



Intercropping Broccoli with Onion and Garlic for Enhanced Yield, Quality and System Profitability in the Eastern Himalayan Foothills Region

R. Lepcha¹, J. C. Jana¹, S. Dutta¹, A. Thapa² , S. Golay¹ and U. Rai³

¹Dept. of Vegetable Science, Horticulture, UBKV, Pundibari, West Bengal (736 165), India

²Centurion University of Technology and Management Paralakhemundi, Gajapati, Odisha (761 211), India

³School of Agriculture, Sikkim Organic Agriculture University, Sikkim (737 121), India



Corresponding  adimangarthapa@gmail.com

 0009-0005-4263-8015

ABSTRACT

A field experiment was conducted over two *rabi* seasons of year 2019–2021 (October, 2019–February, 2020 and October, 2020 to February, 2021) at instructional farm of Uttar Banga Krishi Vishwavidyalaya, Pundibari West Bengal to study the intercropping effect on broccoli with onion and garlic to enhance the yield, quality and system profitability in the Eastern Himalayan Foothills Regions using a randomized block design with seven treatments, including sole and intercropping systems in varying proportions viz; T₁-Sole broccoli. T₂-Sole onion T₃-Sole garlic T₄-Broccoli+onion (1:1) T₅- Broccoli+onion (1:2) T₆-Broccoli+garlic (1:1) T₇-Broccoli+garlic (1:2). During this field experimentation, key parameters assessed included growth, yield, quality, competitive functions, and economic returns. The pooled results during the experiment indicated that intercropping has significantly affected all the observed parameters viz; growth, yield, and quality parameters of broccoli. Among all the intercropping combinations, broccoli+onion (1:1) recorded the maximum growth parameters with a yield of 16.96 t ha⁻¹. The highest LER (1.50) and RCC (16.18) were observed in broccoli+garlic (1:2) intercropping combination. However, production economics suggested broccoli+onion in 1:2 proportion recorded the maximum B:C ratio (3.99). The findings suggest that the strategic intercropping of broccoli onion and garlic offers a sustainable approach to improve productivity and profitability in low-input hill farming systems.

KEYWORDS: Broccoli, intercropping, yield, competitive functions, vitamin C, economic analysis

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Broccoli is an herbaceous plant that is classified under the italic cultivar group of species *Brassica oleraceae*. It is a type of cruciferous vegetable and belongs to the family Brassicaceae, known in the Mediterranean basin and the region of Asia Minor for more than 2,700 years. Morphologically, broccoli is similar to cauliflower, but it differs in several distinct features. The plant forms a central head composed of compact green flower buds supported by thick, fleshy stalks. Unlike cauliflower, the terminal head of broccoli is loose in structure and green in color, with comparatively longer flower stalks. In sprouting types of broccoli, additional long, slender secondary heads commonly known as spears or sprouts develop from the axils of the leaves in addition to the main head. The crop becomes ready for harvest after removal of the main head. Both the sprouts with bud clusters and the terminal head are consumed as salad or in cooked form. Broccoli is a good source of vitamins A and C, carbohydrates, and organic acids. It is also a good source of natural antioxidants and biologically active components. Consuming broccoli not only supplies essential nutrients but also aids in the prevention and treatment of common illnesses. (Jha et al., 2025). The foothill areas of the eastern Himalayan region possess sandy loam soils with good residual moisture and experience a relatively long winter season. These favorable agro-climatic conditions support the extensive cultivation of cole crops by small and marginal farmers. Broccoli, in particular, is predominantly grown as a monocrop in this region, largely following traditional and age-old cultivation practices. Low productivity with a poor market return is a regular phenomenon for the broccoli growers of this zone. Continuously, the cultivable lands are under pressure to increase the productivity. Intercropping of compatible crops has great value and is advantageous in terms of improving the productivity and monetary return from unit land without the use of significant additional resources like space, tillage, nutrients, solar energy and water. Intercropping with the efficient use of water, nutrients, and solar energy helps growers to increase the crop productivity and maintain the soil fertility (Kaur et al., 2025). Intercropping provides indemnification against total crop failure and reduces the incidence of pests and diseases. Broccoli increased yield of with higher productivity and net return in association with

other vegetables has been documented by AI-Bayati et al. (2022) and Barman et al. (2021). However, there is limited information available on suitable intercrops for broccoli under the agro-climatic conditions of the region. In view of this knowledge gap, the present study was undertaken to identify the most appropriate intercropping system for sprouting broccoli with bulbous crops such as garlic and onion, aiming to achieve sustainable, high-quality production along with improved economic returns.

