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# Annual Intercrops: An Alternative Pathway for Sustainable Horticultural Production

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**ABSTRACT**

The greatest challenge to the agriculture in the years to come is to provide sufficient food to growing population in order to fight with hunger and malnutrition. We will have to feed more people with limited water resources, frequent droughts, degrading lands and difficult access to energy. Past strategy for development of the agricultural sector in India has focused primarily on raising agricultural output and improving food security. The Doubling Famer's Income (DFI) strategy as recommended by the Committee include seven sources of income growth *viz.*, improvement in crop productivity, increase in the cropping intensity, enhancement in livestock productivity, resource use efficiency, diversification towards high value crops, improvement in real prices received by farmers and shift from farm to non-farm occupations. Intercropping ensures efficient resource and space utilization including upgrading of soil and orchard nutrient status. So, intercropping has been employed with the main objective of proper utilization of resources under subsistence farming where the production of sufficient food grain is a great challenge. The outcomes of various intercropping practices confirm that vegetable and pulses crops are economically and ecologically most suitable and viable intercrops for fruit crops at early phase of growth. Once bearing starts, there is need of management of cultural practices adapted for intercrops with the requirements of fruit trees. So that productivity of fruit plants will not be decreased.

***Key words**: Economics, Fruit Orchard, Income, Intercropping, Spacing, Vegetables.*

## Introduction

The strategy for doubling farmer's income involved an increase in productivity per unit area with reducing cost of production. There are two sources to boost in agricultural output *viz*., area and productivity. But, due to increasing demand of land for non–agricultural uses and already high share of arable land in total geographical area of the country, further expansion in area under cultivation is not feasible. Improvement in crop productivity through intercropping ensures efficient resource and space utilization in orchard. Intercropping is growing of two or more crops simultaneously on the same piece of land with a definite row pattern (Das *et al*., 2019). The most common objective of intercropping is to produce a better yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop.

Fruit crops are perennial in nature, generally, they commence bearing after long waiting period of 3-7 years. During this period, fallows inter and intra spaces between plant rows can be befittingly utilized for intercropping. If the leftover space is not utilized judiciously, they undergo degradation (Singh *et al*., 2012). During this early phase of less productive stage, the farmers have very marginal returns from the orchard. So, intercropping has been employed with the main objective of better utilization of soil resources available in the interspaces of the fruit trees for additional income by raising additional crops (Maji and Das, 2013). On the other hand, the quality of fruits is not affected due to the growing of intercrops respectively (Singh and Kaur, 2017). It is much less uncertain in that if one crop fails others may still be harvested (Machado, 2009). They also act as a cover crop and the land benefits by the cultivation, irrigation, manuring given to the intercrops (Bakshi *et al*., 2019). Further, the organic matters added from intercrops improve soil fertility and make the intercropping ecologically sustainable and economically feasible to the farmers (Upadhaya *et al*., 1994). For sustainable crop production in dryland conditions, growing of intercrop in fruit orchard, farmers can maximize the water use efficiency, maintain soil fertility, reduce the weed growth, minimize the soil erosion and can full utilization of interspaces left in orchard, which ultimately leads to sustainable production and doubling the farm income (Singh *et al*., 2020).

Intercropping ensures regular income from the orchard, while a short interval crop is intercropped in a long duration crop; the short period crop matures early and provides intermediate income to the farmer. Besides higher productivity and income, it also ensures higher employment opportunities for the farmers (Das *et al*., 2019). Selection of suitable intercrops in orchard is essential to increase production from main crop as well as from the intercrops (Hnamte *et al*., 2013). The accomplishment of intercropping methods depends tremendously on the choice of compatible crop combination and the geometry of the planting in which every crop utilize a destined and diverse zone of atmosphere and soil (Kumari *et al*., 2018). It is particularly imperative not to have crops opposing each other for space, nutrients, water and sunlight. Many crops such as fruits, vegetables, pulses, leguminous crops and fodder crops have been found suitable for intercropping. The objective of this paper was to provide an overall view and estimate of intercropping, summarizing its main advantages supported by a number of key examples from the published literature which point out its great value in the context of intercropping in fruit orchards.

