Economic returns of apricot- and cherry-based agroforestry systems with garlic and onion intercrops in the Kashmir Himalayas

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ABSTRACT: *Fruit-based agroforestry systems in Kashmir have the potential to improve farm productivity and profitability, yet their performance under different intercrop combinations requires systematic evaluation. The present study was conducted at the experimental field of the Division of Silviculture and Agroforestry, Faculty of Forestry, SKUAST-K, Benhama, Ganderbal, from October 2022 to June 2023. A randomized block design (RBD) was used with three replications and ten treatment combinations involving 3-year-old Apricot (Prunus armeniaca) and Cherry (Prunus avium) plantations. Two intercrops garlic (Allium sativum) and onion (Allium cepa) were grown in different combinations: sole fruit trees, sole intercrops, and integrated tree–crop systems. Growth and yield attributes of garlic and onion, including total biomass, bulb diameter, weight per bulb, and related parameters, were generally higher under sole cropping compared to agroforestry conditions. In contrast, fruit yields of apricot and cherry were higher when both intercrops were grown together, particularly under Apricot + Garlic + Onion (7.57 t ha^{-1}) and Cherry + Garlic + Onion (6.74 t ha^{-1}) treatments. The findings demonstrate that integrating garlic and onion with young apricot and cherry plantations can substantially improve the economic performance of the system. The diversified combinations, particularly Apricot + Garlic + Onion, consistently generated higher returns, indicating that such integrations offer a practical and profitable option for farmers in temperate agroforestry regions.*

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1. INTRODUCTION

Agroforestry, a land-use approach combining agricultural, forestry, horticultural, and animal management practices, is increasingly recognized as a viable solution to address critical challenges like food security, environmental change, and depleting agricultural resources. By integrating trees, crops, and livestock on the same land, agroforestry offers a sustainable and multifunctional system that enhances farmers' income while mitigating environmental risks (Cornell, 2014). Beyond its long-established role in South Asian farming traditions, agroforestry has gained renewed global relevance due to increasing pressure on agricultural lands, climate change, and the need for sustainable intensification (Wojtkowski, 2002). While numerous studies from India highlight the ecological and economic value of tree–crop combinations, recent international research provides broader evidence for the performance of temperate fruit-tree agroforestry systems. In Europe, agroforestry adoption has expanded rapidly, and a large meta-analysis of crop performance across temperate alley-cropping systems shows that intercrops under young tree stands perform comparably to sole crops, with yield reductions appearing only as tree canopies mature (Kay *et al.,* 2019). These findings emphasize the importance of spatial design, tree age, and canopy management issues directly relevant to fruit-based systems. Recent work from temperate regions of Central Asia also highlights the effectiveness of integrating apricot and other *Prunus* species with annual field crops, showing that such combinations can enhance land productivity and provide more diverse income opportunities under semi-arid conditions (Yelenov *et al.,* 2019). Despite extensive agroforestry research globally, economic evaluations of apricot- and cherry-based systems remain scarce, especially under high-altitude Himalayan conditions.

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In India, agroforestry has gained momentum as a strategy to combat land degradation, conserve biodiversity, and support rural livelihoods, especially in regions facing deforestation and habitat loss (Kumar *et al*., 2021). The agroforestry system in the Himalayan region, particularly in Kashmir, exemplifies a long-standing tradition of integrating trees with crops and livestock, enhancing biodiversity, and improving livelihoods (Zahoor *et al.,* 2021).

In agroforestry systems, apricot trees are valued for their adaptability, drought resistance, and ability to thrive in various soil types, making them an excellent choice for enhancing biodiversity and providing economic returns. Apricots are particularly well-suited to the Kashmir region, where they contribute to the livelihoods of local farmers through both fresh fruit sales and processed products like dried apricots and jams (Anonymous, 2016). Cherry cultivation in Kashmir is a key agricultural activity, thriving in the region's temperate climate, which is ideal for growing sweet cherries due to its cool temperatures and ample sunlight that enhance the fruit's quality and flavour (Chadha, 2003). Despite its economic advantages, growers face challenges such as susceptibility to climatic variability and fruit disorders, which require careful management to achieve successful production (Kantaroglu and Demirbas, 2020). Most previous studies in India have focused on apple-, aonla-, peach-, or kinnow-based agroforestry models, leaving a clear gap in understanding the performance and economics of apricot and cherry orchards with intercrops.

