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VEGETABLE CROPS AS MOST EFFICIENT AND ECONOMICAL INTERCROPS : A BRIEF REVIEW

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Abstract

Vegetable crops are short durational and shade loving crops with high efficiency of photosynthesis and biological fixation. This ensures their suitability for growing as intercrops under fruit plantation. Intercropping of the vegetables ensures efficient resource and space utilization including improvement of soil and orchard nutrient status, reduction in fruit drop and enhancing fruit yield and quality. It also provides additional income to farmers and helps in maximization of land use.

Key words : Fruit plantation, intercropping, orchard, vegetable crops.

Introduction

Vegetable crops are herbaceous plants having parts like pods, fruits, modified roots, underground stems and leaves that are used for food. These vegetable crops are short durational species, which are most suitable for intercropping in comparision to other species. Intercropping is based on the principle of efficient utilization of canopy space available in fruit orchard. This practice has many advantages for fruit growers including the generation of additional income, improving food security and preventing soil erosion through orchard floor covers. Further, the organic matters added from intercrops improves soil fertility and make the intercropping based agri-horti system ecologically sustainable and economically feasible to the farmers (Upadhaya *et al.*, 1994). In addition to this it has significant role in increasing the productivity and improvement of health of the orchards. Bhattanagar *et al*. (2007) had also proposed the intercropping as one of the techniques of land utilization for optimum production. A wide range of work has been carried out on intercropping practices which have ensured significant effects of intercropping vegetable crops under fruit plantation (table 1).

Among different species of intercrops, growing tuber crops like elephant Foot Yam, Colocassia, Turmeric and Ginger have been reported to be suitable to perennial tree plantation. These are shade loving tuber crops, which has great potential to withstand and grow under canopy of fruit plants. It is due to their higher biological efficiency as food producers and the highest rate of dry matter production per unit area per day among all crops by efficient solar energy transfer (ESET) (Singh *et al*., 2016a). The common vegetable crops suitable for intercropping in fruit orachard are Okra [*Abelmoschus esculentus* (L) Moench.], French bean (*Phaseolus vulgaris* L.), Brinjal (*Solanum melongena* L.), Cauli-flower (*Brassica oleracea* L.), Pea (*Pisum sativum*), Arvi (*Colocasia*), Elephant Foot Yam (*Amorphophallus*), bottle gourd and pumpkin. The present review emphasizes the various aspects of suitability of vegetable crops as intercrops under fruit plantation.

Growth of intercrops under shade of fruit trees

The vegetable crops are shade loving and grow well even under dense orchard. The vegetable crops grown under shade of trees show elongation which might be associated with higher auxin activity under shade condition. Thus, plants show tropic response towards sunlight. However, spread of plant and girth of stem is relatively smaller in crops grown under shade. Overall, there is no significant reduction in biomass which might be associated to their ability to perform photosynthetic activity under low light intensity, justifying the shade loving nature of these crops (Singh *et al*., 2014a). They had further confirmed when intercrops are supplemented

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with organic sources of nutrients, the loss in biomass is not significant and has positive influence on production of both, fruit trees and vegetable intercrops. Resende *et al.* (2001) had reported non-significant difference in fresh mass of lettuce in intercropping when compared with lettuce as monoculture. Sarkar *et al.* (2008) reported that vegetables like chilli, brinjal, *Colocasia*, *Amorphophallus*, bottle gourd and pumpkin were the most acceptable intercrops in papaya under West Bengal condition. Singh *et al.* (1994) suggested suitable intercrops for mango orchard i.e. cowpea (*Vigna unguiculata*), peas (*Pisum sativa*), turmeric (*Curcuma domestica*), radish (*Raphanus sativa*) and *pawpaws*. Singh *et al.* (2015) reported better plant growth when mustard cake and vermicompost was supplemented to urea as source of nitrogen and due to shade loving nature of suran plants. The findings were also in conformity to the observations recorded by Nelliate *et al.* (1974), who suggested the successful cultivation of elephant foot yam, turmeric, ginger, sweet potato and pulses in coconut plantation. Prasanna *et al.* (1995) studied the effects of intercropping of groundnut, cowpea or bitter gourd on banana grown as pure stands and along with sole crop of tapioca in trials conducted for three years (1979-80 to 1983-84) at Mannuthy and reported significant effect on banana or tapioca yield. John and Mini (2005) confirmed the suitability of cow-pea, amaranths and okra for intercropping in terms of equivalent yield, total biomass production of okra and net returns were highest for the okra + cowpea at 60·45 cm. Singh *et al*. (2014b) reported that the maximum plant height (93.71 cm), plant spread (71.13 cm) and stem diameter (3.62 cm) were observed in suran as intercrop followed by turmeric and bunda. Reddy *et al.* (2000) reported that intercropping of radish (cv. Pusa Chetki) in north-south (N-S) alleys between 7-year-old ber cv. Gola adversely affected radish growth and yield compared to intercropping in east-west (E-W) alleys. Radish yields were 38 and 31% of those from sole crops in N-S and E-W alleys, respectively, in the strip closer to ber tree and 19 and 12%, respectively, in the strip further from the ber trees. PAR availability was much lower in the strip closer to the trees than in the strip further away. Differences between intercrop positions in transpiration rates were only significant at midday when they were lowest in strips close to trees in N-S alleys.