**Efficient resource utilization and yield advantage**

Adoption of proper intercropping system can provide substantial yield advantages as compared with the sole cropping without depletion of soil health (Swain *et al.,* 2016). Fruit plants are efficient adequate in providing higher monetary return even under harassed conditions than other annual crops. The approach aims at improving efficiency by efficient exploitation of air space which is not utilized in single level system. The multitier system aims at sustainable management of natural resources like soil, water, space and environment (Saran *et al*., 2015). In case of annual crops, 74% of roots do not go beyond 50 cm soil depth, whereas in case of perennial crops, top 50 cm almost devoid of feeder roots (Awasthi and Saroj, 2004). Patel *et al*. (2003) found that intercropping system recorded 7.0 per cent higher ber fruit yield than ber sole system. The highest ber yield (96.1 q/ha) was recorded with ber+sorghum system followed by ber+green gram (93.2 q/ha) intercropping system. Singh *et al*. (2014) also reported that apple fruit yield linearly increased in each year irrespective of treatments. Highest average apple fruit yield (10.08 t $ha^{-1}$) was recorded with apple + red clover intercropping system. Apple + fenugreek system, recorded highest apple equivalent yield (18.96 t $ha^{-1}$) closely followed by apple + peas intercrops.

According to Kumari *et al*., (2018) yield of mango in different intercrops (garlic *var*., Local, pea *var*., Azad P-1, carrot *var*., Pusa Kesar, palak *var*., All Green, coriander *var*., Pant Haritima, onion *var*., Patna Red, radish *var*., Snow White and French bean var., P-44) varied significantly and the maximum yield (206.07 q/ha) was recorded in palak followed by onion (197.78 q/ha),whereas, it was lowest in coriander (51.33 q/ha). Soni *et al*., (2021) also reported positive effect of Intercropping on height, girth and canopy spread of Kinnow over its sole plantation. In this experiment there were five treatment combinations *viz*., Kinnow + onion + Indian squash; Kinnow + radish + cowpea; sole onion + Indian squash; sole radish + cowpea and sole Kinnow. It was observed that yield of Kinnow was considerably enhanced by intercrops as compared to sole Kinnow cultivation. Though, the productivity of both rabi and *Kharif* season crops was less with Kinnow cultivation as compared to single cropping. The onion in rabi season and Indian squash in *Kharif* season were better options for intercropping system in terms of crop yield equivalents as compared to sole Kinnow. The annual system productivity in terms of onion equivalent yield was 2.81 and 7.58 times higher in Kinnow + (radish-cowpea) and Kinnow + (onion-Indian squash) as compared to individual Kinnow, respectively.

It is observed that crop mixture provide insurance against risk and give stable returns even under unfavorable weather conditions. The major way of the crop mixture can achieve greater stability is from the compensation of one component crop when other fail or grow poorly, because of drought, pest or disease. But when two species are grown separately as sole crops, there is no possibility of compensation. Awasthi *et al*., (2009) conducted an experiment on intercropping under arid conditions of Bikaner in newly established 'NA7' aonla. Mothbean grown during rainy (K*harif*) season was a common crop in rotation with winter (*rabi*) crops, i.e., fenugreek, chickpea, mustard and cumin. Growth parameters in terms of plant height, stem girth, canopy spread and canopy volume of aonla were recorded to be significantly more with intercrops compared with its sole plantation. Higher grain and straw yield were recorded in moth-bean–chickpea and moth-bean-fenugreek crop sequence. Amongst the winter (*rabi*) crops, grain yield of fenugreek, chickpea, mustard and cumin were higher by 28.05, 38.11, 19.96 and 36.50%, respectively, when grown in association with aonla compared to its sole crops.