In Kashmir, agroforestry systems focusing on high-value crops such as apricot and cherry have shown significant potential for enhancing financial returns. The integration of these fruit trees with traditional crops not only diversifies income sources but also mitigates economic risks by distributing investments across various products (Kumar *et al.,* 2021). Additionally, these systems offer long-term financial stability by buffering against market fluctuations and environmental uncertainties (Ghosh *et al.,* 2020). The gains of agroforestry research till date are certainly impressive. There are good number of success stories where tree based cropping systems have yielded good results. In many of the reported studies, fruit-tree- based agroforestry systems outperform sole crop systems economically. It appears that the combined yield of all agroforestry system components is frequently greater in mixed systems than by the same components under monoculture. With this background and keeping in view its importance, the present study has been undertaken to recognize the importance of sustainable land use and income diversification for local agricultural practices with the objective to evaluate the relative economics of the agroforestry system. The findings contribute to local agricultural development by providing empirical data on the economic benefits, productivity potential of this specific agroforestry system, paving the way for informed and improved farming practices in Benhama, Ganderbal. This study provides original empirical evidence by evaluating apricot and cherry orchards at the young (three-year) canopy stage, a condition that has not been previously examined in economic agroforestry assessments in the Kashmir Himalayas. Garlic and onion were selected as intercrops because they are short-duration, low-canopy, shallow-rooted crops highly compatible with young temperate orchards and known to generate reliable economic returns for smallholders.

Despite the global advancement of agroforestry research, specific economic evaluations of apricot- and cherry-based agroforestry systems remain limited, especially in high-altitude Himalayan environments. Prior studies in India largely focus on apple-based or generic temperate agroforestry models, leaving a gap in understanding how different intercrop combinations influence growth, yield, and profitability of apricot and cherry plantations under young orchard conditions. The present study addresses this gap by evaluating the economic performance of garlic and onion intercropping in 3-year-old apricot and cherry orchards under temperate Kashmir conditions. By grounding the work in both local relevance and international agroforestry evidence, this study provides a clearer understanding of the relative economic advantages of fruit-tree-based agroforestry systems and contributes original empirical data from a Himalayan context.

2. MATERIALS AND METHODS

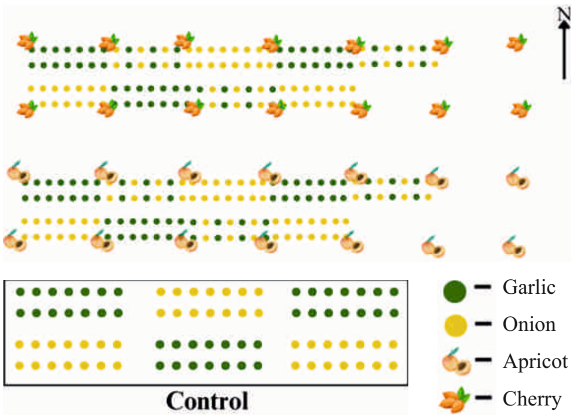
Study area

The study area is located within the Faculty of Forestry in Benhama, Ganderbal, Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir (J&K), situated at approximately 34.2794° N latitude and 74.7717° E longitude. It is positioned at an altitude of 1790 meters (5872 feet) above mean sea level. The site lies in a mid- to high-altitude temperate zone, characterized by four distinct seasons. Winters (December–February) are long and severe, with temperatures commonly falling below – 4°C, frequent frost events, and substantial snowfall. Spring (March–May) remains cold and wet. Summers (June–August) are mild, with maximum temperatures reaching up to ~34°C, while autumn (September–November) is cool and marked by a rapid decline in temperature. The region receives an annual precipitation of approximately 1327 mm, of which a major proportion occurs as winter snowfall, supplemented by spring rainfall distributed over nearly 70 precipitation days per year. The combination of low winter temperatures, moderate summer heat, and high winter precipitation creates a typical Western Himalayan temperate climate, making it suitable for fruit-based agroforestry research.

Experimental setup and design

Layout of the Experimental Field

The experimental details and methodologies adopted in the present study are described as follows. The experiment was conducted under a horti-agricultural agroforestry system comprising both tree and crop components. The tree component consisted of apricot (*Prunus armeniaca* L.) and cherry (*Prunus avium* L.), while the agricultural intercrops included garlic (*Allium sativum* L.) and onion (*Allium cepa* L.). The apricot and cherry trees were three years old at the time of experimentation and were planted at a spacing of 3 m × 3 m, with rows oriented in the east–west direction to ensure uniform light distribution. The intercrops, garlic and onion, were grown between tree rows at a spacing of 30 cm × 10 cm.



