Journal of Applied Horticulture, 21(2): 87-100, 2019
DOI: https://doi.org/10.37855/jah.2019.v21i02.16
Journal of Applied Horticulture
ISSN: 0972-1045

Tree used in horticulture based alley cropping

O. Montes, R. Castro, C. Villanueva, M. Pérez[1] and M. Uribe[2]

[1]*Horticultura. Universidad Autónoma Chapingo. Estado de México 56230, México* [2]*Agroforestería para el Desarrollo Sostenible. Universidad Autónoma Chapingo. Estado de México, 56230, México. *E-mail: Montes.horticulture@outlook.com*

Abstract

Main objective of this paper is selection of tree and vegetable combination for success in new horticulture based alley cropping plantations. In alley cropping, fruit, legume and wood tree are integrated in several associations with annual vegetable, *Mangifera indica, Psidium guajava, Citrus* spp., *Leucaena* spp., *Gliricidia sepium, Cajanus cajan, Populus* spp., *Eucalyptus, Hevea brasiliensis* are the main tree used. *Fabaceae, Brassicaceae, Solanaceae* families and tuber crops are the main associated vegetable crops. This system can be adapted for specific farmers, regions, and countries for vegetable, fruit and wood requirements. The specific credits and subsidies can increase natural, economic, social capital of the world.

Key words: Agroforestry, fruit tree, legume tree, wood tree, annual vegetable, silvoarable system

Introduction

The horticulture associated with trees is not new; several combinations and arrangements have been developed in different parts of the world to domesticate, produce and improve some vegetable and fruit tree species. Actually, the horticulture based alley cropping systems (agroforestry) combine perennial woody crops and non-woody crops (Martin *et al.*, 2019), the vegetables are arranged spatially in order to achieve both economic and environmental benefits of the farming system (Mercado *et al.*, 2008). The choice of crops is determined by the factors like agro-climatic and edaphic conditions, crop root system, pattern of water and nutrient demands and above ground growth habits (Pandey *et al.*, 2017).

Vegetable crops recommended, in alley cropping, are short durational and shade-loving crops with high efficiency of photosynthesis and biological fixation (Singh *et al.*, 2018). Some criteria for selecting of horticultural intercrops are: 1. early maturing; 2. shade tolerance; 3. should not compete with the perennial companion crop; 4. should not be more susceptible than the main crop to diseases they have common (Dhakar *et al.*, 2013). Theoretically, C3 plants planted under shade should be able to perform better than C4 plants and could be better suited for agroforestry practices (Jose *et al.*, 2004), and, the crop variety, management of crops and trees, seasonal climate variability (Bellow *et al.*, 2008), and socio-economic suitability contribute to system performance (Dhakar *et al.*, 2013).

The tree component selection is significant for the success of agroforestry plantation. The dependent species, tree species check erosion and also ameliorate soil in terms of increasing organic matter, fixing nitrogen, and nutrient uptake and recycling through litterfall (Pande *et al.*, 2018). For example, the fast-growing wood tree species in combination with horticultural crop may increase the employment generation for the nursery growers, local labours and small scale wood industries (Shukla *et al.*, 2018), and legume tree for "fallow system" (Kang *et al.*, 1985) provides nitrogen through biological fixation, and help in solubilizing insoluble P in soil, improving the soil physical environment, increasing soil microbial activity, restoring organic matter, and also has smothering effect on weed (Ghosh *et al.*, 2007).

On the another hand, horticulture has become problematic as the drainage effluent contains drained nutrients, salts and residues of agro-chemicals and affects the health of reservoirs, rivers and inland seas into which it is discharged (Fanish and Priya, 2013). In response agroforestry is being viewed as a restoration agent, rehabilitation process, bioremediation (Asati *et al.*, 2007), ameliorate soil health (Dhewa and Daniel, 2017), and the biodrainage plantations purify our environment by absorbing greenhouse gases (Fanish and Priya, 2013). So, agroforestry systems are a biodiversity-friendly alternative to food and wood production (Oliveira *et al.*, 2019).