In an agri-horti system, combine agriculture and horticulture enterprises together for the best utilization of land and other resources. Under harsh environmental conditions intercrops serve as an insurance against total crop failure (Dayal *et al*., 2015). Similarly, Jatav *et al*. (2016) observed that the average plant height, plant girth and plant yield of aonla varied considerably in different cropping model systems. Highest yield of aonla recorded in aonla-khejri followed by aonla-ber. Singh *et al.* (2016) studied the different cropping systems, among that most feasible cropping system were found to be (i) Guava + turmeric (ii) Guava + suran and (iii) Guava + bunda, which were estimated in respect to growth, flowering, fruiting, fruit drops and fruit quality, which were found to be improved with intercropping of vegetables in guava orchard. Sarkar *et al.* (2008) also reported that vegetables like chilli, brinjal, *Colocasia*, *Amorphophallus*, bottle gourd and pumpkin were the most acceptable intercrops in papaya under West Bengal conditions.

Singh *et al*., (2020) studied different combinations of cucurbitaceous crops, *viz*., aonla + bottle gourd, aonla + pumkin, aonla + bitter goud, aonla + cucumber and aonla + sponge gourd in the aonla orchard *var*. NA-7, spaced at 10 m×10 m, attained the age of 8 years, grown under rainfed semiarid conditions. Results of study revealed that the aonla based intercropping with cucurbits in *kharif* is practically feasible and economically viable under rainfed semiarid ecosystem. Among the different combinations, the yield was recorded the maximum in aonla + bottle gourd combination (140.48 q/ha) followed by aonla + pumpkin (132.75 q/ha), aonla + cucumber (121.46 q/ha), aonla + bitter gourd (105.17 q/ha), whereas, as cumulative yield was recorded the lowest in aonla + sponge gourd (103.23 q/ha) without affecting the growth and yield of sole crop aonla. Kumar *et al.* (2000) reported tomato as the most efficient intercrop in papaya orchard and highest yield of papaya (170.35 kg fruits/tree) planted at 2.1 x 2.1 m of spacing and supplied 25% extra dose of fertilizers.

Intercropping of legumes in citrus orchards is beneficial for the citrus production. It improves fruit yield of orchard as compared to sole fruit orchard. Such crops help increase the yield of the main crop by fixing nitrogen in the soil (Abdel-Aziz *et al.*, 2008; Srivastava *et al*., 2007). It has been observed that inter-cropping of mustard with bananas and cucumber with citrus (mandarin) orchards improved the yields of banana and citrus in India (Ouma and Jeruto, 2010). Gill *et al.* (2018) concludes that intercroping in Kinnow orchard helps to improve yield, fruit quality and economic aspect. Abdel-Aziz *et al.* (2008) confirmed improvement of fruit set, vegetative growth and fruit yield with reduced fruit drop in citrus plants, when *Egyptian* clover and fenugreek cover crops were grown as intercrop.

**Improvement of Soil Fertility**

Intercropping practices in orchard not only generate an extra income but the practice also helps to check the soil erosion through ground coverage and improves the physiochemical properties of the soil (Gill *et al*., 2018). Management of soil fertility in intercropping is a form of rotation that every season is done on land. Rhizobium bacteria are able to have a symbiotic relationship with plants of leguminosae family, and thereby can fix atmospheric nitrogen into available nitrogen for plants uptake that results in nitrogen (an essential element for soil fertility and plant growth) addition in the soil (Mousavi and Eskandari, 2011). The role of legumes in soil fertility enrichment by fixing nitrogen biologically, high nutrient availability in the soil due to reducing soil pH and consequently, the improved nutrient status govern the yield and quality enhancement is well-known compared to highly exhaustive crops like wheat and maize as intercrop in citrus orchards (Srivastava *et al.*, 2007; Abdel-Aziz *et al.*, 2008 and Mousavi and Eskandari, 2011). Plant species diversity in ecosystem encourages accumulation of organic material in soil, which in turn increases the general level of microbial activity in soil (Ratnadass *et al*., 2012). The leguminous intercrops *viz.*, cowpea and French bean, were found the most effective crop because of their desirable impact on improvement of nutrient status of soil and plants of mango orchard (Swain, 2014).