The experiment comprised a total of ten treatments, which were laid out in a Randomized Block Design (RBD) with three replications. Each replication consisted of four plants per treatment, resulting in uniform experimental units across all treatments. This design was adopted to minimize experimental error and to facilitate reliable comparison of treatments under the agroforestry system.

The experimental field was ploughed, harrowed for smoothness, and subsequently planked. Manual removal of stones, pebbles, and residual debris was also carried out. In total, ten treatments *viz.,* only Apricot (T_1), only Cherry (T_2), only Garlic (T_3), only Onion (T_4), Apricot + Garlic (T_5), Apricot + Onion (T_6), Apricot + Garlic + Onion (T_7), Cherry + Garlic (T_8), Cherry + Onion (T_9) and Cherry + Garlic + Onion (T_{10}) were employed. The plots were prepared as per the treatments to accommodate the vegetable crops (garlic and onion) during the rabi season.

Weeding was carried out promptly to keep the beds free of unwanted plants. Hoeing and irrigation were applied as needed, based on the crop's requirements. Harvesting of the vegetable crops (garlic and onion) was done in the month of June and July, respectively. For estimation of growth and yield parameters of vegetable crops (garlic and onion) and fruit trees (apricot and cherry), randomized block design were applied. The trees were spaced 3 meters apart in both directions (3m×3m), while the intercrops were planted with a spacing of 30 centimetres between rows and 10 centimetres between plants (30 cm× 10 cm). The details of treatments are presented in Table 1.

To assess crop growth parameters of (garlic and onion) such as plant height, bulb diameter, weight per bulb, weight per 100 cloves, and the number of cloves per bulb, ten plants were randomly selected from each plot at maturity for observation. The total biomass of both crops (garlic and onion) was evaluated by uprooting plants from each replication at the harvesting stage. The plants were separated into different parts, including bulbs (root) and aboveground portions, which were then weighed individually to determine their fresh weight. These samples were initially sun-dried for 4 to 5 days, followed by oven-drying at 60°C until a constant weight was achieved. The dry weight of the plant samples was recorded in grams and subsequently calculated in kilograms per hectare (kg ha^{-1}).

For estimating growth parameters of experimental trees *viz.*, height (m), collar diameter (cm) were measured using a measuring tape (Stanley Model 33-425). Five trees were randomly selected from each from each treatment for this purpose. The crown spread was determined using measuring tape on north to south and east to west directions. It was then calculated using the formula: ($CS = D_1 + D_2/2$).

Where, CS- Crown Spread, D_1 - Crown diameter NS direction and D_2- Crown diameter EW direction.

Table- 1 Details of treatment combinations

Symbol	Treatment
T_1	Only Apricot
T_2	Only Cherry
T_3	Only Garlic
T_4	Only Onion
T_5	Apricot + Garlic
T_6	Apricot + Onion
T_7	Apricot + Garlic + Onion
T_8	Cherry + Garlic
T_9	Cherry + Onion
T_{10}	Cherry + Garlic + Onion

The leaf area of fully expanded leaves was estimated using a pre-calibrated portable leaf area meter. Each leaf was positioned under the leaf area meter's arm and digitally scanned to determine its area. Sixteen leaves per replication were chosen randomly for this assessment using a portable leaf area meter (CI-202 Portable Laser Leaf Area Meter). The fruit colour of apricot and cherry was determined using a colour chart through regular field visits. Fruit maturity was recorded as the period from the initiation of fruiting to the stage when the fruit reached full maturity, based on colour and size. At physiological maturity, all marketable fruits from each sample tree were harvested manually. The total number of fruits was counted, and their fresh weight was recorded using a calibrated digital weighing balance (accuracy ±1 g). Fruit yield was first expressed as kg $tree^{-1}$ and subsequently converted to t ha^{-1} using the tree population per hectare based on the experimental spacing. The fruit length was measured from the base to the top using a measuring scale, and the diameter of fully mature fruits was measured in centimetres at the centre using a digital Vernier calliper (Aerospace Digital Vernier Caliper, 150 mm, accuracy ±0.01 mm,with both measurements taken from five randomly selected trees and five randomly selected fruits. The stone yield was recorded from fruits collected at their firm ripe stage, the stones were removed, weighed, and expressed in t ha^{-1}.

The cost of cultivation of vegetable crops (garlic and onion) as well as maintenance of fruit trees (apricot and cherry) and harvest of its produce was worked out on the basis of net cropped area and number of tree ha^{-1} (Table-2). The requirements of labour and mechanical power for various activities like ploughing, harrowing, weeding, irrigation and harvesting were assessed per hectare according to the rates at the experimental farm. Costs for inputs like seedling and weeding were also calculated. The yield of agricultural crops and fruit trees was converted to gross returns using prevailing local market prices. Net returns were determined by subtracting the total cost from the gross returns. The data obtained was subjected to statistical analysis using a Randomized Block Design of experimentation as per the procedure suggested by Gomez and Gomez (1984). Data analysis was performed using R software.

