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Research Article

Economics of Inter-Cropping: A Case Study of Onion and Tomato at District Muzaffargarh, Punjab-Pakistan

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Abstract: The current research is being conducted in Muzaffargarh district of Punjab, Pakistan to investigate the profitability and land equivalent ratio of intercropping onion and tomato. An economic analysis of intercropping in the Muzaffargarh district can inform farmers about the profitability and sustainability of this practice, aiding their decision-making between intercropping and monocropping. The study utilized a simple random sampling technique to select 45 vegetable growers out of 60, from two major vegetable-growing villages; Hajiwah and Beli Janubi. Descriptive analysis, including frequency distribution, mean, and percentages, was used to analyze the data. The results of the study showed that intercropping had a significantly higher yield (17897 kg/acre) than sole cropping of onions (6075 kg/acre) and tomatoes (16050 kg/acre). Intercropping also had a higher benefit-cost ratio of 1.59, compared to onion sole cropping (1.37) and tomato sole cropping (1.48). The land equivalent ratio was 1.31, which indicated that intercropping was more efficient in terms of land use than sole cropping. The study also revealed that intercropping onions and tomatoes provided additional income to farmers and helped maximize land use. However, farmers encountered challenges such as high seed costs, diseases, low output prices, and high transportation costs. In conclusion, the study suggested that intercropping onion and tomato is a viable agronomic strategy in the Muzaffargarh district, as it improves land-use efficiency and maximizes returns. The study showed that intercropping complemented each other and contributed to increasing yield per unit area and improving nutritional properties.

Keywords: Intercropping, Profitability, Land Equivalent Ratio, Onions and Tomatoes, Muzaffargarh

1. INTRODUCTION

Intercropping is a method of growing two or more crop species in the same field at the same time during the growing season [1] and it is the more efficient use of resources such as soil, water, nutrients, and solar radiation to grow two or more cultivars at the same time on the same land [2]. Intercropping is a traditional but important cropping system approach for increasing total productivity and farmer income, particularly in densely populated countries with limited per capita cropland [3]. Intercropping is effective in generating a variety of crops and is comparable in yield to sole cropping, while also increasing crop resilience, ecosystem services, and nutrient efficiency [4] and climate-resilient intercropping systems have great potential to reduce fossil fuel intensive inputs [5]. Farmers need local expertise and technical assistance based on locally-derived data to achieve optimal intercrop production [6]. Industrial agriculture can be easily diversified through intercropping, which involves the integration of alternative crops or non-crop plants alongside cash crops. This method is relatively simple and effective in promoting diversity within agricultural systems [7] and by incorporating intercropping methods, crop productivity can be significantly enhanced compared to conventional monoculture methods [8].

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A wide range of intercropping has been developed around the world, in places like Indonesia, India, Niger, Mali, Central America, and Western Europe, because it significantly increases land productivity compared to monocultures [9, 10]. Intercropping can improve soil fertility as different crops have different root depths and can therefore access different soil layers, helping to improve soil structure and nutrient availability [11]. To achieve spatial complementarity in intercropping, different plants with varied root patterns should be grown together. For instance, combining deep-rooted and shallow-rooted crops can enable access to distinct soil volumes, enhancing resource utilization and reducing competition for resources [12]. Intercropping increases P availability in the rhizosphere of intercropped plant species [13], as well as improving soil resource utilization [14]. Furthermore, the system increases the land equivalent ratio [15, 16], lowering crop failure risk and increasing food security [17]. The cultivation of particular varieties in intercropping systems has a number of favorable effects [18] and alters the dominant microbial species and soil microbial communities [19, 20].

Higher-income and improved socioeconomic status were the primary drivers of intercropping adoption, and intercropping can be effectively adopted through field training and demonstrations [21]. Intercropping improves farm resource management by increasing total productivity per unit of land and per unit of time and can significantly reduce pest issues [22]. Transitioning to more bio diverse agricultural systems, such as intercropping and agroforestry, can serve as an adaptive measure against climate change. These systems offer a range of benefits at both the farm and ecosystem levels, including biotic, abiotic, economic, and social advantages [23] and intercropping can decrease surface soil evaporation and secondary salinization by increasing the surface coverage of the soil [24]. The practice of intercropping is most prevalent in developing nations [25] and because of its significant yield advantage over sole cropping, it has been recognized as a potentially useful technology to increase crop production [26]. Flexibility, profit maximization, risk reduction, soil conservation, soil fertility improvement, and lower production costs, as well as higher profitability, are some of the main motivations for smallholder farmers to intercrop [27]. Intercrops have the potential to provide a higher yield than sole crops, greater yield stability, efficient use of nutrients [28], reduced disease infestations, and a decrease in the number of pests and weeds [29]. A lot of scientists in the fields of agriculture and ecology are becoming increasingly interested in the intercropping approach to vegetable production as a result of the aforementioned qualities [30]. When lettuce is intercropped with onions, it helps to control Agrotis ipsilon, a significant insect pest that affects lettuce [31] and can enhance the natural suppression of pests [32].

Garlic and strawberry intercropping increase both the gross income and the land equivalent ratio, and intercropping systems had no impact on the production of strawberry pseudo fruits or garlic bulbs [33]. For the effective production of vegetables enriched in selenium, pakchoi and radish can be intercropped to increase selenium accumulation in the edible parts of the crops [34]. The nitrate content of the soil profile decreased because intercropping use soil nutrients more efficiently than sole cropping [35] and intercropping significantly decreased the frequency of forked carrots and increased cauliflower yield [36].

Intercropping maize with legumes has the potential to minimize crop failure risk, increase productivity and income, and increase food security in vulnerable agricultural systems [37] and intercropping also has some issues such as intercropping can lead to competition for resources such as water, light, and nutrients, which can reduce crop yield and quality [38]. Intercropping can be more complex to manage than monoculture systems as it requires careful selection of crop combinations, planting densities, and management practices [39] and some crop species may be incompatible with each other, leading to reduced growth and yield [40]. Both intercropping and rotation are effective methods for enhancing crop productivity and providing ecological benefits [41]. Intercropping can create microclimates that favor the development of certain pests or diseases like increased the incidence of maize stem borers and reduced maize yields compared to monoculture [42] and reduction in the yield of both total and marketable bulbs when onions are intercropped with coriander [43] and a reduction in yields when leeks are intercropped with carrots [44]. The intercropping system had a significant impact on the yield attributes of different component crops, such as radish, small onion, and vegetable cowpea, but a single stand of component crops produced higher yield attributes than the intercropping system [45]. Muzaffargarh is known for its fertile land and the cultivation of various vegetables, particularly tomatoes. However, the majority of farmers in the region are small landholders with limited resources. Analyzing the cost and returns of intercropping can provide valuable insights into the economic feasibility of this farming practice in the area. The land equivalent ratio (LER) is a useful method for assessing the efficiency of intercropping and determining its effectiveness in optimizing land use and increasing yields. The research conducted in the Muzaffargarh district is a significant effort to understand the farming practices and challenges faced by small-scale farmers in the region, as well as to identify strategies for improving their productivity and economic viability. Overall, this research holds great promise for enhancing the livelihoods of farmers and promoting sustainable agricultural practices in the area. The research was carried out with the following objectives: (i) to examine the socio-economic characteristics and existing agronomic practices of sampled farmers; (ii) to analyze the cost and returns of intercropping for sampled farmers; (iii) to evaluate the land equivalent ratio (LER) to determine the efficiency of intercropping; and (iv) to identify constraints in the production and marketing of sampled farmers in the study area.

2. METHODS AND MATERIAL

2.1. Description of Study Area

Muzaffargarh is a district in the Punjab province of Pakistan that spans over an area of 8,249 km^2. It shares borders with the district Layyah to the north and Bahawalpur and Rahimyar Khan districts to the south, across the Chenab River. As per the 2017 census, the district had a population of 4.32 million people, and the literacy rate was 47 percent. The region is known for its agriculture, with numerous citrus and mango farms in the surrounding areas. The climate in Muzaffargarh is arid, with extremely hot summers and mild winters. The annual rainfall in the district is 127 millimeters, as illustrated in Figure 1.