Yield of intercrops under shade of fruit trees

The vegetable crops are shade loving in nature so they are capable to give significant yield under canopy of fruit crops. However, small reduction in yield of intercrops had been recorded by many authers and has been confirmed by Singh *et al*. (2014b) which might be due to reduced solar insolation. Singh *et al.* (2015) reported maximum yield in suran as sole crop, (388.33 and 359.20 q/ha.) followed by T_8 (365.02 and 337.65 q/ha) and T_3 (353.39 and 326.88 q/ha) and lowest was in T_1 (279.30 and 258.34 q/ha) when 100% nitrogen was applied from urea (Singh *et al*., 2015). Thus, the yield of intercrop had not been adversely affected by shade of aonla trees as compared to normal yield recorded in open field. It may be due to shade loving nature of suran and application of nitrogen through various organic sources. It has also been suggested that yield potential of shallow rooted and short duration intercrops was not affected by perennial trees (Prasanna, 1995). Resende *et al.* (2001) have reported greater economic yield in radish as intercrop while Singh *et al.* (2014b) reported maximum marketable yield in Turmeric (130.70 and 118.70 q/ha.) followed by suran (128.40 and 118.70 q/ ha) and bunda (103.80 and 94.10 q/ha) and lowest was in arvi 63.52 q/ha and 57.77 q/ha as intercrop in guva orchard. Sharma *et al*. (2008) reported lower yield of intercrops Wheat (18.68) and Gobi Sarson (10.34) under Kinnow plants in comparison to that of wheat (22.34) and gobi sarson (12.01) grown in open. Sharma (1999) had also confirmed better yield of all intercrops *viz.,* Chilli, Brinjal, okra and cauliflower as intercrops under a 5 years old mango orchard at Bilaspur (M.P.) with highest in Brinjal.

Performance of fruit trees after intercropping of vegetable crops

Intercropping of vegetable crops under canopy of fruit trees does not has negative impact on growth, flowering, fruiting and yield of trees. Intercropping of the vegetables under fruit orchard is based on the resource use maximization (RUM), which has significant impact on productivity and health improvement of fruit trees and generate additional income to farmers (Singh and Sharma, 2016). Abdel-Aziz *et al.* (2008) confirmed enhancement of fruit set, vegetative growth and fruit yield with reduced fruit drop in citrus when Egyptian clover and Fenugreek cover crop were grown as intercrop. Chaudhary and Deka (1997) obtained the highest coconut yield (8365 nuts/ha) by practice of Coconut + Betel wine (*P. betle*) + Banana + Assam lemon + turmeric + *Colocasia* cropping system followed by Coconut + Black pepper (*Piper nigrum*) + Banana + Assam lemon + Pineapple + Ginger (876 nuts per ha.) cropping system during the year 1991-94 under 20 years old coconut plantation in Assam in comparison to Coconut alone. Kumar *et al.* (2000) reported tomato as the most efficient intercrop and resulted highest yield of papaya (170.35 and 99.77 kg fruits per tree) planted at 2.1 x 2.1 m of spacing and

supplied with 25% extra dose of fertilizers was applied. However, there was no any significant effect on quality (TSS and sugar) of papaya fruits. Lachungpa (2004) carried out intercropping of ginger, maize, finger millet, beans and vegetables under Kinnow orchard and reported that, intercropped plots produced maximum no. of fruits as compared to without intercrop, 10% less fruit drop was reduced in mandarian when intercropped with bean and lady finger. Singh *et al.* (2014b) had further reported that the intercrops had not adversely affected the yield of fruit trees and had recorded the maximum fruit yield (46.84 kg/tree) sole crop during the rainy season, followed by intercropping of bunda (46.45 kg/tree), while during winter season crop, the maximum fruit yield (24.74 kg/ tree) was recorded by intercropping of arvi followed by suran (23.12 kg/tree) as compared to other cropping systems.