Finally, alley cropping system is one of the most common agroforestry practices around the world (Wolz and DeLucia, 2018). The vegetables provide regular income to the farmers during the early stages of tree establishment (Kaushik *et al.*, 2017), and is an economically feasible way to protect crop plants from extremes in microclimate and soil moisture and should be considered a potential adaptive strategy for farmers in areas that may suffer from extremes in climate (Lin, 2007). The main objective of this paper is selection of tree and vegetable combination for success in new horticulture based alley cropping plantations.

Legumes tree

The advantages of legume tree in vegetable production based agroforestry systems include: nitrogen fixation, insect pest reduction, disease prevention (Blair *et al.*, 2016; Majumdar, 2011), increase water infiltration (Chaturvedi *et al.*, 2018), promote soil health, increase nutrient availability, reduce fertilizer requirement, and soil erosion control (Palada *et al.*, 1992) and others. The production rate and nutrient concentrations determine the type of legume tree, mainly used for "fallow system", and the amount of nutrients provided by pruning, both depending on climate, soil type, tree species, plant part, tree density and tree pruning regime (Palm, 1995), the asynchrony of nutrient release (mulch application) from alley cropping pruning's and nutrient demand from the crops is often the leading cause for low crop N use efficiency and yield (Seiter and Horwath, 1999). Leguminous trees are used and scientifically validated for use in this type of plantations.

Leucaena leucocephala: *Leucaena leucocephala* is native to Central America (Nehdi *et al.*, 2014) with diversified uses such as cattle and human food, firewood, timber, shade, green manure, soil erosion control, soil health enrichment, windbreaks, fire break, etc. (Harun-Ur *et al.*, 2018). Tree requires warm temperatures for optimal growth, and is drought-tolerant (4m x 0.5m usually recommended), the tree can repeat harvest of the foliage (7-10 month after establishment) up to 10 times a year (Honda *et al.*, 2019). Usually, application of pruning resulted in higher soil moisture retention, organic matter, exchangeable K, Ca, Mg, and also nitrate levels in the soil solution (Kang *et al.*, 1985). This tree is mostly used in horticulture based alley cropping. *Vigna* sp.*, Manihot esculenta,* and *Ipomoea batatas* are some annual vegetables cultivated in *Leucaena* alley cropping.

Palada *et al.* (1992) concluded that prunings provide significant amounts of N, P, K and Ca, and four vegetables in alley cropping can reduce fertilizer requirement. Insaidoo and Quarshie (2007) concluded that with adequate water, the half-rate fertilizer can be efficient particularly when combined with prunings, so that this system could reduce fertilizer requirement for *Solanum melongena*, with no significant change of pH, K and Mg levels in the soil. Moderate nitrogen fertilisation produced higher total growth parameters of *Pisum sativum* in *Leucaena* alley cropping (Zaki *et al.*, 2017). *Abelmoschus esculentus* cultivars were higher yielding in the alley than the non-alley field. *L. leucocephala* planted as alley crops have the potential to suppress nematode populations (Adekunle, 2009). Table 1 shows other vegetable crops and fruit tree in *L. leucocephala* alley cropping.

Cajanus cajan: *Cajanus cajan* is a multipurpose tree (Zu *et al.*, 2006). It is an important food legume crop in the semi-arid regions of the world (Varshney *et al.*, 2010). It grows well in the P-deficient soils of the tropical environment (Fujita *et al.*, 2004), and combines high tolerance to environmental stresses, and provides high biomass productivity (Odeny, 2007). Additionally the tree improves soil fertility, is a source of fodder and firewood, and its use in mulching has provided an alternative to inorganic fertilizers and provides the much needed organic material to maintain soil productivity (Abugre and Twum, 2011). *Manihot esculenta, Ipomoea batatas,* and *Vigna* spp. are annual vegetables cultivated in *C. cajan* alley cropping.