2. MATERIALS AND METHODS

The present experiment was carried out during October, 2019 – February, 2020 and October, 2020 to February, 2021 at the instructional cum departmental field of Uttar Banga Krishi Vishwavidyalaya, West Bengal, India (26° 19' 86" N latitude and 89° 23' 53" E longitude, at an elevation of 43 meters above MSL). The soil of the experimental plot was sandy loam in nature, coarse in texture, and poor in water holding capacity with low pH. The chemical properties of the soil of the experimental plots are presented in Table 1. The Terai zone is characterized by a humid climate with high annual rainfall, elevated relative humidity, moderate temperatures, and a prolonged winter season that results in high residual soil moisture. Temperatures in this region range from a minimum of 7–8°C to a maximum of 24–33.2°C, while the average annual rainfall varies between 210 and 330 cm. Crop growing seasons in this zone are broadly classified into three periods: pre-*kharif* (dry and warm) from March to May, *kharif* (wet and warm) from June to October, and rabi (dry and cool) from November to February. Prior to the establishment of broccoli and its intercrops, composite soil samples were collected from all experimental plots and analyzed to assess the initial soil properties. The experiment was laid out in a randomized block design with 7 treatments and 4 replications. The treatments consisted of T₁-Sole broccoli. T₂- Sole onion T₃- Sole garlic T₄- Broccoli+onion (1:1) T₅-Broccoli+onion (1:2) T₆-Broccoli+garlic (1:1) T₇- Broccoli + garlic (1:2). The planting details of broccoli and component crops have been presented in Table 2. The remaining standard recommended crop management practices were followed as per the package, and the practices of the respective crops were followed for this zone. The data for both the years were computed, and the pooled mean was worked out. The broccoli equivalent yield was calculated in tons (t) by

Table 1: Planting details of sprouting broccoli and intercrops

Crop	Variety	Planting /sowing time	Fertilizer dose N:P ₂ O ₅ :K ₂ O (kg ha ⁻¹)	Spacing	Harvesting
Sprouting broccoli	Green magic	2 nd fort night of November	120:100:80	60×60 cm ²	3 rd week of January
Onion	Sukh sagar	2 nd fort night of November	110:40:60	20×10 cm ²	3 rd week of February
Garlic	Yamuna safed	2 nd fort night of November	60:60:120	20×10 cm ²	2 nd week of March

Table 2: Effect of intercropping on growth and quality parameters of sprouting broccoli

Treatments	Plant height (cm)	No. of leaves	Days taken to 1 st and 50% harvesting	PBFW (g)	PBDW (g)
Sole broccoli	75.04	19.03	62.7	1480.99	203.48
Broccoli+ onion (1:1)	73.44	18.15	64.35	1441.86	188.46
Broccoli+ onion (1:2)	70.31	16.44	65.28	1374.61	174.02
Broccoli+ garlic (1:1)	72.72	17.23	66.33	1422.14	184.13
Broccoli+ garlic (1:2)	69.45	15.22	67.45	1305.95	163.73
SEm±	0.98	0.24	0.88	31.38	5.44
CD ($p=0.05$)	3.25	0.8	2.91	103.92	18.02

*PBFW: Plant biomass on fresh weight basis, PBDW: Plant biomass on dry weight basis

the formula:

$BEY = (\text{Yield of intercrops in a mixed stand} \times \text{price of intercrop}) / (\text{Yield of garlic} + \text{Price of broccoli})$

LER (Land equivalent ratio) is calculated by the following formula- $LER = \sum Y_{ij} / Y_{ii}$

Where, Y_{ij} = Yield of crop in intercropping system and Y_{ii} = Yield of the crop in sole cropping system.

Relative crowding co-efficient (k) is calculated by the formula:

$$Kab = (Y_{ab} \times Z_{ab}) / (Y_{aa} - Y_{ab})$$

Where, Y_{ab} = Yield of crop in a mixed stand, Y_{aa} = Yield of the crop in sole pure stand and Z_{ab} = sown/planting proportion of crop a in mixed stand with b.