Economic return of fruit trees and vegetable crops based intercropping system

Vegetable crops have shown accountable reduction in yield when grown under canopy of fruit orchard but ensure proper management of orchard and so improve yield and productive life of fruit trees. Thus, theses vegetable crops can be considered as sacrificial crops which improve the productivity of orchard at cost of their yield. However, the income generated from orachard due to intercropping of vegetable crops is additional for farmers so net return becomes better. Gadre (1997) had also reported highest net return (17067.02 per ha) and input: output ratio (1:4.76) in papaya based intercropping and confirmed that the cultivation of papaya for papain with suitable intercrops was economically viable. In 25 years old coconut plantation at Spighat (Assam), Nair *et al.* (2000) recieved highest cost: benefit ratio with local cucumber variety while *Luffa cylindrica* and *L. actangula* gave higher net returns than cucumber, with low cost: benefit ratios. Ghosh & Bandopadhyay (2011) reported coconut + black pepper + pineapple was more remunerative intercropping system showing highest net return of Rs. 45600/- per/ha followed by Coconut + Black pepper + Pine apple Rs. 36050/- per/ha. Kumar *et al.* (2013) reported all the intercrops like cowpea, okra, cabbage, potato, onion, etc. followed by *Gladiolus* performed well as intercrops in and Okra - *Gladiolus* intercrop rotation has highest net profit. In a farmer based study, Ijaz *et al*. (2014) reported that the average yield of Kinnow without intercropping (12454 kg ha^{-1}) was higher than those with intercropping (7492 kg ha^{-1}), but the income from the intercrop makes it more profitable.

Singh and Singh (2015) reported the highest gross income T_8 (Rs. 3, 93,890/ha) followed by T_3 (Rs. 3, 82,850/ ha), and T_2 (Rs.3, 77,990/ha) as compared to aonla grown as sole crop (Rs. 52,420/ha). Similarly, the highest net return (Rs. 2, 92,481.25/ha) was obtained in T_8 followed by (Rs. 2,82,660.25/ha) in T_3 and Rs. 2,79,578.75/ha in T_2 and lowest was in sole crop of aonla (Rs. 38,057.75/ ha). Hugar *et al.* (1991) had also supported intercropping of vegetables in guava plantation with high return per hectare. The estimated cost: benefit ratio obtained from different cropping systems have clearly indicated that the highest cost-benefit ratio (1:2.884) was recorded from T_8 followed by (1:2.841) in T_2, (1:2.821) in T_3 and (1:2.727) in T_5, as compared to sole crop aonla (1:2.650); whereas the least cost: benefit ratio (1:1.955) was estimated in T_{10}. The high cost: benefit ratio of these cropping systems may be due to high corms yield and market price of produce with low investment involved in their cultivation (Singh and Singh, 2015). Similar results were obtained by Kashyap *et al.* (1989). Nedunchezhiyan *et al*. (2008) also recommended the application of N: P: K along with mulching for elephant foot yam + green gram intercropping system for optimum yield and higher benefit: cost ratio (2.02). Uddin *et al.* (2009) conducted an experiment at farmer's field to study the economic feasibility of intercropping potato, lalsak, spinach and French bean in hybrid maize and reported that maize + spinach provided highest yield (15.62 tonnes/ ha) with highest gross income (86,257 taka/ha) followed by maize + lalsak and maize + potato, however, sole crop maize had produced lowest yield (9.65 tonnes/ha) with least gross return. Ghosh *et al.* (2010) conducted an experiment on 3-year-old Mosambi sweet orange 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 cowpea, ridge gourd, groundnut, radish, black gram, okra, amaranthus and cluster bean. The highest net return was calculated from Mosambi + groundnut combination (Rs. 35,820.0/ha) followed by Mosambi + okra (Rs. 22,520.0/ha) and Mosambi + cowpea (Rs. 22,420.0/ha). Hiwale (2015) reported that subabool a leguminous fodder-fuel-fertilizer subabool can be intercropped with fruit trees, *viz*., guava, ber, pomegranate, and kinnow.