Alves *et al.* (2004) concluded that biomass incorporation in *Beta vulgaris* and *Daucus carota* crops resulted in high positive N-balance, and uptake of P increased significantly. In *Solanum lycopersicum* highest yield (9.35 tons/ha) was obtained at the highest rate of mulch/fertilizer interaction (15 tons/ha and 150 kg N/ha), and mulch reduced the dependence on inorganic fertilizers (Abugre and Twum, 2011). Table 1 shows other vegetable crops and fruit tree in *Cajanus cajan* alley cropping and another legume tree.

Gliricidia sepium: *Gliricidia sepium* is a medium-size tree*,* native to tropical zone of Central America (Montero *et al.*, 2017), and is integrated into farming practices for poles, firewood, hedges, forage, green manure and soil stabilization. The pruning interval of 6-12 weeks is usually recommended (Suttie, 2015), and leaves release máximum nitrogen within 15 days (Kumar *et al.*, 2016). The tree grows best in tropical, seasonally dry climates (4-6m x 0.5 m usually recommended spacing) (Adekunle, 2009). It is widely used to provide crop shade for coffee, cacao and other shade-loving crops (Marak and Wani, 2018). *Manihot esculenta, Vigna* spp.*,* and *Brassica oleracea* are some annual vegetables cultivated in *Gliricidia* alley cropping.

Kuntashula *et al.* (2004) concluded the highest cabbage and onion yields were obtained from manure + half-rate fertilizer application. Olasantan (2000) concluded that pruning applied (mulch) at the rate of 30 kg ha^{-1} was more economical in *Abelmoschus esculentus* and *Solanum lycopersicum* yield than application of 60 kg ha^{-1}. Paulino *et al.* (2011) concluded that the quantity of N added to the orchard with *Gliricidia* pruning was higher than the recommended fertilization for soursop tree plots. Table 1 shows other vegetable crops and fruit tree in *Gliricidia* alley cropping.

Wood tree

Vegetable-based alley cropping synergistically fulfil the demand of vegetable crops and timber to human and industry (Bhusara *et al.*, 2018). Many farmers are inclined to intercrop young timber trees with well-fertilized annuals to confer nutrient and weeding benefits to the trees while gaining short-term returns on the land (Nissen *et al.*, 2001). Usually the rows are planted in a North-south orientation (Newman *et al.*, 1997), to derive optimal benefits from intercropping timber. Farmers should make important initial decisions on selecting tree species and planting density with a good understanding of their tradeoffs (Nissen and Midmore, 2002).

Tectona grandis: Teak (*Tectona grandis*) is a species of tropical regions and is native to India, and can grow under a wide range of climatic and edaphic conditions (Singh *et al.*, 2017). It is one of the most valuable tropical hardwood species in the international timber market (Deb *et al.*, 2017). Teak alley cropping involves high-value crops, for example, banana, pineapple, fruit trees, coffee, etc. (Pachas *et al.*, 2019). Intercropping distance of 3m x 2m is recommended (Patel *et al.*, 2018). *Capsicum* spp.*, Solanum tuberosum,* and *Solanum melongena* are some annual vegetables cultivated in *T. grandis* alley cropping. *S. melongena* L. exhibited increase in various growth as well as yield parameters under teak system as compared to monocrop, number of fruits per plant, fruit circumference, fruit length, average fruit weight and yield (Sondarva *et al.*, 2018). Similarly various cucurbitaceous crops under teak can provide additional income to the teak farmers (Patel *et al.*, 2018). Table 2 shows another vegetable crops and fruit tree in *Tectona grandis* alley cropping.