3. RESULTS AND DISCUSSION

Growth and yield of Fruit trees

In present study, the growth and yield of fruit trees were significantly higher in intercropping system as compared to sole cropping with maximum fruit yield in agroforestry and minimum in mono-cropping (Table-2). The quantity of fruit yield from apricot and cherry trees in present study was lower than the typical yields per hectare in the Kashmir valley. This disparity could be attributed to the relatively young age of the orchard and the drier conditions prevailing at the study site (Directorate of Horticulture, 2017). This outcome

Table 2: Cost (USD ha^{-1}) involved in growing vegetable crops (garlic and onion) and fruits trees (apricot and cherry) in various land-use systems.

	Garlic	Onion
Land preparation	36.14 USD	36.14
Seed rate	289.16 USD	301.20
Levelling of land	289.16	289.16
Seed sowing	36.14	289.16
Irrigation	289.16	289.16
Cultural operations	289.16	289.16
After care operations	289.16	289.16
Harvesting	289.16	289.16
Total Cost	510.84	510.84

Particulars	Apricot	Cherry
Land rental	312.05	312.05
Manures	298.19	301.08
Plant protection	169.28	172.27
Irrigation	42.89	42.29
Overhead cost	111.57	112.05
Total cost	934.34	939.76

Prevailing market prices of produce: Garlic- USD 0.53kg^{-1}, Onion USD 0.42 kg^{-1}, Apricot USD 0.36kg^{-1} and Cherry USD 1.01 kg^{-1}

further supports the widely documented concept that young orchards respond more positively to intercrops because of lower canopy competition and enhanced below-ground resource complementarity. In the present study the maximum height was observed in cherry orchard in T_{10} (Cherry + Garlic + Onion). However, for Apricot orchard the maximum tree height was recorded in T_7 (Apricot + Garlic + Onion). The possible clarification behind this could be that the cherry trees often exhibit faster growth rates and a tendency to reach taller heights due to their physiology and growth patterns compared to apricot trees (Kantaroglu and Demirbas 2020). Similarly, collar diameter was recorded maximum in apricot orchard, in T_7 (Apricot + Garlic + Onion), might be attributed to inherent species-specific traits favouring collar diameter expansion in apricot trees. In agroforestry systems, the increased growth parameters of fruit trees are a result of mutually beneficial environment that fosters better growth conditions, promoting increased height for all tree species involved compared to their growth in monoculture due to reduced competition and enhanced resource utilization (Chauhan and Dhiman 2002). These patterns highlight how nutrient cycling, microclimate moderation, and improved soil structure under agroforestry collectively enhance tree vigour even at early orchard stages. Crown spread and leaf area were significantly higher in cherry orchard the maximum value was recorded in T_{10} (Cherry + Garlic + Onion) However in apricot orchard the maximum value for crown spread and leaf area was recorded in T_7 (Apricot + Garlic + Onion) respectively. The extended crown spread and increased leaf area could be attributed to the synergistic effects of the agroforestry system, demonstrating its positive influence on the overall canopy development and foliage of the trees (Chauhan and Dhiman 2002) (Table-1). The enhanced canopy development is also linked to favourable microclimatic modifications, such as moderated temperature and reduced evapotranspiration around trees grown with intercrops. Regarding fruit-related parameters, the maturity time, length, and diameter of fruits were significantly affected by the treatments. The maximum maturity time were recorded in T_1 (Only Apricot) (Table-3), the diverse ecological interactions in agroforestry, such as complementary nutrient uptake and

Table 3: Average values for the initial and final growth parameters of apricot and cherry trees as influenced by intercrops under apricot-cherry based agroforestry system