Fig. 1. Map of the study area (District Muzaffargarh, Punjab-Pakistan)

2.2. Data Collection

The study was conducted as part of the "Strengthening Vegetable Value Chains in Pakistan" (SVVCP) project, which was funded by the Australian Centre for International Agricultural Research (ACIAR). The primary objective of this project was to enhance the value chains of three target vegetable crops in Pakistan (onions, potatoes, and tomatoes) using a community-based approach. The initiative aimed to improve the livelihoods and household incomes of resource-poor communities sustainably, by enhancing the capabilities of value chain actors such as farming families, traders, and intermediaries. The project focused on two villages, Baily Janobi and Hajiwah, in Muzaffargarh district, known for vegetable cultivation. To gather primary data, the Social Sciences Research Institute (SSRI) at NARC conducted a baseline survey, interviewing 45 vegetable growers who were randomly selected from 60 farmers involved in intercropping (onions and tomatoes) and sole cultivation of tomatoes. Of the 45 farmers surveyed, 24 were engaged in sole onion cropping as well. The selected farmers were interviewed using a structured questionnaire that covered topics such as nursery management, intercropping, farm management practices, and production and marketing constraints.

2.3. Data Analysis

To achieve the objectives of the study, a descriptive statistic was used to analyze the percentages, frequency, and mean. The profitability of intercropping was examined on the basis of gross margin, the net return, benefit-cost analysis, and land equivalent ratio.

- To estimate the cost of onion production, the following equations were used:

  $$\mathbf{VC = \sum (Xi\ Pi)}$$
  $$\mathbf{TC = TVC + TFC}$$

  Where,
  TC = Total cost of production (Rs. /acre)
  TVC = Total Variable costs (Rs. /acre)
  TFC = Total Fixed costs (Rs. /acre)
  Xi = Quantity/Number of inputs per acre
  Pi = Price of inputs (Rs. /acre)

- To estimate the profitability of onion production, the following equations were used:
  Where,

  $$\mathbf{GR = \sum (Y_i\ P_i)}$$
  $$\mathbf{NR = GR\text{-}TC}$$
  $$\mathbf{GM = GR\text{-}VC}$$
  $$\mathbf{BCR = GR/TC}$$

  GR = Gross return (Rs. /acre)
  NR = Net return (Rs. /acre)
  GM = Gross margin (Rs. /acre)
  Y_i = Quantity of output (Kg/acre)
  P_i = Price of onion (Rs. /kg)

- To find out the economics of the individual intercropping system, the following equation was used:

Land Equivalent Ratio (LER)

LER indicates the proportion or amount of land area that is needed for sole cropping to produce the same yield as intercropping [Mead and Willey, 1980]. The LER was calculated using the following formula to determine the economics of the individual intercropping system.

$$\mathbf{LER = L_1 + L_2 = YI_1/YS_1 + YI_2/YS_2}$$

Where,
L_1 and L_2 = LERs for the individual crops (tomato and onion)
YI_1 and YI_2 = Individual crop yield in intercropping
YS_1 and YS_2 = Yields as sole crops

If LER is > 1, intercropping is considered advantageous; if LER is < 1, intercropping is considered disadvantageous; and if LER = 1, then there is no profit or loss from intercropping.

3. RESULTS AND DISCUSSION

The study consisted of three sections. The first section examined the socioeconomic characteristics of the sampled farmers. The second section focused on farm characteristics, while the third section discussed the farming practices of the farmers.

3.1. Age Group of Sampled Farmers

The respondents' agricultural experience increased with age, implying that older farmers had more risk-related interactions than younger farmers. According to the data, farmers between the ages of 41 and 50 (33 %) scored the highest, while those beyond 50 (16 %) scored the lowest (Figure 2). The sampled farmers' average age was 40.3 years, indicating that the majority of them were of working age and could increase agricultural production in the field with support and a supportive environment. Overall, the data implies that there is a correlation between age and agricultural experience, with older farmers having encountered and navigated through more risk-related situations. This suggests that elder farmers possess valuable insights and skills from their extensive exposure to diverse agricultural challenges.

3.2. Educational Level of Sampled Farmers

Based on the study findings, 38 percent of the sampled farmers were illiterate, 22 percent had only primary education, 27 percent had high school education, and 13 percent had graduate degrees (Figure 3). The average formal education of the sampled farmers was 5.1 years, which suggests that the majority of the sampled farmers in the research area had little formal education. The results illustrate that most farmers have limited formal education, impacting their ability to embrace new agricultural practices and adapt to changes. This underscores the need for focused educational efforts to narrow the knowledge gap and enhance their engagement with innovations.