Singh *et al*. (2015) reported that the maximum estimated cost of cultivation was estimated in Suran (Rs. 39,160/ha) followed by Turmeric (Rs. 31,510/ha), Bunda (Rs. 18,800/ha) and Arvi (Rs. 18,320/ha) and minimum was in sole crop guava (Rs. 17,320/ha). The high cost of cultivation involved in growing of intercropping system might be due to high cost of planting materials. Higher

Table 1 : Recommendations of various intercropping systems using vegetable crops as intercrops.

Intercropping system	Advantages	Authors
Coconut based intercropping	Successful cultivation of elephant foot yam, turmeric, ginger, sweet potato and pulses.	Nelliate *et al*. (1974)
Intercropping of chilli (*Capsicum annuum*) plants with maize	*A. gossypii* and associated Chilli veinal mottle virus (CVMV) Virus spread was faster and trap catches of winged vectors were greater in monoculture of maize as compared to intercropping chilli pepper.	Hussein and Samad (1993)
Mango based intercropping system	Leaf N content of young Dashehari mango trees was not affected by intercrops however, the turmeric-radish treatment increased leaf P and K contents.	Singh *et al*. (1995)
Coconut based mixed cropping under Assam conditions	Highest coconut yield (8365 nut/hectare) was reported in mixed cropping sequence of Coconut-Colocassia- betelvine- Assam lemon.	Chowdhury and Deka (1997)
Papaya and mung bean intercropping systems	The highest net return, benefit: cost ratio, replacement value of intercropping and sub-monetary advantage with papaya + 6 moong beans rows.	Islam *et al.* (1997)
Okra + cassava/maize cropping system	The N fertilization of 60 kg/ha was found to be applicable to okra grown between the cassava/maize rows using dwarf and early-maize cultivar with relatively narrow leaves.	Olasantan (1999)
Mango based intercropping systems	Intercropping with okra in kharif, gram in rabi and then okra in summer induced high levels of fruit drop in 6-year-old mango (cv. Langra) trees but it gave additional monetary returns from the intercrops.	Sharma (1999a)
Mango based intercropping systems	Brinjal produced the highest marketable fruit yield under both open and shaded conditions (319.10 and 62.69 q/ha, respectively) in 5-year-old mango (cv. Langra) trees.	Sharma (1999b)
Pea-barley intercropping system	Greater yield (4.6 tonnes grain/ha) in pea-barley intercrop comparison to pea and barley as sole crop.	Hauggaard-Neilsen *et al.,* (2001a)
Intercrops of field pea (*Pisum sativum* L.) and spring barley (*Hordeum vulgare* L.) on a temperate sandy loam	Intercropping of pea and barley improved the utilization of plant growth resources (LER > 1) as compared to sole crops.	Hauggaard-Neilsen *et al.* (2001b)
Mixed intercropping of pea and barley	Pea cultivars are capable of improving SNF (Symbiotic Nitrogen Fixation) input into cropping system without depressing the yield of barley component.	Hauggaard-Nielsen and Jensen (2001)
Vegetable crops based intercropping system	The high efficiency of biological productivity and income in intercropping (cauliflower/lettuce, cauliflower/radish, cauliflower/bean, and cauliflower/ onion intercrops) by the complementary use of growth resources.	Yildirim and Guvenc (2005)
Paired row planting of radish (*Raphanus sativus* L.) intercropped with vegetable amaranthus (*Amaranthus tricolor* L.)	The land equivalent ratio was superior in all tested intercropping treatments.	Brintha and Seran (2009)
Strawberry–vegetable intercropping systems	Increase in total yield and productivity.	Karlidag and Yildirim (2009)
Intercropping mango, mandarian and clover crops with date palm	Higher level of ZnO, Mn in soil, higher fruit yield of date plam and highest net profit.	Abouziena *et al* (2010)