Competitive ratio (CRa) is calculated by using the formula $CRa = (LERa / LERb) \times (Z_{ba} / Z_{ab})$, where LER = Land equivalent ratio of the component crop (a and b), Z_{ab} = Sown proportion of the crop a in the mixture with b and Z_{ab} = sown proportion of the crop b in the mixture with a. Vitamin C content was determined by the titrimetric method based on the reduction of 2,6-dichlorophenol indophenol by ascorbic acid. The experimental data were compiled and mean values were calculated. The significance of different sources of variation was tested using Fisher and Snedecor's F-test. Treatment effects were evaluated at the 5% level of significance ($p=0.05$), and the least significant difference was determined using statistical tables described by Fisher

and Yates (10). All statistical analyses were carried out using the INDOSTAT 8.0.

3. RESULTS AND DISCUSSION

The data presented in Table 2 indicate a significant effect of intercropping on most of the growth parameters of broccoli. The maximum values for all observed traits were recorded in the sole cropping of broccoli, confirming that broccoli performs best under non-competitive conditions. Among the intercropping treatments, the combination of broccoli with onion in a 1:1 ratio recorded the highest plant height (73.44 cm), number of leaves (18.15), plant fresh weight (1441.86 g), and dry weight (188.46 g). This was closely followed by the broccoli+garlic (1:1) treatment.

However, the result indicated that broccoli intercropping with garlic in a 1:2 ratio recorded the least value for most of the growth parameters. Monshi et al. (2023) reported that intercropping significantly affect the growth parameters of broccoli when intercropped with red amaranthus and raddish leafy vegetable intercropping combination. Broccoli intercropped with onion in a 1:1 proportion exhibited the highest growth performance, which might be due to the reduced competition for resources, such as nutrients, water, and light, due to the balanced plant population density. Similar observation in increased plant height of main crop was also reported by Begam et al. (2024) in maize and cowpea intercropping system. The root systems and canopy structures of broccoli and onion complement each other; growing them together in the right proportion enhances growth performance and land use efficiency, Al-Wagaa et al. (2020). Garlic has been shown to exert stronger allelopathic effects due to higher amounts of sulfur-containing compounds, such as diallyl sulfides and allicin; these compounds can prevent vegetative growth of companion crops. Similar trends were observed when broccoli was intercropped with garlic (particularly at a 1:2 ratio), showing reduction in growth parameters, indicating allelopathic suppression. Similar results were also reported by Yildirim et al. (2020) and Dhar et al. (2022). The effects of different intercropping combinations on broccoli yield and quality parameters are presented in the Table 3. The number of sprouts and weight of sprouts per plant does not show a significant variation among treatments, indicating no considerable difference among treatments. However, significant differences were recorded with head weight, yield t^{-1} ($t \text{ ha}^{-1}$), and broccoli equivalent yield (BEY). The highest head weight (617.41 g) and yield (20.28 $t \text{ ha}^{-1}$) were recorded in the sole broccoli treatment, followed closely by broccoli+onion 1:1 (609.13 g, 16.96 $t \text{ ha}^{-1}$). Similar observation was coined by Malav et al. (2025) where they observed that intercropping in cauliflower recorded highest curd weight. The lowest head weight (519.17 g) and yield

Table 3: Effect of intercropping on yield parameters of sprouting broccoli

Treatments	No. of sprouts plants ⁻¹	Weight of sprouts plant ⁻¹	Head Diameter	Head weight	Yield t ha ⁻¹	BEY	Vit. C
Sole broccoli	5.82	231.82	42.1	617.41	20.28	20.28	95.25
Broccoli+onion (1:1)	5.83	215.78	41.5	609.13	16.96	23.52	93.55
Broccoli+onion (1:2)	5.53	209.35	39.25	535.38	15.72	23.81	84.67
Broccoli+garlic (1:1)	5.54	212.31	40.15	566.32	16.19	24.62	91.55
Broccoli+garlic (1:2)	5.43	211.56	38.5	519.17	14.66	26.28	82.66
SEm±	0.19	6.07	0.54	7.7	0.09	0.32	1.25
CD ($p=0.05$)	N.S.	NS	1.79	25.5	0.31	1.04	4.15