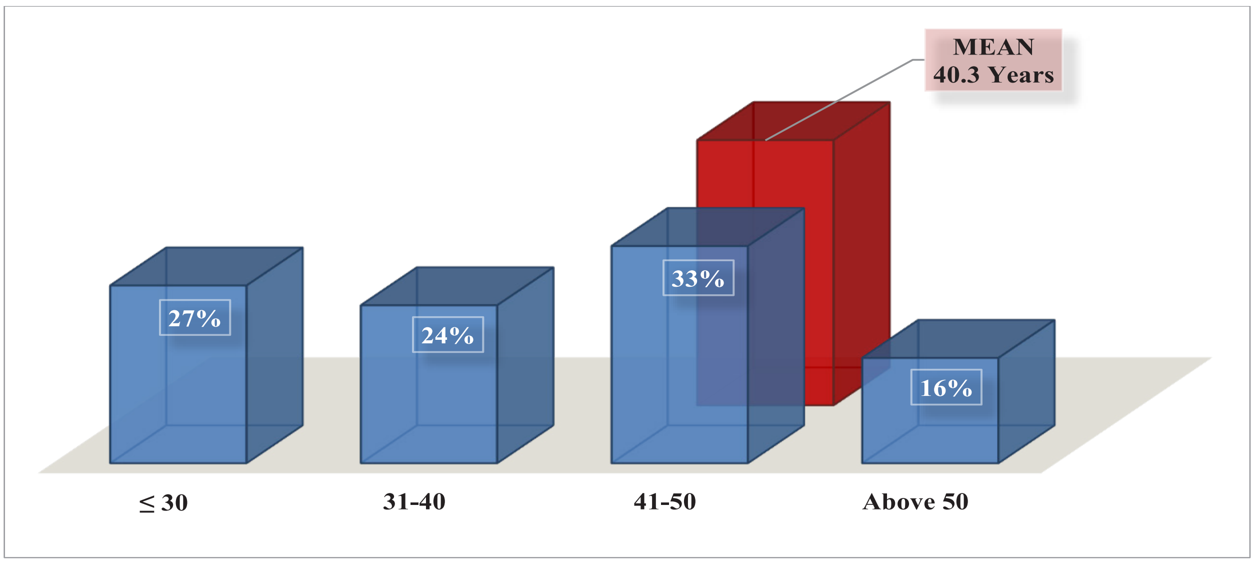

Fig. 2. Age group of sampled farmers

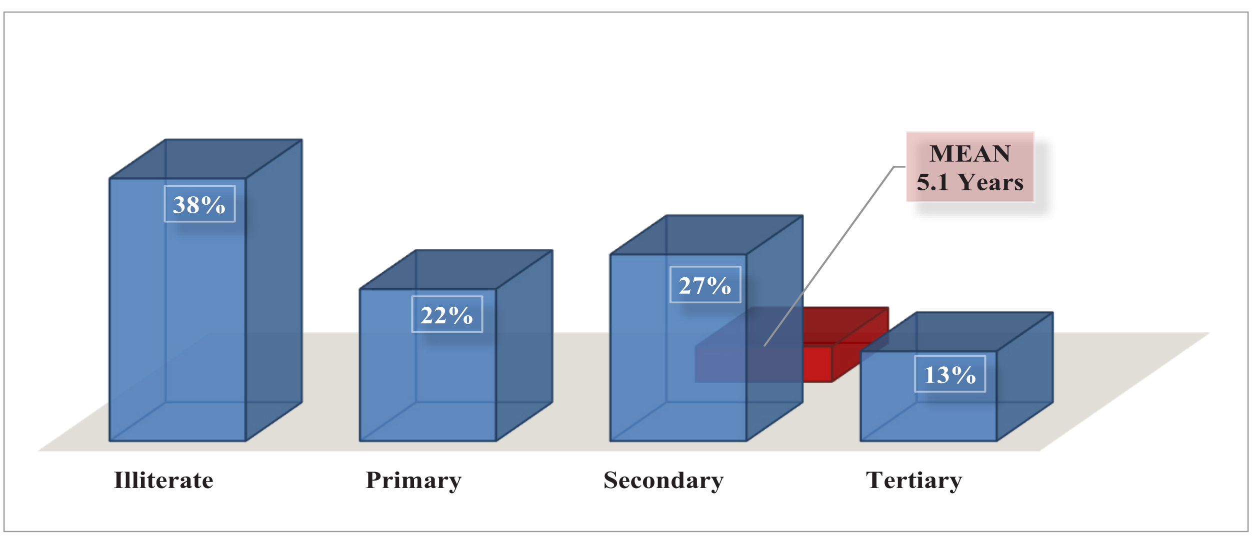

Fig. 3. Educational level of sampled farmers

3.3. Farming Experience of Sampled Farmers

The amount of risk exposure and the implementation of a risk management approach are both influenced by a farmer's level of farming experience. A farmer with numerous years of farming experience has greater knowledge than a farmer with little farming experience. According to Figure 4, the majority (44 %) of the farmers in the research region had a respectable amount of agricultural experience, which varied from 11 to 20 years, whereas (38 %) had less than 10 years of experience. Only 9 % of the farmers chosen had been farming for more than 30 years, while 9 % had been farming for between 21 and 30 years. The sampled farmers had an average of 15.9 years of farming experience. The diversity of farming expertise within the research area influences how individuals are exposed to risks and how they navigate uncertainties. Farmers with greater experience tend to be more skilled at managing agricultural uncertainties by leveraging their accumulated knowledge and making well-informed decisions.

3.4. Household Size of Sampled Farmers

Figure 5 findings regarding household size reveal that more than half (55 %) of the sampled farmers had 6–10 family members, followed by 27 percent who had less than 5 family members. The sampled

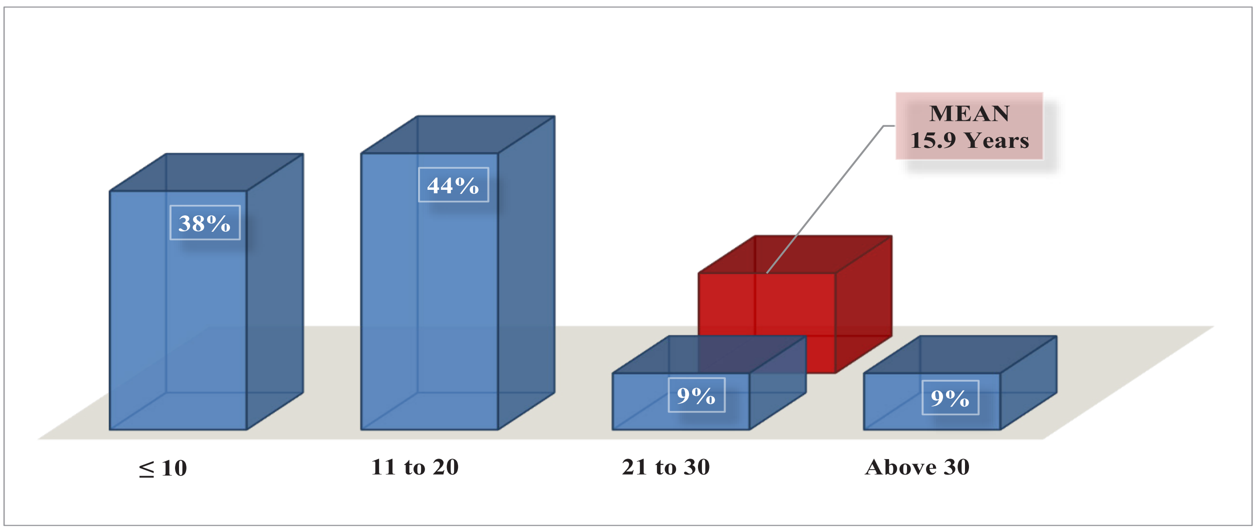

Fig. 4. Farming experience of sampled farmers

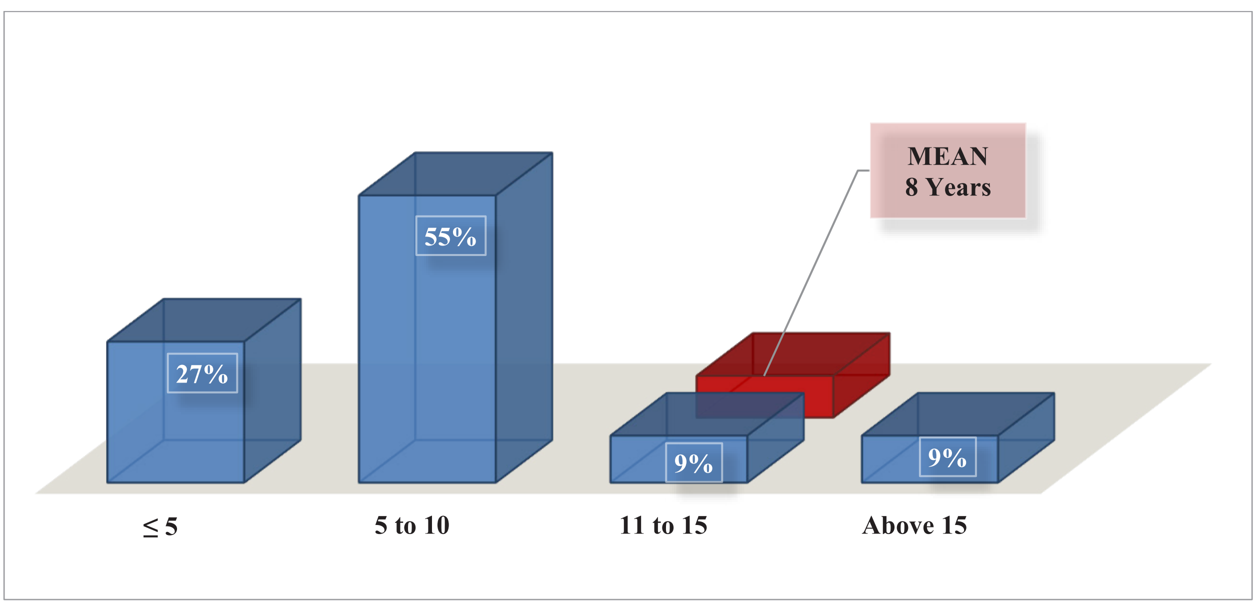

Fig. 5. Household size of sampled farmers

farmers had an average family size of 8 people. Family members of farmers make significant labor contributions to the family labor pool, but this also increases the farmers' reliance ratio. The results show that a substantial number of sampled farmers have larger households, and family members play a vital role in farm work. This boosts productivity but also raises the reliance ratio, making the household more sensitive to economic changes. To address this, it's crucial to manage labor, diversify income, and enhance efficiency to safeguard the welfare of these farming families.

3.5. Family Type of Sampled Farmers

Families are progressively dissolving, and more people are choosing to live separately in order to enhance their standard of living. The majority of the sampled farmers (62 %) were part of nuclear families, whereas (38 %) were part of joint families. Figure 6 demonstrates a rising trend towards nuclear families (62 %), reflecting a preference for independent living, likely motivated by a desire to improve living standards. Concurrently, joint families (38 %) continue to emphasize the lasting importance of strong family bonds and communal living practices in the region.

3.6. Sampled Farmers' Involvement in Farming

Figure 7 depicts the sampled farmers' part-time and full-time participation in farming activities. More than half (51 %) were actively involved in farming, while the remaining 49 percent were only partially involved. The results show a significant number of farmers fully committed to farming, while others engage only part-time. This highlights varying reliance on agriculture for livelihoods, offering insights into rural economies and livelihood approaches in the study area.

3.7. Occupational Distribution of Sampled Farmers

Farming is the primary occupation in rural areas because it provides the majority of the income for those who live there. Figure 8 shows the job descriptions of the sampled farmers. The sampled farmers who rely solely on farming represented 76 percent, while 24 percent also held other employment in addition to farming. The findings indicate that farming is really important in rural areas because it helps people earn a lot of money. The information in Figure 8 also shows that most people mainly depend on farming for their income, while some others have different ways of making money.