Hevea brasiliensis: *Hevea brasiliensis* is a tree belonging to the *Euphorbiaceae* family, indigenous to the tropical forests of the Amazon basin (Wadeesirisak *et al.*, 2017), and is the worldwide primary commercial source of natural rubber (Zhang *et al.*, 2019). It is susceptible to low temperatures (Chen *et al.*, 2019). The

Table 1. Legume tree + annual vegetable and fruit tree

Legume tree	Annual vegetable and fruit tree	Reference
Leucaena leucocephala *Leucaena* spp.	(1) *Vigna* sp., (2) *Manihot esculenta,* (3) *Ananas comosus,* (4) *Dioscorea* spp., (5) *Solanum melongena,* (6) *Solanum tuberosum,* (7) *Coriandum sativum,* (8) *Solanum lycopersicum,* (9) *Capsicum annuum,* (10) *Brassica oleracea,* (11) *Curcuma longa,* (12) *Abelmoschus esculentus,* (13) *Pisum sativum,* (14) *Ipomoea batatas,* (15) *Allium cepa, (*16) *Cucurbita* sp., (17) *Tagetes minuta,* (18) *Ocimum basilicum,* (19) vegetables.	(1) (Akinnifesi *et al.*, 1998; Atta-Krah, 1990; Chaturvedi *et al.*, 2001; Duguma *et al.*, 1988; Ghosh *et al.*, 2007; Hulugalle and Kang, 1990; Jha and Chaturdevi, 1995; Kang *et al.*, 1985; Lal, 1989; Lawson and Kang, 1990; Mittal and Singh, 1989; Ngambeki, 1985; Paningbatan, 1986; Schroth, 1995; Singh and Van den Beldt, 1989; Ssekabembe, 1985; Vanlauwe *et al.*, 1998; Vinaya and Suresh, 1988), (2) (Atayese *et al.*, 1993; Barreto and Fernandes, 2001; Bayard *et al.*, 2007; Dhakar *et al.*, 2013; Ernst, 1994; Fagbola *et al.*, 1998; Hy *et al.*, 2002; Leihner *et al.*, 1996; Liasu *et al.*, 2006; Moura *et al.*, 2017; Osonubi *et al.*, 1995; Oyetunji and Osonubi, 2007; Oyetunji *et al.*, 2003; Schroth, 1995; Singh, 1987; Tonye, 1989; Tonye *et al.*, 1994), (3) (Adinya *et al.*, 2010; Asati *et al.*, 2007; Firoz *et al.*, 2012; Gogoi, 2015), (4) (Budelman, 1990; Dhakar *et al.*, 2013; Schroth, 1995), (5) (Insaidoo and Quarshie, 2007), (6) (Brook, 1992; Yamoah *et al.*, 1989), (7) (Schroth *et al.*, 2000), (8) (Palada *et al.*, 1992), (9) (Soreng and Kerketta, 2017), (10) (Mappaona *et al.*, 1994), (11) *(Adekunle, 2009; Narain et al.*, 1997), (12) (Palada *et al.*, 1992), (13) (Zaki *et al.*, 2016), (14) (Balasubramanian and Sekayange, 1991), (15) (Kuntashula *et al.*, 2004), (16) (Sampaio *et al.*, 2015), (17) (Thakur *et al.*, 2005), (18) (Verma *et al.*, 2017), (19) (Upadhyay and Yadava, 2009).
	(1) *Theobroma grandiflorum* and *T. cacao,* (2) *Musa* spp., (3) *Citrus aurantium,* (4) *Citrus reticulata,* (5) *Coffea* spp., (6) *Cocos nucifera,* (7) *Citrus aurantifolia,* (8) *Carica papaya,* (9) fruit tree.	(1) (Oelbermann *et al.*, 2004; Sampaio *et al.*, 2015; Schroth *et al.*, 2000; Singh, 1987), (2) (Schroth and Sinclair, 2003; Singh, 1987; Wilson and Swennen, 1989), (3) (Abd-allah *et al.*, 1999), (4) (Abd-allah *et al.*, 1999), (5) (Schroth *et al.*, 2000), (6) (Schroth and Sinclair, 2003), (7) (Dyal *et al.*, 1996), (8) (Hymavathi *et al.*, 2010), (9) (Hymavathi *et al.*, 2010).
Cajanus cajan	(1) *Manihot esculenta,* (2) *Ipomoea batatas,* (3) *Vigna* spp., (4) *Dacus carota,* (5) *Ananas comosus,* (6) *Capsicum annuum,* (7) *Beta vulgaris,* (8) *Phaseolus* spp., (9) *Dioscorea* spp., (10) *Solanum lycopersicum.*	(1) (Akondé *et al.*, 1997; Atayese *et al.*, 1993; Ernst, 1994; Leihner *et al.*, 1996; Lose *et al.*, 2003; Murray and Bannister, 2004; Salami *et al.*, 2005), (2) (Brook, 1992; Isaac *et al.*, 2003; Kang, 1993; Murray and Bannister, 2004; Nedunchezhiyan *et al.*, 2012), (3) (Blair *et al.*, 2016; Kang, 1993; Kang *et al.*, 1985; Singh, 2016), (4) (Alves *et al.*, 2004; Isaac *et al.*, 2003), (5) (Firoz *et al.*, 2012; Murray and Bannister, 2004), (6) (Palada *et al.*, 1992), (7) *(Alves et al.*, 2004), (8) (Alves *et al.*, 2004; Isaac *et al.*, 2003), (9) (Murray and Bannister, 2004), (10) (Abugre and Twum, 2011).
