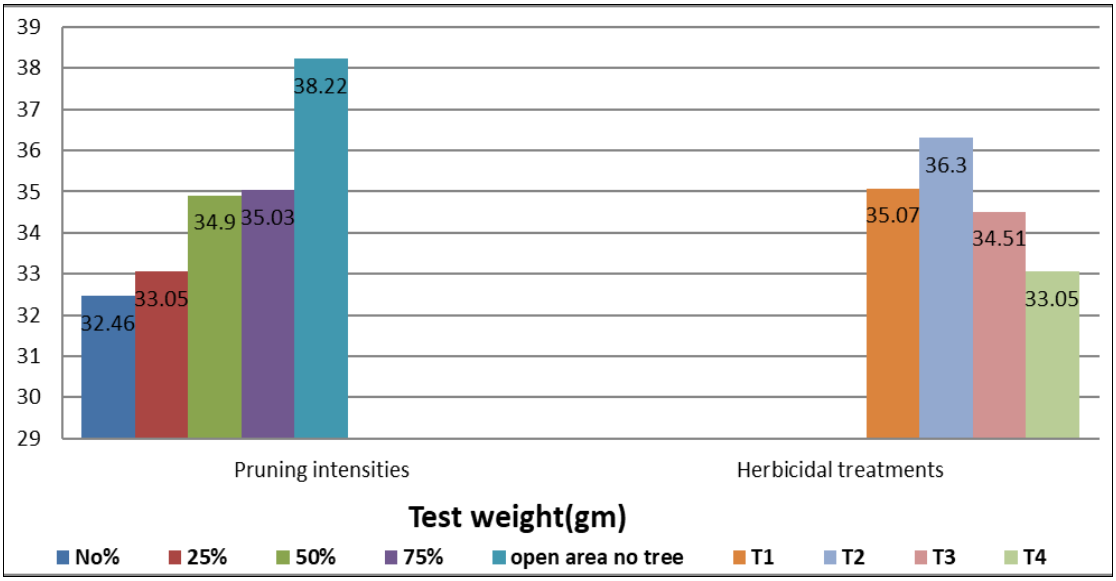

Fig 1: Test weight as influenced by different intensities of pruning and herbicidal treatments.

Wheat grain yield was significantly influenced by both pruning intensity and weed management (Table 2 and Fig 2). The open condition yielded the highest grain yield (3302.58 kg ha^{-1}), followed by 75% pruning (2737.67 kg ha^{-1}) and 50% pruning (2443.88 kg ha^{-1}). The lowest grain yield (1905 kg ha^{-1}) under no pruning highlights the negative influence of tree shade on crop performance. These results are consistent with earlier studies demonstrating that pruning enhances light penetration and photosynthetic efficiency in agroforestry crops (Sharma *et al*., 2016; Singh *et al*., 2018) [20, 27].

Similar trends were observed in weed management treatments (Table 2 and Fig 2). Hand weeding at 30 DAS resulted in the highest grain yield (2798.60 kg ha^{-1}), followed by pendimethalin (2604 kg ha^{-1}) and metribuzin (2443 kg ha^{-1}), while the lowest yield was recorded under the weedy check (2102 kg ha^{-1}). Weeds significantly reduce moisture, nutrients, and light availability, resulting in poor crop growth. These results corroborate previous findings emphasizing the critical role of weed suppression in maintaining yield levels (Chhokar *et al*., 2012; Yadav *etal*., 2023) [6, 25]. Interaction effects were found non-significant, indicating independent contributions of pruning and weed management.

Straw yield followed a trend similar to grain yield (Table 2 and Fig 2). The highest straw yield was observed under open conditions (4800.51 kg ha^{-1}), with 75% pruning (3826.53 kg ha^{-1}) performing better than other pruning

levels. Among weed treatments, hand weeding recorded the highest straw yield (4090.87 kg ha^{-1}), while the weedy check yielded the lowest (3283.2 kg ha^{-1}), further indicating the negative impact of weed interference on biomass accumulation.

Biological yield was highest under open conditions (6903.1 kg ha^{-1}), followed by 75% pruning (6564.2 kg ha^{-1}) and 50% pruning (6176.4 kg ha^{-1}) (Table 2 and Fig 2). No pruning resulted in the lowest biological yield (5220 kg ha^{-1}). In weed management, hand weeding produced the highest biological yield (6889.50 kg ha^{-1}), followed by pendimethalin (6218.60 kg ha^{-1}) and metribuzin (5904.73 kg ha^{-1}), with the weedy check recording the least (5385.60 kg ha^{-1}). The interaction effects remained statistically non-significant.