3.8. Farm Area Owned by Sampled Farmers

Figure 9 reveals that 27 % of the sampled farmers were tenants and did not have their own land, while the majority (47 %) had less than one acre, followed by 20 % had 1-3 acres, and 6 % had more than 3 acres, while an average farm size was 0.98 acre. The findings illustrate that the sampled farmers were primarily smallholders, often tenants cultivating small plots of land. This inference is strengthened by the average farm size, which was less than one acre, indicating a scarcity of large-scale farming within the sample.

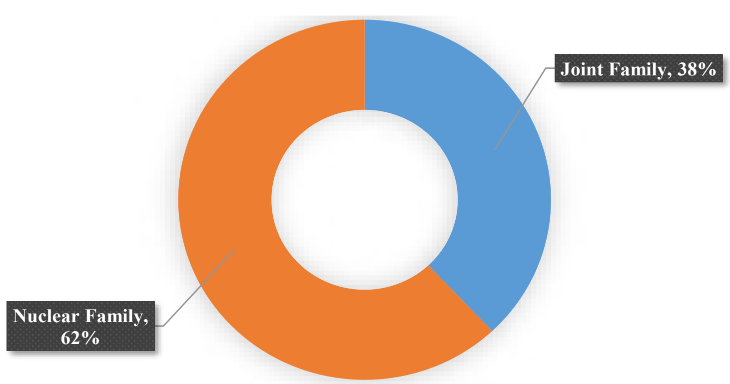

Fig. 6. Family type of sampled farmers

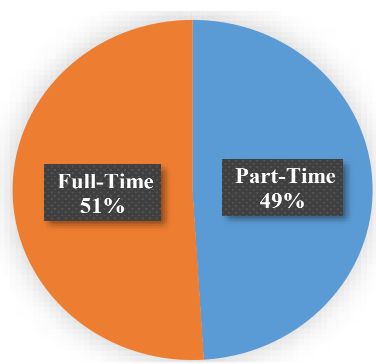

Fig. 7. Sampled farmers' involvement in farming

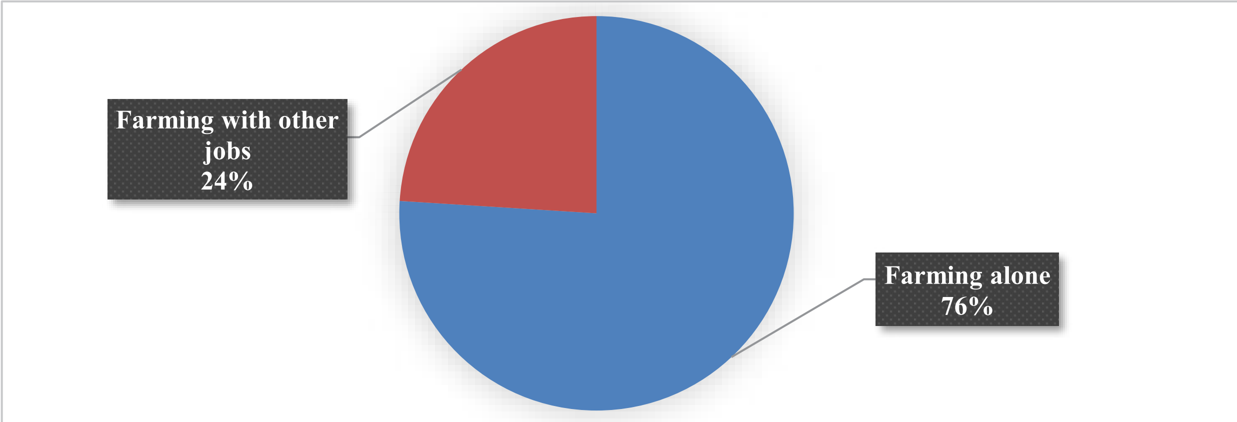

Fig. 8. Occupation of sampled farmers

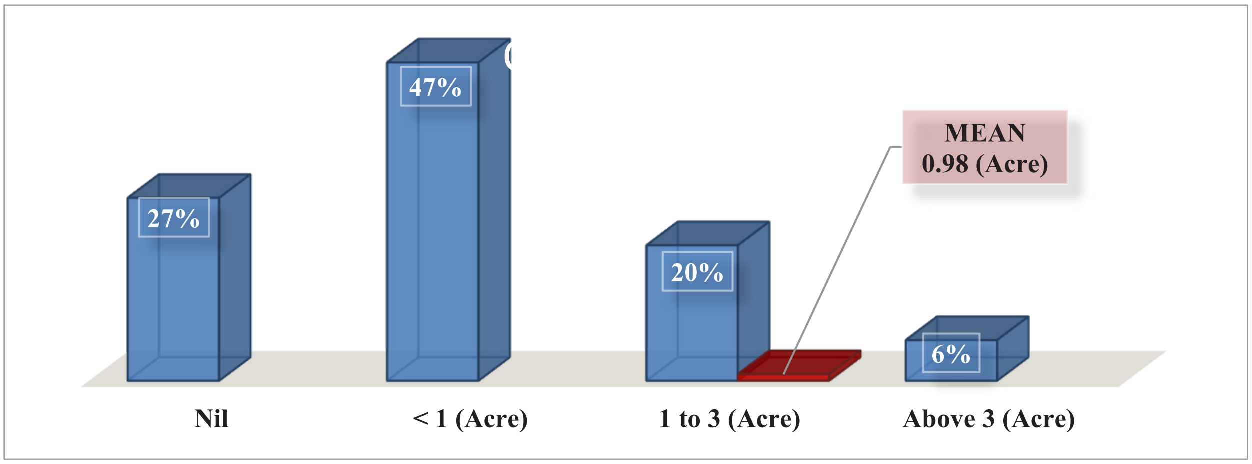

Fig. 9. Farm area owned by sampled farmers

3.9. Tenancy Status of Sampled Farmers

The tenancy status of the sampled farmers is shown in Figure 10. Only 15 % of the sampled farmers were owners; more than half (58 %) were owner-cum-tenants, while 27 % were tenants. Hence, the majority of the sampled farmers had a mixed tenancy status as owner-cum-tenants. This underlines a close interconnection between land ownership and tenancy in this farming community. This diversity implies a variety of economic and property dynamics in action. Further investigation is warranted to comprehend the drivers behind these trends and their potential implications for the agricultural sector.

3.10. Farm Equipment Owned by Sampled Farmers

Table 1 provides information about the farm machinery that the sampled farmers possessed. The study's findings showed that 20 percent of sampled farmers did not possess any agricultural equipment. The majority of sampled farmers (38 %) had their spray pumps; 20 percent had diesel engines; and 16 percent had tube wells. The study revealed a prominent possession of spray pumps and diesel engines among sampled farmers, while essential equipment like tractors, cultivators, and rotavators were less common. Despite limited ownership, the availability of farm equipment for rent in the study area was reported to be sufficient according to farmers.

3.11. Sources of Information

Table 2 shows the major sources of information obtained by sampled farmers in the study area. The majority (76 %) of the sampled farmers indicated fellow farmers as their source of information for agricultural and marketing purposes. Similarly, the other important source were seed dealers,

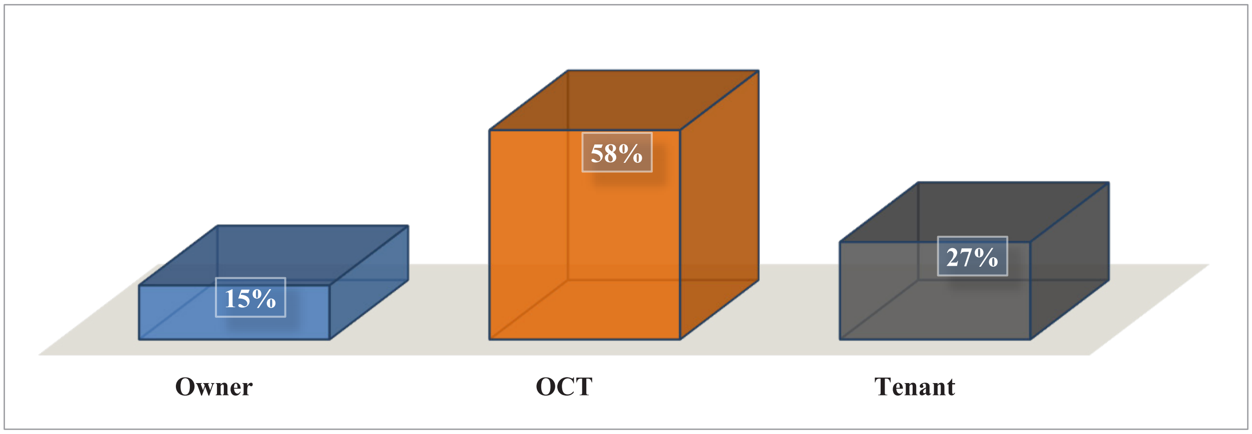

Fig. 10. Tenancy status of sampled farmers

Table 1. Percentage distribution of farm equipment owned by sampled farmers

Farm Equipment (owned)	Frequency	Percentage
Nil	09	20
Tractor	01	02
Cultivator	01	02
Rotavator	01	02
Sprayer	17	38
Tube well	07	16
Diesel Engine	09	20
Total	**45**	**100**

Source: Field survey data, 2019-20

middlemen, and agricultural extension workers, representing (13 %), (7 %), and (4 %), respectively. These findings emphasize the strong reliance on informal networks within the farming community for obtaining relevant information.