It is apparent that legume intercropping in mango and citrus orchard supported high microbial activity and further accelerated by organic matter incorporation. Results also indicated that the herbicidal treatments at the level tested were not drastic enough to be considered deleterious to soil microbial and soil respiration which are important to soil fertility. In addition to the more direct short-term supply of nutrients from decomposing leaf litter, nutrients can also be supplied indirectly from the mineralization of soil organic matter formed from the cumulative input of organic residues. Microbes play a key role in the process of organic matter decomposition and release of nutrients (Sarathambal *et al.*, 2015). According to Srivastava *et al*. (2007) legume-based intercropped orchards maintained much higher level of leaf nutrients (2.35% N, 0.13% P, 2.08% K, 86.5 ppm Fe, 71.1 ppm Mn, 22.2 ppm Cu, and 22.0 ppm Zn) than the orchards without intercrops (2.29% N, 0.13% P, 2.47% K, 79.2 ppm Fe, 63.8 ppm Mn, 21.7 ppm Cu, and 23.2 ppm Zn). Jatav *et al*. (2016) reported that maximum value of OC, EC, pH, available nitrogen (kg/ha), available potassium (kg/ha) under aonla-khejri-cluster bean-ajwain cropping model followed by aonla-ber-cluster bean-fennel. Greatest water holding capacity at 0.33 and 6% bar was observed under aonla+ber (2.28 and 1.10%) followed by aonla+khejri (2.07 and 1.03%), aonla+bael (2.44 and 0.99%), aonla+karonda (1.76 and 0.61%) and aonla+moringa (1.84 and 0.56%). Physical and microbial properties of soil improved more under cropping model aonla-khejri and aonla-ber as compared to other models.

The soil productiveness of the field increased through intercropping due to improvement in soil characters *i.e.*, soil pH, EC, water holding capacity, OC, available nitrogen, phosphorus and potassium (Raut, 2018). In intermediate farming with cover crops, mixing the remaining part after harvest as a green manure significantly increases soil organic matter content (Montagnini and Nair, 2004). Similar observations has been reported by Nandi and Ghosh (2016) inferred that soil pH was improved in all the plots under medicinal plants as compared to sole plot (no inter cropped). Soil nitrogen content under Pundina was highest (0.078%) and lowest in Aloevera (0.046). Phosphorus and potassium content in the soil did not vary significantly in different inter cropped plots. Ghosh *et al*. (2017) also noticed that the guava + banana and guava + eggplant systems were proved to be the most significant intercropping system by improving physio-chemical properties like bulk density, water holding capacity, SOC, available NPK of the soil. Singh *et al.* (2014) reported the highest available soil N in apple + lentil intercrop (429 kg/ha) with gain of 9.80 kg $ha^{-1}$ after four consecutive years intercropping, closely followed by apple + fenugreek (429 kg/ha) with 9.7 kg/ha N gain, apple+ lucerne (429 kg/ha) with 9.3 kg/ha N gain, apple + peas (428.0) 8.5 kg/ha N gain, whereas maximum nitrogen loss was observed with apple + mustard intercrop (417kg/ha) with loss of 2.7 kg/ha. Highest available soil K was recorded with apple+fenugreek (403 kg/ha) with gain of 5.4 kg/ha, whereas minimum available potassium was observed with apple + coriander intercropping (385 kg/ha) with loss of 12.4 kg/ha after four years of consecutive cropping.

Intercropping of grapevines *var*. Thompson Seedless with all used medicinal plants increased nitrogen, phosphorus, potassium and organic matter in the soil, which improved vines nutritional status, vegetative growth, yield and quality of fruit (Belal *et al*., 2017). Likewise, Swain (2016) carried out an experiment on guava based intercropping systems comprising of nine inter-crops such as mango, ginger, turmeric, tomato, cowpea, French bean, ragi, niger, upland paddy with control to study the effect of various intercropping systems on plant and soil health of guava orchard. The results revealed that guava + cowpea system showed significant improvement in bulk density, electrical conductivity, water holding capacity, organic carbon content, pH of soil, maximum available nitrogen and potassium content in the soil, while, the maximum available phosphorus content were obtained in guava + mango- ginger system. Similarly, Raut and Sharad (2016) also conduct field experiment at farmer's field using various intercrops systems *viz.* black gram, ginger, maize and paddy in 7-8 years old mango orchard of Totapari and Banganapalli varieties. They found that the intercrops influenced the yield attributing characters of the mango and black gram performed better as compare to other intercrops. Maximum number of fruits/branch, fruits/plant and yield of mango obtained with black gram intercrop.