Harvest index (HI) also varied significantly (Table 2 and Fig 2). Open conditions recorded the maximum HI (47.91%), reflecting highly efficient assimilate partitioning towards grains. The 75% and 50% pruning intensities also recorded higher HI values (41.9% and 39.4%), whereas no pruning and 25% pruning recorded comparatively lower values. Weed management treatments showed enhanced HI over the weedy check, with pendimethalin, metribuzin, and hand weeding recording statistically similar HI values. The weedy check recorded the minimum HI, likely due to reduced grain formation resulting from competition. These results corroborate earlier findings suggesting that reduced shading and effective weed management improve resource efficiency and grain yield (Kumar *et al*., 2020) [14].

Table 2: Effect of various treatments and biological yield and grain yield with straw and harvest index

Treatments	Wheat parameters			
	Biological yield (Kg/ha)	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**Harvest index (%)**
Pruning intensities				
P_0: No pruning	5220	1905.3	3314.6	36.6
P_1: 25% pruning	5634.4	2046.4	3587.9	36.5
P_2: 50% pruning	6176	2443.9	3732.4	39.4
P_3: 75% pruning	6564.2	2737.7	3826.5	41.9
Open area no tree	6903	3302.6	4800.5	47.9
SEm ±	129.19	72.04	111.4	0.97
CD (P = 0.05)	387.27	215.95	334.1	2.91
Herbicidal treatments				
T_1: Pendimethalin @ 1.0 lit./ha as Pre-emergence	6218.6	2604	3614.5	41.65
T_2: Hand weeding at 30 DAS	6889.5	2798.6	4090.8	40.37
T_3: Metribuzin @ 250 g/ha as post - emergence	5904.7	2443.7	3461	40.98
T_4: Weedy check (control)	5385.6	2102.4	3283	38.92
SEm ±	79.37	18.22	80.35	0.59
CD (P=0.05)	244.53	56.14	247.56	1.82

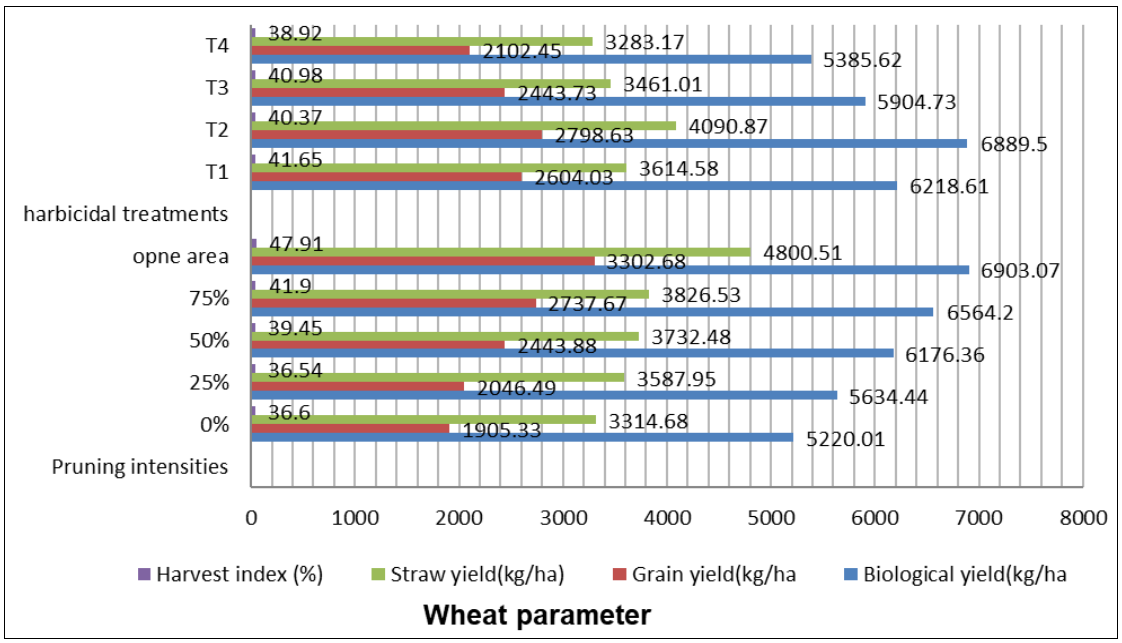

Fig 2: Effect of various treatments an biological yield and grain yield with straw and harvest index

Economic evaluation (Table 3) revealed considerable variability in cultivation cost, gross monetary return, net monetary return, and benefit-cost ratio (B:C ratio). The cost of cultivation increased with pruning intensity due to greater labour requirements. Total costs ranged from ₹32,518 to ₹38,768 ha^{-1} in no-pruning conditions and ₹34,518 to ₹42,768 ha^{-1} under pruning treatments. Similar cost increases due to canopy maintenance have been reported by

Nair (1993) [17] and Sharma & Prasad (2014) [19].