3.12. Sources of Irrigation

Table 3 showed the major irrigation sources of the sampled farmers in the study area. The majority (75.6 %) of the sampled farmers were using tube wells, while 24.4 percent were using both canal and tube wells for irrigation purposes. The study underscores the dominance of tube wells as the primary irrigation source underscores the importance of groundwater for sustaining agricultural productivity. The fact that many farmers are using both canals and tube wells for irrigation shows that they are smart and flexible in dealing with water challenges.

Table 2. Percentage distribution of sampled farmers by sources of information

Sources of Information	Frequency	Percentage
Fellow farmers	34	76
Agricultural extension	02	04
Arhti/Middle-men	03	07
Seed dealers	06	13
Total	**45**	**100**

Source: Field survey data, 2019-20

Table 3. Irrigation sources of sampled farmers for selected vegetables

Irrigation Sources	Frequency	Percentage
Tube well	34	75.6
Canal + Tube well	11	24.4
Total	**45**	**100**

Source: Field survey data, 2019-20

3.13. Acquisition of Loan

Farmers used a variety of sources to get agricultural credit to meet their financial needs. The data pertaining to loan acquisition is shown in Table 4. Only 31 % of sampled farmers obtained credit for their farm operations. The low percentage of farmers accessing formal financial institutions, coupled with significant reliance on self-financing and informal sources, emphasizes the need for targeted policies and interventions to improve farmers' access to affordable and timely credit. Addressing these challenges is crucial for promoting sustainable agricultural growth and rural development.

3.14. Sources of Loan

The different loan programs available to farm businesses in the study area are listed in Table 5. More than half (57 %) of the sampled farmers borrowed money from commission agents, who are the most frequent source of debt among them. This is followed by NGOs (22 %), commercial banks (14 %), and relatives (7 %). The distribution of loan programs and sources of debt among farmers in the study area reflects a complex financial landscape. While commission agents dominate as a source of credit, the presence of NGOs and commercial banks, along with borrowing from relatives, underscores the diversity of options available to farmers. Efforts to enhance financial literacy, improve access to formal credit, and regulate informal sources can contribute to a more sustainable and equitable credit ecosystem for agricultural communities.

Table 4. Loan obtained by sampled farmers

Loan Obtained	Frequency	Percentage
Yes	14	31
No	31	69
Total	**45**	**100**

Source: Field survey data, 2019-20

Table 5. Percentage distribution of sampled farmers by sources of loan obtained

Sources of Loan	Frequency	Percentage
Bank	02	14
Commission Agents	08	57
NGOs	03	22
Any others	01	07
Total	**14**	**100**

Source: Field survey data, 2019-20

3.15. Purpose of Loan

Table 6 lists the purpose of borrowed money received by the sampled farmers in the study area. The majority of the sample's farmers (79 %) had taken out loans for crops, followed by loans for livestock (7 %), and then loans for businesses (14 %). Crop-related loans dominate, reflecting the fundamental role of agriculture in these communities. Livestock and business loans showed farmers' efforts to diversify income sources and improve their overall economic well-being. Access to credit for these purposes can play a significant role in promoting sustainable agricultural practices, livestock management, and rural development.

3.16. Loan Size Obtained

Table 7 displays the loan amounts obtained by the sampled farmers in the study area. About half (50 %) of the sampled farmers received loans up to $50,000, 22 % received loans between $50,000 and $1,000,000, and 28 % received loans exceeding $1,000,000 in total. The availability of loans across different amounts states the importance of offering a diverse range of financial products to cater to the unique requirements of farmers at different stages of development.

Table 6. Percentage distribution of farmers according to the purpose of the loan

Purpose of Loan	Frequency	Percentage
Crop	11	79
Livestock	01	07
Business	02	14
Total	**14**	**100**

Source: Field survey data, 2019-20

Table 7. Size of loan obtained by sampled farmers

Loan Size (Rs)	Frequency	Percentage
≤ 50000	07	50
50001-100,000	03	22
Above 100,000	04	28
Total	**14**	**100**

Source: Field survey data, 2019-20

3.17. Profitability of Intercropping

The economics of intercropping presented in Table 8 revealed that the total gross revenue was Rs. 289668/acre, whereas the total cost amounted to Rs. 182756/acre. Similarly, the gross margin was found to be Rs. 124912 per acre, while the net return over the total cost was found to be Rs. 106912 per acre. Hence, the benefit-cost ratio comes to around 1.59. It is evident that the percentage share of the total variable costs is 90.2 percent, and the fixed cost was 9.8 percent of the total cost of production. The variable costs include land preparation (6.8 %), seeds (11 %), nursery raising and transplanting costs (3 %), manures (2.6 %), fertilizers (5.7 %), weeding and hoeing (5.5 %), insecticides and pesticides (6.3 %), irrigation (5.8 %), harvesting and curing (14 %), and transportation and marketing costs (27.2 %) of total production costs. Among the different items of cost, the transportation and marketing cost, harvesting and curing cost, the rental value of land cost, and seed cost were the major items of cost of cultivation in intercropping. The benefit-cost ratio of intercropping was also higher, with a value of 1.59 than sole crops. So intercropping onions with tomatoes was more profitable as compared to sole crops. The findings revealed that the practice of intercropping onions

Table 8. Profitability of intercropping (Rs. /acre)

S. No.	Operating Costs	Cost /Acre	Percent
A	**Variable Costs**	**164756**	**90.2**
a)	Land preparation	12487	6.8
b)	Seed cost (Tomato)	17279	9.5
c)	Seed cost (Onion)	2811	1.5
d)	Nursery raising & transplanting cost	5500	3.0
e)	Farmyard manure	4762	2.6
f)	Fertilizers	14261	5.7
g)	Hoeing and weeding	10137	5.5
h)	Plant protection	11547	6.3
i)	Irrigation	10623	5.8
j)	Harvesting and curing (Tomato)	23500	12.9
k)	Harvesting and curing (Onion)	2040	1.1
l)	Transportation & marketing cost (Tomato)	48095	26.3
m)	Transportation & marketing cost (Onion)	1714	0.9
B	**Fixed Costs**	**18000**	**9.8**
a)	Rental value of land (for 6 months)	18000	9.8
C	**Total Costs (C= A+B)**	**182756**	**100**
D	Yield (kgs/acre) (tomato)	16032	-
E	Sale price (Rs./kg)	15.8	-
F	Gross revenue (Rs./acre) **(D*E)**	253300	-
G	Yield (kgs/acre) (onion)	1865	-
H	Sale price (Rs./kg)	19.5	-
I	Gross revenue (Rs./acre) **(G*H)**	36368	-
J	Total gross revenue **(F+I)**	289668	-
K	**Gross Margin** (Rs./acre) **(J-A)**	**124912**	-
L	**Net Return** (Rs./acre) **(J-C)**	**106912**	-
M	**Benefit-Cost Ratio** (Rs./acre) **(J/C)**	**1.59**	-

Source: Field survey data, 2019-20

and tomatoes was found to be economically favorable. The benefit-cost ratio, which measures the profitability of the venture, indicated that intercropping yielded positive financial returns. Additionally, the comparison of intercropping's benefit-cost ratio with that of sole crops further supports the conclusion that intercropping was more profitable.