*BEY: Broccoli equivalent yield

(14.66 t ha⁻¹) were observed in the broccoli+garlic (1:2) treatment. The improved performance of broccoli intercropped with onion, especially in a 1:1 ratio, might be due to reduced competition for resources, better root zone complementarity, and possibly allelopathy-neutral or beneficial interactions. However, allelopathic effects of garlic can be blamed for the notable decline in yield parameters in the garlic intercropping treatments, especially in the 1:2 ratio. Garlic is known to emit sulfur-containing chemicals that have phytotoxic effects on neighboring crops, including diallyl sulfides, ajoene, and allicin. These substances may reduce vegetative growth and biomass buildup by interfering with cell division, nutrient intake, and chlorophyll biosynthesis (Yang et al., 2019). These outcomes support the findings of Singh et al. (2010), who found that improper management of allelopathic interactions in intercropping systems may result in decreased crop production. Similar findings on yield parameters of broccoli was also reported by Dhar et al. (2022) where they observed that intercropping in broccoli yielded better production qualities and financial returns than monocropping. Kumari et al. (2021) reported significant effect on yield parameters of red cabbage when intercropped with radish. Mrnka et al. (2020) reported the yield of cauliflower was significantly increased in cauliflower and carrot intercropping system. Ali et al. (2025) also reported significant effect of intercropping on yield of brinjal from brinjal and onion intercropping system. Similarly, BEY (Broccoli equivalent yield) was highest (26.28) in the broccoli+garlic (1:2) treatment, suggesting a higher efficiency relative to the biological input despite the lower yield. Dhar et al. (9) reported similar finds during their observation where they observed that broccoli based intercropping systems were promising in terms of BEY as compared to mono cropping system. However, the different intercropping combination showed a significant difference in terms of vitamin C content. The highest vitamin C content (95.25 mg 100 g⁻¹) was recorded when broccoli was grown alone, which was

followed by broccoli+onion (1:1) with a value of 93.11 mg 100 g⁻¹, while broccoli+garlic (1:2) showed the lowest (82.66 mg 100 g⁻¹) Vitamin C content was highest in sole broccoli and reduced in mixed treatments. Treatment with broccoli and garlic (1:2) recorded the lowest vitamin C content; this decline in vitamin C content might be due to the enzymatic interactions or oxidative degradation during the combination of vegetables, as supported by findings from Kumar and Singh (2020), who reported that vitamin C is sensitive to processing and interactions with sulfur-containing compounds in garlic. The higher vitamin C content recorded in the sole broccoli cropping system may be attributed to improved nutrient availability and a more favorable growing environment, which enhance ascorbic acid biosynthesis in broccoli heads. Similar increases in vitamin C content under improved crop and nutrient management practices have been reported by Hussain et al. (2021), who observed enhanced ascorbic acid concentration under integrated nitrogen management, and Choudhary et al. (2025), who reported improved vitamin C content with integrated nutrient management. These findings suggest that better crop management practices promote the accumulation of vitamin C in broccoli. The data presented in Table 4 indicated that different intercropping combinations revealed notable variation in competitive functions. The Land Equivalent Ratio (LER) is a key

Table 4: Effect of intercropping on competitive functions of broccoli

Treatments	LER	RCC	Competitive ratio	
			MC	IC
Broccoli+onion (1:1)	1.28	9.1	3.81	0.26
Broccoli+onion (1:2)	1.40	16.18	2.15	0.47
Broccoli+garlic (1:1)	1.33	8.32	3.02	0.33
Broccoli+garlic (1:2)	1.50	15.08	2.11	0.47