Symbol	Treatments	Tree height (m)	Collar diameter (cm)	Final crown spread (m)	Leaf area (cm^2)	Fruit length (cm)	Fruit diameter (cm)	Fruit Yield ($t\ ha^{-1}$)	Stone Yield ($t\ ha^{-1}$)	Fruit maturity time (days)	Fruit colour
T_1	Only Apricot	3.40	6.52	2.25	27.86	2.46	2.00	7.24	2.07	124	Green to light yellowish-orangish green
T_2	Only Cherry	3.81	5.92	2.78	33.64	1.91	1.32	6.49	1.72	100	Dark red
T_3	Only Garlic	-	-	-	-	-	-	-	-	-	-
T_4	Only Onion	-	-	-	-	-	-	-	-	-	-
T_5	Apricot + Garlic	3.57	6.99	2.65	29.56	2.79	2.25	7.48	2.28	120	Green to light yellowish-orangish green
T_6	Apricot + Onion	3.48	6.76	2.48	29.00	2.62	2.17	7.39	2.20	120	Green to light yellowish-orangish green
T_7	Apricot + Garlic + Onion	3.64	7.26	2.76	30.06	2.90	2.38	7.57	2.34	120	Green to light yellowish-orangish green
T_8	Cherry + Garlic	3.97	6.22	3.19	35.62	2.05	1.61	6.66	1.86	97	Dark red
T_9	Cherry + Onion	3.89	6.08	2.94	35.14	1.99	1.44	6.57	1.78	97	Dark red
T_{10}	Cherry + Garlic + Onion	4.05	6.38	3.31	36.02	2.11	1.89	6.74	1.92	97	Dark red
	CD ($p \leq 0.05$)	0.24	0.29	0.21	1.77	0.40	0.36	0.18	0.16		
	W ($p \leq 0.05$)	0.16	0.19	0.12	0.10	0.16	0.09	0.22	0.24		

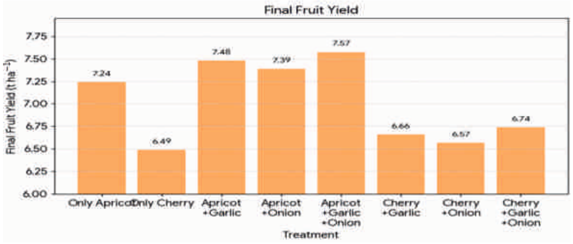


Fig. 01 : Graphical Representation of Fruit Yield (t ha^{-1})

microclimate regulation, might stimulate earlier maturation (Kantaroglu and Demirbas 2020). Similarly, the largest fruit length and fruit diameter were observed in T_7 (Apricot + Garlic + Onion). However, in cherry orchard the maximum value noted for fruit length and diameter in T_{10} (Cherry + Garlic + Onion). Cherry fruits are inherently smaller in size compared to apricot fruits. In agroforestry systems, the mutualistic interactions between various species can foster improved pollination, nutrient availability and enhanced soil conditions. This collective synergy often results in better overall fruit development. Similar results were reported by (Bijalwan 2012). The highest fruit and stone yield in apricot orchard were recorded in T_7 (Apricot + Garlic + Onion) However, in cherry orchard the highest fruit and stone yield in cherry orchard was recorded in T_{10} (Cherry + Garlic + Onion) (Table-2). The lower yield of cherry compared to apricots can be explained by the relatively smaller size of cherry fruit. The incorporation of leaf biomass into the soil and subsequent decomposition likely promoted an improved source-sink relationship, consequently leading heightened fruit yield within the Apricot-Cherry based agroforestry system. These findings collectively show that improved nutrient cycling efficiency and enhanced soil biological activity under tree–crop interfaces play a critical role in strengthening fruit yield parameters.

Growth and yield of Garlic

In the present study the maximum value of sprouting time (14 days) were recorded in T_5 (Apricot + Garlic), T_7 (Apricot + Garlic + Onion), T_8 (Cherry + Garlic) and T_{10} (Cherry + Garlic + Onion), whereas the minimum sprouting time (11 days) were recorded in T_3 (Only Garlic). The possible explanation for this observation could be linked to the moisture content within the agroforestry system, creating cooler soil conditions compared to sole cropping. This alteration in moisture and consequent temperature variance might significantly impact the growth patterns and timing of sprouting in the intercropped vegetables, such as garlic, potentially elongating the duration required for complete sprouting. The results are similar with the findings of Yadav (2003). Plant height variations were also noted with T_8 (Cherry + Garlic) exhibited the maximum height. The possible reason for this is when crops are grown in proximity to fruit trees, they tend to become much taller and allocate most of their resources to vertical growth rather than lateral growth. The similar findings were reported by (Sayed *et al.,* 2009). The information depicted in the table indicated that the maximum total biomass was recorded in T_3 (Only Garlic). The data in the table showed that the total biomass values were higher in monoculture compared to agroforestry systems. This could be attributed to continuous and sufficient sunlight without obstruction, along with no competition between trees and crops for light, nutrients, or moisture in open conditions, aiding in the synthesis of food materials has also been documented by (Sayed *et al.,* 2009). The other parameters such as diameter of bulb, weight per bulb, weight per 100 cloves, number of cloves per bulb were recorded maximum in T_3 (Only Garlic) (Table-4). The reason for less growth performance of garlic in intercropping is due to high root competition between the crops and trees in the upper soil layer, potentially leading to a substantial decline in crop yield. This reduction is also influenced by decreased light interception and stronger below-ground competition in tree–crop interfaces, which are well-known constraints in vegetable production under partial shade. The reduced growth performance observed in intercropping systems aligns with prior research highlighting high root competition and shading as significant factors contributing to diminished crop yields (Patil, 2010).