3.18. Profitability of Onions (Sole)

The economics of onion (sole) cultivation presented in Table 9 revealed that the gross revenue was Rs. 118463/acre, whereas the total cost amounted to Rs. 86379/acre. Similarly, the gross margin was found to be Rs. 50083 per acre, while the net return over the total cost was found to be Rs. 32083 per acre. Hence, the benefit-cost ratio comes in around 1.37. The percentage shares of variable costs and fixed costs of production were 79.2 percent and 20.8 percent of the total cost of production, respectively. The variable costs include land preparation (13.3 %), seeds (5.9 %), nursery raising and transplanting costs (5.2 %), manures (6.4 %), fertilizers (12.5 %), weeding and hoeing (6.7 %), insecticides and pesticides (1.9 %), irrigation (12.2 %), harvesting and curing (7.8 %), and transportation and marketing costs (6.6 %) of total production costs. Among the different items of cost, the rental value of land, land preparation cost, fertilizer cost, and irrigation cost were the major items of cost of cultivation in onion (sole) production. The data suggests positive economic outcomes for sole onion cultivation, individual farmers should conduct a comprehensive analysis to determine the suitability of this crop within their overall farming strategy.

3.19. Profitability of Tomatoes (Sole)

The economics of tomato (sole) cultivation presented in Table 10 revealed that the gross revenue was Rs. 253590 per acre, whereas the total cost amounted to Rs. 170921 per acre. The gross margin was determined to be Rs. 100669 per acre, with a net return over the total cost of Rs. 82669 per acre. The benefit-cost ratio comes to around 1.48, which shows that the tomato crop is a remunerative

Table 9. Profitability of onions (sole) (Rs. /acre)

S. No.	Operations/Inputs	Cost /Acre	Percent
A	**Variable Costs**	**68379**	**79.2**
a)	Land preparation	11511	13.3
b)	Seed cost	5137	5.9
c)	Nursery raising and transplanting cost	4533	5.2
d)	Farmyard manure	5500	6.4
e)	Fertilizers	10767	12.5
f)	Weeding and hoeing	5800	6.7
g)	Plant protection (insecticides/pesticides)	2200	1.9
h)	Irrigation	10511	12.2
i)	Harvesting and curing	6750	7.8
j)	Transportation and marketing cost	5670	6.6
B	**Fixed Costs**	**18000**	**20.8**
a)	Rental value of land (for 6 months)	18000	20.8
C	**Total Cost of Production (C= A+B)**	**86379**	**100**
D	Yield (kgs/acre)	6075	-
E	Sale price (Rs./kg)	19.5	-
F	Gross revenue (Rs./acre) **(D*E)**	118463	-
G	**Gross Margin** (Rs./acre) **(F-A)**	**50083**	-
H	**Net Returns** (Rs./acre) **(F-C)**	**32083**	-
I	**Benefit-Cost Ratio** (Rs./acre) **(F/C)**	**1.37**	-

Source: Field survey data, 2019-20

enterprise for the farmers. The percentage shares of variable costs and fixed costs of production were 89.5 percent and 10.5 percent of the total cost of production, respectively. The variable costs include land preparation (7.4 %), seeds (10.5 %), nursery raising and transplanting costs (2.8 %), manures (2.6 %), fertilizers (7.4 %), weeding and hoeing (5.0 %), insecticides and pesticides (3.9 %), irrigation (6.1 %), harvesting and curing (13.7 %), and transportation and marketing costs (28.2 %) of total production costs. Among the various items of cost, transportation and marketing cost, harvesting and curing cost, and seed cost were the major items of cultivation cost in tomato (sole) production. Based on the presented data, cultivating tomatoes as a sole crop appears to be a profitable endeavor. Farmers should conduct a thorough analysis of their specific circumstances and consider other relevant factors before making decisions about crop selection and cultivation practices.

3.20. Profitability Comparison of Intercropping and Monocropping

Intercropping involves growing two or more crops together on the same piece of land, while monocropping involves cultivating only one crop. According to Table 11, the total cost of intercropping amounted to Rs. 182756/acre, which was higher than the cost of producing onions (Rs. 86379/acre) and tomatoes (Rs. 170921/acre) as sole crops. The net revenue generated from intercropping was higher than that of individual crops. Intercropping exhibited the highest benefit-cost ratio of 1.59 compared to sole crops of tomatoes (1.48) and onions (1.37), indicating that intercropping is less costly than sole cropping. Other studies conducted in various countries, including China, Egypt, and Ethiopia. [Wu *et al*., 2016; Abdel-Baset, 2020; Nigussie *et al*., 2017], have demonstrated that intercropping leads to a significant increase in crop yield per unit area compared to single-crop farming. Additionally, intercropping has been found to reduce the costs of inputs associated with farming.

3.21. Land Equivalent Ratio (LER) of Intercropping

The land equivalent ratio is a concept in agriculture that describes the relative land area required under

Table 10. Profitability of tomatoes (sole) (Rs. /acre)

S. No.	Operations/Inputs	Cost /Acre	Percent
A	**Variable Costs**	**152921**	**89.5**
a)	Land preparation	12690	7.4
b)	Seed cost	17984	10.5
c)	Nursery raising & transplanting cost	4862	2.8
d)	Farmyard manure	4405	2.6
e)	Fertilizers	12673	7.4
f)	Weeding and hoeing	8500	5.0
g)	Plant protection (insecticides/pesticides)	9610	3.9
h)	Irrigation	10503	6.1
i)	Harvesting and curing	23500	13.7
j)	Transportation and marketing cost	48195	28.2
B	**Fixed Costs**	**18000**	**10.5**
a)	Rental value of land (for 6 months)	18000	10.5
C	**Total Cost of Production (C = A+B)**	**170921**	**100**
D	Yield (kgs/acre)	16050	-
E	Sale price (Rs./kg)	15.8	-
F	Gross revenue (Rs./acre) **(D*E)**	253590	-
G	**Gross Margin** (Rs./acre) **(F-A)**	**100669**	-
H	**Net Return** (Rs./acre) **(F-C)**	**82669**	-
I	**Benefit-Cost Ratio** (Rs./acre) **(F/C)**	**1.48**	-

Source: Field survey data, 2019-20

Table 11. Profitability comparison of intercropping and sole cropping (Rs. /acre)

S. No.	Cropping System	Total Cost (Rs.)	Gross Revenue (Rs.)	Net Revenue (Rs.)	BCR	Ranking
1	Sole tomato	170921	253590	82669	1.48	**II**
2	Tomato and onion	182756	289668	106912	1.59	**I**
3	Sole onion	86379	118463	32083	1.37	**III**

Source: Field survey data, 2019-20

sole cropping (monoculture) to produce the same yield as under intercropping [49]. The results showed that the land equivalent ratio (LER) was greater than one, which implies that intercropping was more productive than sole cropping. Specifically, the total LER found was 1.31, indicating that the intercropping system produced 31 % more yield than the same area of land planted in sole crops. This suggests that intercropping is a more efficient way of utilizing land, as it enables higher yields without the need for additional land. Various studies on intercropping have shown that planting tomatoes and onions together can lead to a higher land equivalent ratio (LER). The findings presented here are in line with previous research conducted by [Soniya *et al.*, 2021; Yildirim and Guvenc, 2005; Lamlom and Ahmed, 2021], indicating that intercropping, coupled with appropriate nutrient management, can result in more efficient land utilization and higher crop yields. However, a contrasting study conducted by [Ahmed et al., 2023] discovered that intercropping tomatoes and onions had a negative effect on yield, and the resulting LER was less than one.

3.22. Production Constraints

To assess production issues, eight factors are considered, and the two most important production issues mentioned by sampled farmers were seed costs and disease and pest management, which represented 97.8 percent and 93.3 percent, respectively. Similarly, the lowest level was the access to quality water by sampled farmers in the study area (Table 13). The information presented underscores the importance of addressing key production challenges to enhance agricultural productivity and the economic well-being of farmers. Strategies aimed at reducing seed costs, improving disease and pest management practices, and sustaining access to quality water resources could contribute to a more sustainable and prosperous agricultural sector.