**Weed Control**

Weeds are among the major constraints to crop production system, its reducing productivity and profitability of horticultural crop. In a crop production system, weeds fight for the same resources as the crops, such as sunlight, space nutrients and water restrictive crop productivity. Worldwide, up to 40% yield loss because of weeds has been reported (Oerke, 2006). Intercropping provided excellent weed suppression, where intercropping can be used as an effective weed control strategy by increasing shade and crop competition with weeds through tighter crop spacing (Gold *et al.,* 2006; Linares *et al.,* 2008 and Bauri *et al.,* 2010). These findings are also in accordance with the findings of Singh and Sairam (2016) who observed that the growing cowpea as an intercrop in banana orchard resulted in the developments of thick canopy covering the whole ground area and suppressed weed growth completely for a period of 75 days. The superior banana yield obtained from these experiments show the beneficial effect of controlling weeds by suitable agro-techniques like intercropping with leguminous cover crops contributing to improvement of soil structure and fertility. In addition, cover crops used in organic citrus orchards suppress weeds, and thus improved the yield of citrus fruit in Florida organic citrus orchards (Linares *et al.*, 2008).

**Economic Benefits**

Intercropping can increase income of smallholder farmers through reduction of economic risk and market fluctuation resulting from growing a single crop which is more prone to natural hazards and helping the farmers in better utilization of land by having more than one crop produced per unit area (Singh *et al*., 2020). In the same way, Patel *et al*., (2003) achieved the highest gross income of Rs. 24613/ha with ber+green gram system closely followed by ber+sorghum system with gross return of Rs. 24180/ha. Intercropping in ber on an average recorded 10.0 per cent higher monetary returns over ber sole system. Similarly, Awasthi *et al*., (2009) obtained the higher returns when the intercrops were grown in association with aonla rather than sole cropping. Moth-bean grown in rotation with cumin earned maximum net returns (Rs 28260/ha), followed by mothbean–chickpea (Rs 25024/ha) and mothbean– mustard (Rs 17499/ha) with nominal returns in mothbean–fenugreek crop sequence. Singh and Kaur (2017) revealed that the productivity of intercropping systems was found to differ significantly and the Kinnow with pea intercropping system were set up to be the best from the view point of comparable yield and economics. Soni *et al*. (2021) stated that the B: C ratio of Kinnow + (onion-Indian squash) and Kinnow + (radish-cowpea) was improved to 3.65 and 2.06, respectively, as compared to sole Kinnow (B: C ratio of 1.50). Raut (2018) revealed that intercropping in guava orchard gives additional income to the growers in juvenile phase of the plant.

Work carried out by Tiwari and Baghel (2014) also confirmed highest net return from mango + (pigeon pea + tomato) combination (Rs. 81077.50) followed by mango + cowpea-bengal gram (Rs. 71677.13) and mango + tomato (Rs. 67034.38). Similarly, highest benefit, cost ratio (2.02) was recorded in the mango +guava + cowpea intercropping systems, which was almost similar to mango + guava+ turmeric, mango + guava + French bean and mango + guava + tomato (Swain, 2014). In another experiment it was observed that the highest average gross return (Rs. 241000), net return (Rs. 99177) and B: C ratio (1.70) in turmeric + litchi, followed by biennial turmeric + wheat and turmeric + mango cropping systems (Saran *et al.,* 2015). Similarly, Ghosh and Pal (2010) conducted an experiment on three year-old mosambi orchard planted at 5 m × 5 m spacing and growing under rainfed laterite soil to identify the suitable and profitable intercrops, the intercrops grown were radish, okra, ridge gourd, amaranthus, cowpea, groundnut, black gram, and cluster bean. The highest net return (Rs. 35,820.0/ha) was obtained from Mosambi + groundnut combination followed by mosambi + okra (Rs. 22,520.0/ha) and mosambi + cowpea (Rs. 22,420.0/ha). Hnamte *et al.* (2013) also observed highest benefit-cost ratio of the intercropping system in lemon + French bean intercropping with a B:C ratio of 4.56 and 5.05 for the first and the second years respectively, whereas, it was lowest from sole lemon for two years in a row.