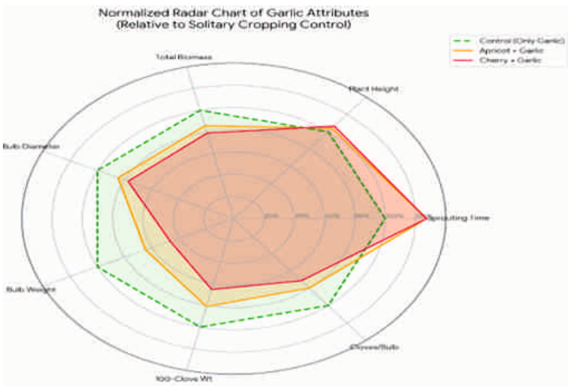


Fig. 02: Normalized profiles of Garlic growth and yield attributes in solitary cropping (Control) compared to Apricot and Cherry intercropping systems.

Growth and Yield parameters of Onion

In the present findings from the research revealed that the growth and yield parameters of onion were significantly affected by different treatments under apricot and cherry-based agroforestry system. Table-5. The data revealed that highest value of plant height was recorded in T_9 (Cherry +Onion). This increase in height can be attributed to altered light availability and microclimatic conditions created by the partial shading of fruit trees, which may induce vertical growth as an adaptive response. Consequently, this

Table 4: Average values for the growth and Yield parameters of garlic under apricot-cherry based agroforestry system.

Symbol	Treatments of Garlic (days)	Sprouting time	Plant Height (cm)	Total biomass (kg ha-1)	Diameter of Bulb (cm)	Weight per bulb (g)	Weight per 100 cloves (g)	Number of cloves per bulb
T_1	Only Apricot	-	-	-	-	-	-	-
T_2	Only Cherry	-	-	-	-	-	-	-
T_3	Only Garlic	11.00	35.51	1567.77	3.82	22.87	222.12	10.30
T_4	Only Onion	-	-	-	-	-	-	-
T_5	Apricot + Garlic	14.00	36.95	1344.43	3.24	14.80	180.06	8.22
T_6	Apricot + Onion	-	-	-	-	-	-	-
T_7	Apricot + Garlic + Onion	14.00	36.86	1384.30	3.50	15.18	181.18	8.38
T_8	Cherry + Garlic	14.00	37.82	1237.51	2.96	10.68	145.12	7.36
T_9	Cherry + Onion	-	-	-	-	-	-	-
T_{10}	Cherry + Garlic + Onion	14.00	37.44	1280.11	3.10	11.00	146.28	7.48
	CD (p?0.05)	1.77	0.42	39.00	0.40	1.09	1.57	0.52
	W (p?0.05)	0.47	0.08	0.13	0.32	0.10	0.19	0.18

proximity could lead to an increase in overall plant height while potentially impeding the proper development of onion bulbs (Yadav 2003).

Similarly, total biomass, diameter of bulb, weight per bulb, were recorded highest in T_4 (Only Onion). The maximum value for growth and yield parameters were noted in the open (monoculture) system compared to an agroforestry setup. The possible reason for this is increased accessibility of light, area, water and nutrients in a singular cropping approach compared to the intercropped field. In sole cropping onions have access to full array of nutrients, water and sunlight without having to share them with other crops. This allows them to develop larger diameters, heights and biomass as they allocate more resources to their growth. In mixed cropping, onions often have to compete for essential resources, resulting in reduced growth and yield (Ferdous *et al*., 2022). These findings clearly demonstrate how reduced light interception and intensified root interactions under tree canopies restrict bulb development in onions.

Net returns from the system

The economic assessment of various cropping systems showed higher returns from agroforestry system rather than sole cropping (Table-8) indicated that the cost of cultivation from intercrops were found maximum in T_4 (Only Onion). However, for fruit trees the maximum cost of cultivation was incurred in T_2 (Only Cherry), T_8 (Cherry + Garlic), T_9 (Cherry + Onion) and T_{10} (Cherry + Garlic + Onion). Sole cropping requires higher inputs like fertilizers, water, and labour, while agroforestry reduces costs through better resource use, nutrient cycling, and natural pest control (Singh *et al.,* 2022).