3.23. Marketing Constraints

Eight major marketing issues for producers have been identified and presented in Table 14. The three major marketing issues identified by the sample farmers were low prices, perishability of the product, and high travel costs representing 93.3 %, 91.1 %, and 77.8 % respectively. Similarly, the unavailability of packing materials was the lowest level for sampled farmers in the study area. The information provided highlights the need for targeted interventions and support mechanisms to address the identified marketing challenges, thereby improving market access and financial outcomes for agricultural producers.

4. CONCLUSION AND RECOMMENDATIONS

The study concluded that intercropping onions with tomatoes provides farmers with additional income and helps them meet their household needs. Compared to purchasing crops, intercropping is a more cost-effective option for farmers. It is a traditional farming practice in the study area, with a majority of farmers intercropping onions

Table 12. Land equivalent ratio (LER) of intercropping system

Cropping System	Intercrop Yield (YI)	Sole Crop Yield (YS)	Partial LER (YIi/ YSi)	Total LER ∑ (YIi/ YSi)
Tomato	16032	16050	1.00	**1.31**
Onion	1865	6075	0.31	

Source: Field survey data, 2019-20

Table 13. Production constraints faced by farmers

Production Constraints	Respondents (N=45)		
	Number	Percentage	Rank
Seed cost	44	97.8	I
Disease and pest management	42	93.3	II
Technical training	17	37.8	III
Quality seed	16	35.6	IV
Late sowing	11	24.4	V
Availability of labor	07	15.6	VI
Availability of water	06	13.3	VII
Availability of quality water	02	6.7	VIII

Source: Field survey data, 2019-20

Table 14. Onion marketing constraints faced by sampled farmers

Marketing Constraints	Respondents (N=45)		
	Number	Percentage	Rank
Low price	42	93.3	I
Perishability	41	91.1	II
High charges for transportation	35	77.8	III
Costly packing materials	34	75.6	IV
Lack of markets	34	75.6	V
Lack of market information	25	55.6	VI
Exploitation by Brokers and Middlemen	19	42.2	VII
Unavailability of packing material	12	26.7	VIII

Source: Field survey data, 2019-20

with tomatoes, especially for domestic use. The economic indicators, including gross margin, net return, benefit-cost ratio, and land equivalent ratio, showed promising results for intercropping over sole cropping. Intercropping had the highest benefit-cost ratio of 1.59, which was higher than the ratios observed in sole cropping of tomatoes (1.48) and onions (1.37), highlighting its cost-effectiveness. The LER value was greater than one (1.31), supporting the benefits of intercropping and indicating that farmers can increase their profits by growing onion crops at different densities. However, unpredictable weather conditions, market volatility, rising input costs, and low planting densities for onions are factors that can hinder profitability. To optimize land use and increase crop yields, farmers can benefit from adopting intercropping along with appropriate management techniques. Adopting intercropping practices can help farmers overcome challenges and increase profitability, contributing to a sustainable and resilient agriculture system.

Based on the findings of the study, the following recommendations can be made:

- To boost intercropping productivity and profitability for onions and tomatoes, farmers should prioritize the use of high-quality seeds.
- Increasing onion planting density can improve the total return of onion-tomato intercropping by optimizing resource utilization and enhancing yields.
- Governments can alleviate local market instability by intervening with market information systems, price stabilization measures, and support programs.

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6. DECLARATION

The study findings are exclusive to this publication and have not been published or considered for publication elsewhere. In case of acceptance for publication, the copyright of the article will be transferred to the Pakistan Academy of Sciences.

7. CONFLICT OF INTEREST

There is no conflict of interest among the authors.

8. REFERENCES

1. F. Ofori, Francis, and W. R. Stern. Cereal–legume intercropping systems. *Advances in agronomy* 41: 41-90 (1987).
2. D. Wang, P. Marschner, Z. Solaiman, and Z. Rengel. Growth, P uptake, and rhizosphere properties of intercropped wheat and chickpea in soil amended with iron phosphate or phytate. *Soil Biology & Biochemistry* 39(1): 249-256 (2007).
3. M.A.D. Dasbak, and J. E. Asiegbu. Performance of pigeon pea genotypes intercropped with maize under humid tropical ultisol conditions. *Journal of Animal and Plant Sciences* 4(2): 329-340 (2009).
4. C. Li, T.J. Stomph, D. Makowski, H. Li, C. Zhang, F. Zhang, and W. van der Werf. The productive performance of intercropping. *Proceedings of the National Academy of Sciences* 120(2): 2201886120 (2023).
5. X. Tang, C. Zhang, Y. Yu, J. Shen, W. van der Werf, and F. Zhang. Intercropping legumes and cereals increase phosphorus use efficiency; a meta-analysis. *Plant. Soil* 460: 89–104 (2021).
6. F. Mamine. Barriers and levers to developing wheat–pea intercropping in Europe: a review. *Sustainability* 12: 6962 (2020).
7. K.A. Bybee-Finley, and M.R. Ryan. Advancing intercropping research and practices in industrialized agricultural landscapes. *Agriculture* 8(6): 80 (2018).
8. C. Li, E. Hoffland, T.W. Kuyper, Y. Yu, H. Li, C. Zhang, F. Zhang, and W. van der Werf. Yield gain, complementarity and competitive dominance in intercropping in China: A meta-analysis of drivers of yield gain using additive partitioning. *European Journal of Agronomy* 113: 125987 (2020).
9. L. Li, S.M. Li, J. H. Sun, L.L. Zhou, X.G. Bao, H.G. Zhang, & F.S. Zhang. Diversity enhances agricultural productivity via rhizosphere phosphorus facilitation on phosphorus-deficient soils. *Proceedings of the National Academy of Sciences* 104(27): 11192-11196 (2007).
10. R.J. Zomer, A. Trabucco, R. Coe, and F. Place. Trees on farm: analysis of global extent and geographical patterns of agroforestry. *ICRAF Working Paper-World Agroforestry Centre* 89: (2009).
11. H. Hauggaard-Nielsen, and E.S. Jensen. Facilitative root interactions in intercrops. *Plant and Soil* 274(1-2): 237-250 (2005).
12. A. Hassan, D.B. Dresbøll, C.R. Rasmussen, A. Lyhne-Kjærbye, M.H. Nicolaisen, M.S. Stokholm, Q.S. Lund, and K. Thorup-Kristensen. Root distribution in intercropping systems–a comparison of DNA based methods and visual distinction of roots. *Archives of Agronomy and Soil Science* 67(1): 15-28 (2021).
13. P. Hinsinger, E. Betencourt, L. Bernard, A. Brauman, C. Plassard, J. Shen, X. Tang, and F. Zhang. P for two, sharing a scarce resource: soil phosphorus acquisition in the rhizosphere of intercropped species. *Plant Physiology* 156(3): 1078–1086 (2011).
14. A. Javanmard, A.D.M. Nasab, A. Javanshir, M. Moghaddam, and H. Janmohammadi. Forage yield and quality in intercropping of maize with different legumes as double-cropped. *Journal of Food, Agriculture and Environment* 7(1): 163-166 (2009).
15. M.R. Islam, M. T. Rahman, M. F. Hossain, and N. Ara. Feasibility of intercropping leafy vegetables and legumes with brinjal. *Bangladesh Journal of Agricultural Research* 39(4): 685-692 (2014).
16. J. Hossain, M. S. Alom, M. A. K. Mian, and M. R. Islam. Economic feasibility of intercropping of chili with sweet gourd. *International Journal of Agricultural Research, Innovation and Technology* 5(2): 64-69 (2015).
17. L. Rusinamhodzi, M. Corbeels, J. Nyamangara, and K.E. Giller. Maize-grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Research* 136: 12-22 (2012).
18. H. Eskandari. Intercropping of maize (*Zea mays*) with cowpea (*Vigna sinensis*) and mungbean (*Vigna radiata*): Effect of complementarity of intercrop components on resource consumption, dry matter production and legumes forage quality. *Journal of Basic and Applied Scientific Research* 2(1): 355-360 (2012).
19. Y.N. Song, F. S. Zhang, P. Marschner, F. L. Fan, H. M. Gao, X. G. Bao, J. H. Sun, and L. Li. Effect of intercropping on crop yield and chemical and microbiological properties in rhizosphere of wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and faba bean (*Vicia faba* L.). *Biology and Fertility of Soils* 43(5): 565-574 (2007).
20. Y. He, N. Ding, J. Shi, M. Wu, H. Liao, J. Xu. Profiling of microbial PLFAs: implications for interspecific interactions due to intercropping which increase phosphorus uptake in phosphorus limited acidic soils. *Soil Biol. Biochemistry* 57: 625–634

(2013).