	(1) *Prunus* sp., (2) *Mussa* sp., (3) *Citrifolia sinensis,* (4) *Santalum yasi,* (5) *Carica papaya,* (6) *Psidium guajava,* (7) *Annona squamosa*, (8) *Acharus sapota*, (9) *Tamarindus indica.*	(1) (Alves *et al.*, 2004; Murray and Bannister, 2004), (2) (Sangwan *et al.*, 2015), (3) (Harrison and Harrison, 2016), (4) (Harrison and Harrison, 2016), (5) (Jakhar *et al.*, 2010), (6) (Pareek and Awasthi, 2008), (7) (Pareek and Awasthi, 2008), (8) (Pareek and Awasthi, 2008), (9) (Pareek and Awasthi, 2008).
Gliricidia sepium *G. maculata*	(1) *Manihot esculenta,* (2) *Vigna* spp., (3) *Dioscorea* spp., (4) *Brassica oleracea,* (5) *Abelmoschus esculentum,* (6) *Capsicum frutescens,* (7) *Solanum melongena,* (8) *Solanum lycopersicum,* (9) *Allium cepa,* (10) *Ipomoea batatas,* (11) vegetables.	(1) (Amara *et al.*, 1996; Barreto and Fernandes, 2001; Böhringer and Leihner, 1996; Evensen *et al.*, 1995; Ghuman *et al.*, 1991; Kass *et al.*, 1992; Lose *et al.*, 2003; Moura *et al.*, 2017; Oelbermann *et al.*, 2004; Okon, 2011; Osonubi *et al.*, 1995; Kass 1987.; Salami and Osonubi, 2003; Tonye *et al.*, 1994; Wilson *et al.*, 1986), (2) (Budelman, 1990; Budelman and Pinners, 1987; Duguma *et al.*, 1988; Evensen *et al.*, 1995; Hulugalle and Kang, 1990; Lawson and Kang, 1990; Paningbatan, 1986), (3) (Schroth, 1995), (4) (Kuntashula *et al.*, 2004; Mafongoya and Jiri, 2016; Ribeiro *et al.*, 2018), (5) (Adekunle, 2009; Olasantan, 2000; Schroth *et al.*, 1995), (6) (Iijima *et al.*, 2003), (7) (Mafongoya and Jiri, 2016; Palada *et al.*, 1992), (8) (Olasantan, 2000; Wilson *et al.*, 1986), (9) (Mafongoya and Jiri, 2016), (10) (Brook, 1992), (11) (Upadhyay and Yadava, 2009).
	(1) *Theobroma cacao,* (2) *Carica papaya,* (3) *Musa* sp., (4) *Mangifera* sp., (5) *Anona muricata.,* (6) *Cocos nucifera*	(1) (Lasco *et al.*, 2001; Schroth *et al.*, 2000), (2) (Jakhar *et al.*, 2010; Ribeiro *et al.*, 2018), (3) (de Paula *et al.*, 2015), (4) (Paulino *et al.*, 2011), (5) (Paulino *et al.*, 2011), (6) (Kaba *et al.*, 2019).
Acacia auriculiformis *A. lenticularis,* *A. stenophylla,* *A. tortills,* *A. indica*	(1) *Capsicum annuum,* (2) *Ipomoea batatas,* (3) *Vigna radiata,* (4) *Manihot esculenta,* (5) *Pisum sativum,* (6) *Vicia faba,* (7) *Dacus carota,* (8) *Solanum tuberosum,* (9) *Cicer arientinum,* (10) *Allium sativum,* (11) *Pachyrhizus erosus,* (12) *Solanum lycopersicum,* (13) *Cucumis sativum,* (14) *Raphanus raphanistrum*, (15) *Ananas comosus.*	(1) (Chaturvedi *et al.*, 2001; Shapo and Adam, 2008), (2) (Brook, 1992; Chaturvedi *et al.*, 2001), (3) (Chaturvedi *et al.*, 2001), (4) (Chaturvedi *et al.*, 2001), (5) (Schroth *et al.*, 2000), (6) (Shapo and Adam, 2008), (7) (Shapo and Adam, 2008), (8) (Chaturvedi *et al.*, 2001), (9) (Hymavathi *et al.*, 2010), (10) (Chaturvedi *et al.*, 2001), (11) (Chaturvedi *et al.*, 2001), (12) (Hanada, 1990), (13) (Hanada, 1990), (14) (Hanada, 1990), (15) (Bhatt *et al.*, 2006).
	(1) *Mangifera indica.*	(1) (Escaño and Tababa, 1998).
Prosopis cineraria	(1) *Vigna aconitifolius,* (2) *Cyamopsis tetragonoloba,* (3) *Brassica tourneforti,* (4) *Euruca sativa,* (5) *Capsicum* sp.	(1) (Dhakar *et al.*, 2013; Handa and Newaj, 2017; Kaushik *et al.*, 2003; Singh, 2009), (2) (Dhakar *et al.*, 2013; Kaushik *et al.*, 2003), (3) (Kaushik *et al.*, 2003), (4) (Kaushik *et al.*, 2003), (5) (Ranashinghe and Newman, 1993).
	(1) *Psidium guajava,* (2) *Zizyphus mauritiana.*	(1) (Dalal *et al.*, 2015; Nedunchezhiyan *et al.*, 2012), (2) (Singh and Singh, 2015).