*LER: Land equivalent ratio; RCC: Relative crowding coefficient; MC: Main crop; IC: Intercrop

indicator of the productivity of intercropping systems compared to sole cropping. In the present study, all intercropping treatments recorded LER values greater than 1.0, indicating a yield advantage over monoculture. Among the different treatments, broccoli+garlic (1:2) had the greatest LER (1.50), followed by broccoli+onion (1:2) (1.40), broccoli+garlic (1:1) (1.33), and broccoli+onion (1:1) (1.28). Turan et al. (2022) also reported a similar finding in cauliflower and lettuce intercropping system, where he observed LER value higher than 1 in intercropping system as compared to mono cropping. Rahman et al. (2024) coined a similar observation in cauliflower based intercropping system, where they observed that highest LER was recorded when cauliflower is intercropped with French bean and cauliflower. Highest LER was recorded in broccoli intercropped with onion and garlic might be due to the efficient use of resources and the differences of harvest time, root and above ground properties or intercrops resource usage can decrease competition among intercrops due to complementary effect of them (Yildirim and Turan, 2013). Yaldirim et al. (2020), also reported a highest LER when broccoli is intercropped with onion. Ali et al. (2025) also reported intercropping advantage over mono cropping in brinjal and onion based intercropping system. Singh and Kaur (2023) observed the highest LER value in cabbage based intercropping system as compared to monocropping. The highest RCC (16.18) was recorded in the broccoli+onion (1:2) treatment, closely followed by broccoli+garlic (1:2) with 15.08, whereas the lowest RCC was observed when broccoli was intercropped with a 1:1 ratio for both onion and garlic. The competitiveness and dynamics of competition between intercropped species are revealed by the Competitive Ratio (CR). The main crop (broccoli) showed the highest competitive ratio (3.81) when intercropped with onion in a 1:1 ratio, indicating strong competitiveness. However, this value significantly dropped in the 1:2 ratio (2.15), suggesting that increasing the proportion of onion reduced broccoli's dominance. RCC values greater than 1 for all treatments suggest that the component crops in all systems are mutually beneficial, though garlic and onion in the 1:2 ratio appear to outperform other combinations. Similar findings were reported by Meena et al. (2020). The data presented in Table 5 indicated that different intercropping combinations revealed notable variation in economic performance. The highest B:C ratio (3.99) was observed in broccoli+onion (1:2) with a gross return of ₹ 997,700 ha⁻¹ and net return of ₹ 747,950 ha⁻¹, suggesting superior economic performance and resource use efficiency. This was closely followed by B:C ratios of 3.54 (for broccoli and garlic 1:2) and 3.52 (for broccoli and onion 1:1), which yielded net returns of ₹ 641,275 ha⁻¹ and ₹ 627,625 ha⁻¹, respectively, and gross returns of ₹ 894,000 ha⁻¹ and ₹

876,300 ha⁻¹. The lowest B:C ratio (2.32) was recorded in the monocropping of garlic, followed by sole broccoli (2.68) and sole onion (2.82). Intercropping bulb crops with high-value vegetables like broccoli can significantly enhance productivity and economic returns due to complementary resource use. whereas monocropping showed the lowest B:C ratio, confirming that intercropping can significantly enhance profitability. The lower returns in monocropping could be due to less efficient use of space and resources, along with greater vulnerability to pests and diseases. The present findings are in agreement with those of Kaur et al. (2025), who reported that broccoli-based intercropping systems significantly enhanced net returns and the benefit-cost (B:C) ratio compared with monocropping. Hossem et al. (2024) and Turan et al. (2022) concluded that intercropping play an vital role to enhance the farm income of the framers, which make intercropping more economical, that increase land use and fertilizer use efficiency.

Table 5: Effect of intercropping on economics of broccoli

Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B: C ratio
Sole broccoli	226780	608400	381620	2.68
Sole onion	296007	835100	539093	2.82
Sole garlic	250150	580000	329850	2.32
Broccoli+onion (1:1)	248675	876300	627625	3.52
Broccoli+onion (1:2)	249750	997700	747950	3.99
Broccoli+garlic (1:1)	250285	790500	540215	3.16
Broccoli+garlic (1:2)	252725	894000	641275	3.54

1US\$=INR71.59 and 72.80 (Average value of February months)

4. CONCLUSION

Intercropping of broccoli with onion and garlic in different proportion significantly influenced vegetative growth, yield, and quality parameters of broccoli. From the above LER, RCC, competitive ratio, and economic analysis, we can conclude that intercropping broccoli with bulbous crops (onion and garlic) can be recommended as profitable for the vegetable growers of West Bengal. To conclude, this seminal work lays down the fact that intercropping shows appreciable output as compare to mono cropping regarding growth yield and quality parameters of broccoli, which can be suggested for future recommend treatment for better outcomes.

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