The gross and net returns from intercrops were obtained minimum when intercrops were cultivated in conjunction with fruit trees as opposed to sole cropping. The maximum gross return and net return from intercrops was found to be in T_3 (Only Garlic) Sole cropping often yields higher returns due to focused management and efficient resource use, while agroforestry may face reduced intercrop yields due to competition and complex management (Singh *et al*., 2022). However, the gross and net returns from fruit trees were obtained maximum when intercrops were cultivated in conjunction with fruit trees. The maximum gross return and net return from fruit trees was calculated in T_7 (Apricot + Garlic + Onion) The possible reason for this could be the interplay between fruit trees and intercrops in agroforestry enhances overall productivity, mitigates risks and reduces input costs. This dynamic interaction results in higher gross and net returns as observed in T_7 (Apricot + Garlic + Onion) surpassing the relatively limited productivity of sole cropping, as seen in T_2 (Only Cherry) (Dutt and Thakur 2020).

The total net return was maximized when intercrops were grown in association with fruit trees rather than sole cropping. The maximum total net return was obtained in T_7 (Apricot + Garlic + Onion). The total net return was

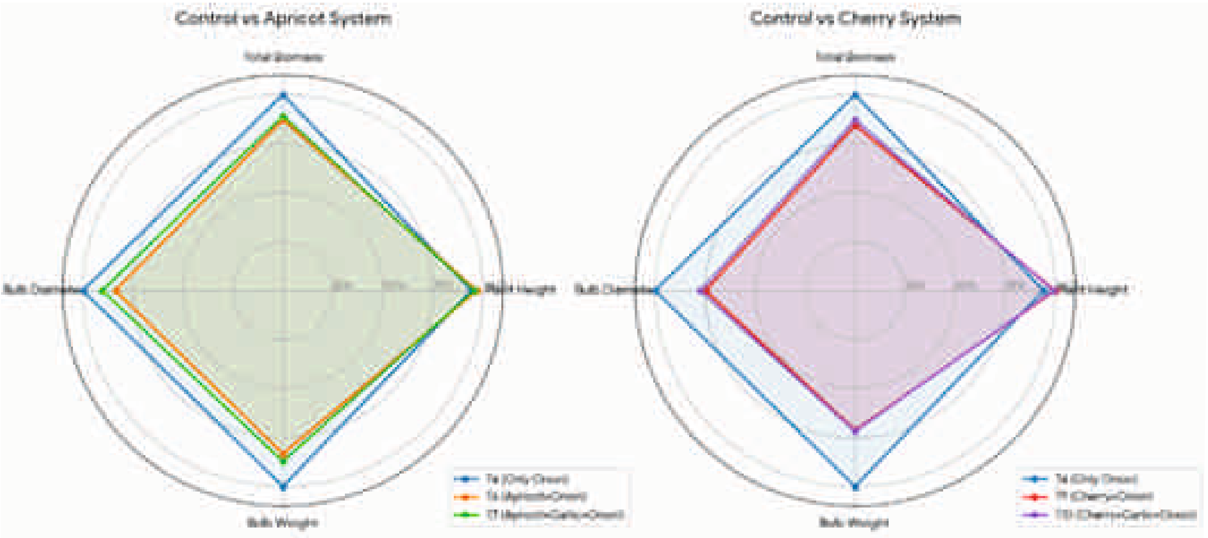


Fig:3 Normalized profiles of onion growth and yield attributes in solitary cropping (Control) compared to Apricot and Cherry intercropping systems.

Table 5: Average values for the growth and yield parameters of onion under apricot-cherry based agroforestry system

Symbol	Treatments	Plant Height (cm)	Total biomass (kg ha^{-1})	Diameter of Bulb (cm)	Weight per bulb (g)
T_1	Only Apricot	-	-	-	-
T_2	Only Cherry	-	-	-	-
T_3	Only Garlic	-	-	-	-
T_4	Only Onion	40.72	1950.60	5.33	43.40
T_5	Apricot + Garlic	-	-	-	-
T_6	Apricot + Onion	41.96	1700.43	4.46	36.16
T_7	Apricot + Garlic + Onion	41.34	1740.30	4.82	37.86
T_8	Cherry + Garlic	-	-	-	-
T_9	Cherry + Onion	43.22	1644.68	3.98	30.92
T_{10}	Cherry + Garlic + Onion	42.88	1699.43	4.12	31.20
	CD (p ? 0.05)	0.78	54.00	0.40	1.80
	W (p ? 0.05)	0.08	0.12	0.32	0.19