In the same way, Negi *et al*. (2019) conducted an experiment on eight year-old aonla orchard with papaya as a filler tree and different pulse, oilseed and vegetable and spice crops as intercrop under rain fed farming situation. They observed that aonla + papaya + cowpea - pea, aonla + papaya + okra - gram and aonla + papaya + cowpea-fenugreek intercropping sequences gave additional net return of Rs. 72554, Rs. 70656/ha and 70495 and benefit: cost ratio (3.01, 2.96 and 3.00) respectively. Hore *et al.* (2004) also found good yield of ginger intercrop in arecanut plantation and found higher B:C ratio (2.11) from intercropping of ginger (without filler plants) followed by ginger (with filler plants). Singh *et al*. (2020) obtained the highest net profit/ha with aonla + bottle gourd combination (Rs. 147312.80) followed by aonla + pumpkin (Rs.100525.00) and it was recorded least in aonla + sponge gourd combination. Similarly, the B: C ratio was found maximum in aonla + bottle gourd (4.44) followed by aonla + pumpkin (3.11) and it was recorded minimum in aonla + sponge gourd (2.42). Ijaz *et al*. (2014) observed that average yield of Kinnow without intercropping (12454 kg/ ha) was higher than those with intercropping (7492 kg/ha), but the income from the intercrop makes it more profitable.

Pal and Tarai (2015) conducted an experiment to find the best intercropping combination in between mosambi and some profitable vegetable crop such as leafy radish (*Raphanus sativus* L.), cluster bean (*Cyamopsis tetragonoloba* L.), groundnut (*Arachis hypogea*) etc., were grown as intercrops. From the experiment it was proved that the leafy radish gave good economic return in one month whereas, cluster bean gave the highest economic return among these. Singh *et al*. (2014) evaluated eleven needs based intercrops comprising of spices and condiments, vegetables, legumes, forage and oil seed crops including the control and observed that apple fruit yield linearly increased in each year irrespective of treatments. Apple + fenugreek recorded highest benefit: cost ratio (5.30) followed by apple + swiss chard (3.81). Similarly, Pradhan, *et al*. (2018) recorded the highest net profit from pineapple intercropping with straw mulch (Rs. 1, 40,000/ ha) with B:C ratio of 1.67, followed by papaya-pineapple intercropping with straw mulch in mango orchard. Dayal *et al*., (2015) while working on nutrient management for the fruit–legume alley cropping system showed that application of 50% recommended dose of fertilizer (RDF) and zinc sulphate @ 20 kg/ha with biofertilizers resulted in the highest net returns (13,273/ha) and benefit: cost ratio (2.15) in cowpea. Cluster bean as an intercrop with ber gave the highest net returns with RDF which was at par with application of 50% RDF with biofertilizer and zinc sulphate @ 20 kg/ha.

## Conclusion

The outcomes of various intercropping practices confirm that intercropping ensures numerous benefits like improvement of yield, environmental security, employment generation and additional return to the farm families. Besides these benefits, it controls weed population, check soil erosion, conserve soil moisture and organic matter and protects the soil from leaching of nutrients. In intercropping, legumes and vegetables are economically and ecologically most suitable and viable intercrops for fruit plantation at early phase of growth. Legumes as component crops play versatile roles like biological N fixation, soil quality improvement and enhancement of environmental quality by reducing the use of chemical N fertilizer and additional protein yield output. Therefore, intercropping with its advantages of risk minimization, reduction of soil erosion, increased food security should be practiced.

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