Gross monetary return (GMR) was highest under 25% pruning with hand weeding (₹ 1,63,039 ha^{-1}), while the lowest GMR among pruning treatments was observed under 75% pruning with the weedy check (₹ 1,34,141 ha^{-1}). Excessive pruning may reduce photosynthetic reserves of trees, affecting crop-tree interactions an observation previously highlighted by Puri & Khosla (1993) [18].

Net monetary return (NMR) followed a similar pattern, with the highest NMR (₹ 1,22,271 ha^{-1}) under 25% pruning with hand weeding and the lowest (₹ 97,623 ha^{-1}) under 75% pruning with weedy check (Table 3).

The B:C ratio clearly favoured moderate pruning integrated with herbicidal weed management. The highest B:C ratio (3.16) was recorded under 25% pruning with pendimethalin, followed by 50% pruning with pendimethalin (3.12) and 50% pruning with metribuzin (3.13). Lower B:C ratios in open-field conditions highlight the superiority of agroforestry systems over sole cropping. Similar findings were reported by Chavan *et al*. (2015) [5]. Overall, the results indicate that moderate pruning levels (25-50%) combined with effective herbicidal weed control offer the most productive and economically profitable management strategy under *Dalbergia sissoo*-based agroforestry systems. Excessive pruning or inadequate weed control lowers productivity and profitability, emphasizing the importance of integrated canopy and weed management.

Table 3: Effect of various treatments cost of cultivation and gross monetary return and net monetary return with B:C ratio

Treatments	Common Cost of cultivation (Rs/ha)	Treatment wise Cost of cultivation (Rs/ha)	Gross monetary return (Rs/ha)	Net monetary return (Rs/ha)	B:C Ratio
No pruning + Pendimethalin @ 1 lit./ha as pre - emergence	32518	33618	125784	92167	2.74
No pruning + Hand weeding	32518	38768	134984	96216	2.48
No pruning + metribuzin @ 250 gm/ha post-emergence	32518	33718	119640	85922	2.54
No pruning + Weedy check	32518	32518	115212	82694	2.54
25% pruning + Pendimethalin @ 1lit./ha as pre - emergence	32518	35618	148258	112640	3.16
25% pruning + Hand weeding	32518	40768	163039	122271	2.99
25% pruning + metribuzin @ 250 gm/ha post-emergence	32518	35718	140092	104374	2.92
25% pruning + Weedy check	32518	34518	132772	98254	2.84
50% pruning + Pendimethalin @ 1lit./ha as pre - emergence	32518	36418	150180	113762	3.12
50% pruning + Hand weeding	32518	41568	149452	107884	2.60
50% pruning + metribuzin @ 250 gm/ha post-emergence	32518	36518	151010	114492	3.13
50% pruning + Weedy check	32518	35318	133659	98341	2.80
75% pruning + Pendimethalin @ 1 lit./ha as pre - emergence	32518	37618	141190	103572	2.75
75% pruning + Hand weeding	32518	42768	154172	111404	2.60
75% pruning metribuzin @ 250 gm/ha post-emergence	32518	37718	140587	102869	2.72
75% pruning + Weedy check	32518	36518	134141	97623	2.70
Open crop only + Pendimethalin @ 1 lit./ha as pre - emergence	32518	33618	89176	55558	1.65
Open crop only + hand weeding	32518	38768	99760	60992	1.60
Open crop only + metribuzin @ 250 gm/ha post-emergence	32518	33718	82103	48385	1.43
Open crop only + weedy check	32518	32518	72383	39865	1.25

Conclusion

Pruning intensity and herbicidal weed management significantly influenced wheat productivity and economic returns under *Dalbergia sissoo*-based agroforestry. Moderate pruning (25-50%) enhanced light interception and microclimatic conditions, increasing test weight, grain yield, straw yield, biological yield, and harvest index, while avoiding the higher labour costs of intensive pruning (75%). Weed management, particularly hand weeding, pre-emergence pendimethalin (1.0 L ha^{-1}), and post-emergence metribuzin (250 g ha^{-1}), effectively reduced weed competition and improved wheat yield and quality compared to the weedy check. Economic analysis showed that 25% pruning with hand weeding provided the highest gross (₹ 1,63,039 ha^{-1}) and net returns (₹ 1,22,271 ha^{-1}), while the maximum B:C ratio (3.16) was achieved under 25% pruning with pendimethalin. Excessive pruning (75%) combined with poor weed control reduced both productivity and profitability. Moderate pruning integrated with effective herbicidal weed management offers the most productive and economically viable strategy for wheat cultivation under *D. sissoo* agroforestry, enhancing light availability, reducing weed-induced losses, and maximizing profitability.

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