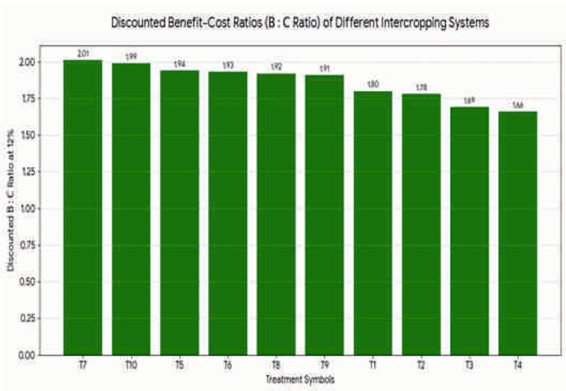


Fig: 4 Comparative Analysis of Economic Viability using Discounted (B:C) Ratio

significantly elevated in agroforestry systems compared to the sole cropping of Garlic and Onion. The increased net returns in agroforestry interventions stem from additional income derived from fruit trees, an advantage absent in sole cropping (Dutt and Thakur 2020). The study indicates that cultivating Garlic and Onion alongside Apricot and Cherry trees ensures consistent income through agroforestry.

Analysis of the data present in Table-8 unveiled that highest benefit-cost ratio among treatments was noticed when intercrops were cultivated alongside fruit trees rather than in sole cropping. The highest benefit-cost ratio in T_7 (Apricot + Garlic + Onion). Agroforestry system tend to benefit from diversified income sources, reduced input costs and enhanced ecological resilience, contributing to higher overall returns relative to the investment made compared to the sole cropping (Bhat *et al.* 2019; Singh *et al.,* 2022). These economic gains also reflect ecological processes such as nutrient recycling, moderated microclimates, and improved soil moisture retention, all of which collectively enhance long-term system sustainability and profitability.

Table 6: Relative economics of different treatments

Symbols	Treatments	Cost of cultivation on intercrops ($ ha^{-1})	Gross return from intercrop ($ ha^{-1})	Net return on intercrop ($ ha^{-1})	Cost of cultivation from fruit trees ($ ha-1)	Gross return on fruit trees ($ ha^{-1})	Net return on fruit trees ($ ha^{-1})	Total net returns from system ($ ha^{-1})	Discounted B:C Ratio @12%
T_1	Only Apricot	0	0	0	934.65	2,620.48	1,687.59	1,687.59	1.80
T_2	Only Cherry	0	0	0	939.90	2,619.85	1,679.95	1,679.95	1.78
T_3	Only Garlic	506.02	1,361.17	855.74	0	0	0	855.74	1.69
T_4	Only Onion	506.02	1,361.49	850.65	0	0	0	850.65	1.66
T_5	Apricot+Garlic	433.73	1,278.67	844.82	934.10	2,718.31	1,900.00	2,662.00	1.94
T_6	Apricot+ Onion	433.33	1,265.89	832.56	923.09	2,701.38	1,850.00	2,615.90	1.93
T_7	Apricot+ Garlic+ Onion	438.10	1,353.57	835.71	923.09	3,094.64	2,195.36	2,744.17	2.01
T_8	Cherry+Garlic	428.57	1,203.81	801.43	928.57	2,807.14	1,801.55	2,471.43	1.92
T_9	Cherry+Onion	433.33	1,202.86	800.48	928.57	2,778.57	1,777.89	2,448.81	1.91
T_{10}	Cherry+Garlic+Onion	438.10	1,346.31	834.52	928.57	2,998.45	2,097.66	2,731.45	1.99

4. CONCLUSION

This study clearly indicates that garlic and onion are economically compatible intercrops under apricot- and cherry-based agroforestry systems in the temperate conditions of the Kashmir Valley. Among the evaluated combinations, apricot + garlic, apricot + onion, cherry + garlic, and cherry + onion recorded superior economic returns, reflecting better utilization of available space and resources in young orchards. The inclusion of both intercrops did not adversely affect system performance, suggesting their suitability for horti-agricultural diversification. Although the experiment was conducted for one growing season in three-year-old orchards, the results provide useful quantitative evidence on short-term profitability and intercropping feasibility in fruit-based agroforestry systems. These findings highlight the potential of such systems to enhance farm income and resource-use efficiency during the early, non-bearing stages of orchards. However, long-term evaluations involving mature trees and multiple seasons are required to assess sustained productivity, ecological interactions, and overall system profitability.

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