21. S. Boora, B. Kaur, R. Tyagiq, and D.K. Bishnoi. Extent of Adoption of Intercropping Practices among Farmers of Haryana. *Indian Journal of Extension Education* 59(1): 24-27 (2023).
22. S. Anitha, V.L. Geethakumari, and G.R. Pilial. Effect of intercrops on nutrient uptake and productivity of chilli-based cropping system. *Journal of Tropical Agriculture* 39(1): 60-61 (2006).
23. A.J. Burgess, M.E.C. Cano, and B. Parkes The deployment of intercropping and agroforestry as adaptation to climate change. *Crop and Environment* (2022).
24. Z. An, M. Zhang, J.H. Qin, H.G. Hu, and T.Y. Ning. Effects of wheat-maize/alfalfa intercropping mode on soil salinity and annual yield in saline-alkali field. *Shandong Agricultural Sciences* 51(06): 69-74 (2019).
25. R. Francis, D.R. Decoteau. Developing an effective southern pea and sweet corn intercrop system. *HortTechnology* 3(2): 178-184 (1993).
26. M.A. Awal, H. Koshi, and T. Ikeda. Radiation interception and use by maize/peanut intercrop canopy. *Agricultural and forest meteorology* 139(1-2): 74-83 (2006).
27. J.M.M. Matusso, J.N. Mugwe, and M. Mucheru-Muna. Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. *Research Journal of Agriculture and Environmental Management* 3(3): 162-174 (2014).
28. T.H. Seran, and I. Brintha. Review on maize based intercropping. *Journal of Agronomy* 135-145 (2010).
29. L. Ren, S. Su, X. Yang, Y. Xu, Q. Huang, Q. Shen. Intercropping with aerobic rice suppressed Fusarium wilt in watermelon. *Soil biology and biochemistry* 40(3): 834–844 (2008).
30. R.W. Brooker, A.E. Bennett, W.F. Cong, T.J. Daniell, T.S. George, P.D. Hallett, L. Li. Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. *New Phytologist* 206(1): 107-117 (2015).
31. F. Sulvai, B.J.M. Chaúque, and D.L.P. Macuvele. Intercropping of lettuce and onion controls caterpillar thread, *Agrotis ípsilon* major insect pest of lettuce. *Chemical and Biological Technologies in Agriculture* 3(1): 1-5 (2016).
32. S. Daryanto, B. Fu, W. Zhao, S. Wang, P.A. Jacinthe, and L.Wang. Ecosystem service provision of grain legume and cereal intercropping in Africa. *Agricultural Systems* 178: 102761 (2020).
33. F.T. Hata, M.U. Ventura, M.T.D. Paula, G.D. Shimizu., J.C.B.D. Paula, D.A.O. Kussaba, and N.V.D. Souza. Intercropping garlic in strawberry fields improves land equivalent ratio and gross income. *Ciência Rural* 49: (2019).
34. W. Tang, W. Tang, Y. Xie, X. Li, H. Li, L. Lin, Z. Huang, B. Sun, G. Sun., L. Tu, and Y. Tang. Effects of intercropping on Se accumulation and growth of pakchoi, lettuce and radish. *International Journal of Phytoremediation* 1-8 (2022).
35. F. Zhang, and L. Li. Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency. *Plant and soil* 248(1): 305-312 (2003).
36. L. Mrnka, T. Frantík, C.S. Schmidt, S. E. Baldassarre, and M. Vosátka. Intercropping of Tagetes patula with cauliflower and carrot increases yield of cauliflower and tentatively reduces vegetable pests. *International Journal of Pest Management* 69(1): 35-45 (2023).
37. L. Rusinamhodzi, M. Corbeels, J. Nyamangara, and K.E. Giller. Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field crops research* 136: 12-22 (2012).
38. R. Bhattacharyya, S. Kundu, R. Pandey, and M. Sharma. Resource use efficiency and productivity of maize and soybean in intercropping system under conservation agriculture practices. *Agricultural Research* 8(3): 348-355 (2019).
39. M.A. Altieri. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems & Environment* 74(1-3): 19-31 (1999).
40. J.A. Odhiambo, G. Mutua, and A.M. Kibe. Intercropping in smallholder farming systems of Kenya: Challenges and prospects. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 121(1): 21-30 (2020).
41. Q. Lv, B. Chi, N. He, D. Zhang, J. Dai, Y. Zhang, and H. Dong. Cotton-Based Rotation, Intercropping, and Alternate Intercropping Increase Yields by Improving Root–Shoot Relations. *Agronomy* 13(2): 413 (2023).
42. H.B. Zhou, J. L. Chen, L.I.U. Yong, F. Francis, E. Haubruge, C. Bragard, J. R. Sun, and D.F. Cheng. Influence of garlic intercropping or active emitted volatiles in releasers on aphid and related beneficial in wheat fields in China. *Journal of Integrative Agriculture* 12(3): 467-473 (2013).
43. A.H.M.M.R. Talukder, J. Rahman, M.M. Rahman, M. Biswas, and M. Asaduzzaman. Optimum ratio of coriander intercropping with onion. *International Journal of Plant & Soil Science* 4(94): 404-410 (2015).
44. B.H. Kabura, B. Musa, and P. E. Odo. Evaluation of the yield components and yield of onion (Allium cepa L.)-pepper (Capsicum annum L.) intercrop in the Sudan Savanna. *Journal of Agronomy* (2008).
45. T. Soniya, S. Kamalakannan, T. Uma Maheswari,

and R. Sudhagar. Effect of intercropping on growth and yield of tomato (Solanum lycopersicum L.). *Annals of Plant and Soil Research* 23(1): 36-41 (2021).

46. X. Wu, F. Wu, X. Zhou, X. Fu, Y. Tao, W. Xu, K. Pan, and S. Liu. Effects of intercropping with potato onion on the growth of tomato and rhizosphere alkaline phosphatase genes diversity. *Frontiers in Plant Science* 7: 846 (2016).
47. S.H. Abdel-Baset. Effect of intercropping onion with sugar beet on productivity of both crops and root-knot nematodes control under different onion plant densities and slow-release N fertilizer rates. *Journal of Plant Production Sciences* 9(1): 61-75 (2020).
48. A. Nigussie, B. Lulie, and M. Chala, M. Intercropping of Onion with Rosemary as Supplementary Income Generation at Wondo Genet Sidama zone, Southern Ethiopia. *Academic Research Journal of Agricultural Science and Research* 5(2): 107-115 (2017).
49. R. Mead, and R. W. Willey. The concept of a "land equivalent ratio" and advantages in yields from intercropping. *Experimental Agriculture* 16(3): 217-228 (1980).
50. T. Soniya, S. Kamalakannan, T.U. Maheswari, R. Sudhagar, S. Kumar. Effect of intercropping on yield, system production efficiency and economics of tomato (Solanum lycopersicum). *Crop Research* 56(1and2): 23-29 (2021).
51. E. Yildirim, and I. Guvenc. Intercropping based on cauliflower: more productive, profitable and highly sustainable. *European Journal of Agronomy* 22(1): 11-18 (2005).
52. M. M. Lamlom, and A. M. Ahmed. Effect of sesame-tomatoes intercropping systems under different dates of sesame on improving productivity of crops. *Egyptian Journal of Agricultural Research* 99(1): 108-117 (2021).
53. S.H. Abdel-Baset. Effect of intercropping onion with sugar beet on productivity of both crops and root-knot nematodes control under different onion plant densities and slow-release N fertilizer rates. *Journal of Plant Production Sciences* 9(1): 61-75 (2020).
54. A.U. Ahmed, B.M. Auwalu, H.M. Garba, I.G. Halilu, and M.B. Adamu Response of Tomato (*Solanum lycopersicum* L.) and Onion (*Allium cepa* L.) to Different Intercrops in Sudan Savanna Ecological Zone of Nigeria. *Direct Research Journal of Agriculture and Food Science* 11(3): 49-53 (2023).