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Ground nut based cropping system	Red amaranth, spinach and coriander are most suitable intercrops for ground nut in terms of economic feasibility.	Monim *et al.* (2010)
Mango-based intercropping systems	The mango + guava + cowpea system improved bulk density, electrical conductivity, water-holding capacity, organic carbon, pH, available nitrogen and potassium in soil while the mango + guava + ginger system had highest available phosphorus.	Swain *et al*. (2012)
Maize fodder in lemon, kinnow, grapefruit and musambi	lower infestation of citrus leaf miner (P*hyllocnistis citrella* Stantan) due to improved population of coccinellides which acts as predator on citrus leaf miner.	Ahmed (2013)
Aonla and guava based intercropping system	Tuber crops like aroids, turmeric and ginger are suitable intercrops for orchard in terms of high benefit: cost ratio.	Singh *et al*. (2016a)
Guava based cropping system	The most feasible cropping system are found to be (i) Guava + turmeric (ii) Guava + suran and (iii) Guava + bunda.	Singh *et al*. (2016b)
Aonla + Elephant Foot Yam cropping system	Low oxalate content in corms of intercropped Amorphophallus supplemented with vermicompost and mustard cake.	Singh *et al*. (2016c)
Elephant Foot Yam as intercrop in coconut plantation	Corms size of 500g with spacing of 40 x 40 cm were best for growth and yield of elephant foot yam grown as intercrop under coconut garden.	Salam *et al*. (2017)

cost of cultivation has also been reported due to intercropping under papaya orchard (Gadre, 1997). Singh *et al.* (2015) had further reported high gross and net income in turmeric (Rs. 1,39,720/ha and Rs. 1,08,210/ ha), bunda (Rs. 1,12,050/ha and Rs. 93,250/ha), and Arvi (Rs. 1,04,670/ha and Rs. 86,350/ha) in guava plantation as compared to guava grown as sole crop (Rs. 68,650/ ha). Higher gross income has also been recorded from the various intercrops under papaya plantation (Gadre, 1997). The investigations had revealed that growing of intercrops in guava orchard increased the net return per ha due to additional income obtained from inter crops (Hugar *et al.,* 1991). The observation is in agreement with findings of Kashyap *et al.* (1989) in mango based cropping system (mango + guava) and Islam *et al.* (1997) in papaya + mung bean cropping system. The highest cost: benefit ratio was obtained from Guava + Bunda (1:5.96) followed by Guava + Arvi (1:5.71), Guava+ Turmeric (1:4.43) and Guava + Suran (1:4.16) cropping system, as compared to sole crop guava (1:3.96). Higher cost: benefit ratio obtained due to intercropping than the guava as sole crop alone was in accordance to observation recorded in several other investigations (Bhuwa *et al.,* 1988; Rajput *et al.,* 1986; Kashyap *et al.,* 1989). Prasanna *et al.* (1995) has also reported the higher cost: benefit ratio from intercropping bananas with tapioca. Singh *et al.* (2016a) had reported that highest gross income and net return due to intercropping of Elephant foot yam (T_3) (Rs.2.334 x 10^5/ha and Rs. 1.844 x 10^5/ha, respectively) followed by Bunda (Rs. 1.421 x 10^5/ha and Rs. 1.131 x 10^5/ha, respectively) and Arvi (Rs. 1.247 x 10^5/ha and Rs. 0.972 x 105/ha, respectively) and lowest was in sole crop of guava (Rs. 0.570 x 105/ha and Rs. 0.445 x 10^5/ha, respectively). The highest benefit: cost ratio was obtained from Guava + Bunda (3.90:1) followed by Guava + Arvi (3.76:1), Guava + Turmeric (3.68:1) and Guava + Suran (3.53:1) cropping system as compared to sole crop guava (3.07:1).

Adaptability of intercropping system

Although intercropping vegetable crops in fruit orchard has greater potential to improve orchard and farm productivity but adaptability by the farmers is very low ahich might be associated with lack of awareness and small farm or land holding. Hossen (2013) conducted a survey for adoption of intercopping system in jackfruit in Kachina and Habirbari village. The findings of the study indicated that majority (82.9 percent) of the growers had low adoption while 15.4 percent had medium adoption and 1.7 percent had high adoption of intercropping with jackfruit. Correlation analysis indicates that among the selected characteristics education, farm size, income from jackfruit and intercrop were primary factors influencing the adoption of intercropping systems.

Conclusion

The outcomes of various intercropping practices confirm that vegetable crops are economically and ecologically most suitable and viable intercrops for fruit plantation at early phase of growth. Once bearing starts, there is need of synchronization of cultural practices adapted for intercrops with the requirements of fruit trees

so that productivity of trees will not be decreased.

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