Table 3 Effect of spawn rate on total yield, biological efficiency, and contamination incidence

Treatment	Total yield (g/bag)	Biological efficiency (%)	Contamination (%)
T_1 (4%)	310 ± 8.2^{d}	15.5 ± 0.41^{d}	25.0
T_2 (6%)	372 ± 8.2^{c}	18.6 ± 0.41^{c}	12.5
T_3 (8%)	428 ± 8.2^{b}	21.4 ± 0.41^{b}	0.0
T_4 (10%, farmer practice)	468 ± 8.2^{a}	23.4 ± 0.41^{a}	0.0
T_5 (12%)	472 ± 8.2^{a}	23.6 ± 0.41^{a}	0.0
F-value	71.23***	71.23***	-
p-value	<0.001	<0.001	-
CV (%)	5.28	5.28	-
Grand mean	410.0	20.5	7.5

Note: Means in a column followed by different lowercase letters differ significantly at $p \leq 0.05$ (DMRT). *** $p \leq 0.001$. Contamination incidence is reported descriptively as the percentage of bags affected and was not subjected to ANOVA. Values for total yield and biological efficiency are mean ± SE (n = 4). SE: standard error; CV: coefficient of variation

3.4 Benefit-cost analysis

Because spawn cost rises directly with spawn rate while yield gains taper off beyond 8%-10%, the benefit-cost ratio did not increase monotonically with spawn rate (Table 4). The 8% spawn rate (T_3) returned the highest benefit-cost ratio (1.34), narrowly ahead of 6% (1.33) and comfortably above the conventional 10% farmer practice (1.30). The 12% spawn rate, despite giving the numerically highest yield, actually returned the lowest BCR (1.18), because the extra spawn cost was not matched by a proportional yield gain over T_4.

Table 4 Cost, return, and benefit-cost ratio by spawn-rate treatment

Treatment	Total cost (NPR/bag)	Gross return (NPR/bag)	Benefit-cost ratio
T_1 (4%)	60	77.5	1.29
T_2 (6%)	70	93.0	1.33
T_3 (8%)	80	107.0	1.34
T_4 (10%, farmer practice)	90	117.0	1.30
T_5 (12%)	100	118.0	1.18

4 Discussion

4.1 Effect of spawn rate on colonization and cropping duration

The progressive shortening of spawn run, pinhead initiation, and first-harvest time with increasing spawn rate agrees with the general understanding that a higher density of inoculation points speeds up mycelial establishment throughout the substrate (Bhatti et al., 2007; Royse, 2014; Bhandari et al., 2022). The plateau between 10% and 12% suggests that once colonization points are dense enough, further increases in spawn rate buy very little additional time, since colonization speed becomes limited more by substrate quality and environmental conditions than by inoculum density alone a pattern also noted by Paudel and Dhakal (2020) working with different straw-based substrates in Nepal.

4.2 Effect of spawn rate on yield components and biological efficiency

The trade-off between fruiting body number and individual fruiting body size at higher spawn rates reflects a well-documented density-dependent response in *Pleurotus* cultivation: more numerous pinheads draw on a shared, finite pool of substrate nutrients, which constrains the maximum size any single fruiting body can reach (Chang and Miles, 2004). Despite the smaller individual mushrooms, total yield and biological efficiency were still highest at 10%-12% spawn rate, because the increase in fruiting body number outweighed the drop in individual size a pattern consistent with reports from other straw-based *Pleurotus* trials in South Asia (Ahmed et al., 2009).

The marked reduction in contamination incidence above 6% spawn rate lends some support to Nepalese growers' traditional preference for spawn rates at or above 10%: faster colonization leaves less time and fewer spare nutrients for competing molds to establish, which effectively works as a low-cost, non-chemical form of contamination control (Chang and Hayes, 1978).