Table 2. Wood tree + annual vegetable and fruit tree

Wood tree	Annual vegetable and fruit tree	Reference
Tectona grandis	(1) *Capsicum* spp., (2) *Solanum tuberosum,* (3) *Solanum melongena,* (4) *Vigna* spp. (5) *Ocimum* spp., (6) *Manihot esculenta,* (7) *Curcuma longa,* (8) *Piper nigrum,* (9) *Ananas comosus,* (10) *Abelmoschus esculentus,* (11) *Cicer arietinum,* (12) *Cucumis sativus,* (13) vegetables.	(1) (Handa and Newaj, 2017; Weersum, 1982), (2) (Singh, 1987; Weersum, 1982), (3) (Bhoyar *et al.*, 2016; Bhusara, 2014; Gunaga, 2017), (4) (Bhoyar *et al.*, 2016; Chaturvedi *et al.*, 2001), (5) (Kumar *et al.*, 2017, 2015), (6) (Weersum, 1982), (7) (Singh, 1987), (8) (Singh, 1987), (9) (Dhewa and Daniel, 2017; Singh, 1987), (10) (Gunaga, 2017), (11) (Bhoyar *et al.*, 2016), (12) (Patel *et al.*, 2018), (13) (Hymavathi *et al.*, 2010).
	(1) *Mangifera indica,* (2) *Carica papaya,* (3) *Cocos nucifera,* (4) *Theobroma cacao,* (5) *Psidium guajava,* (6) *Pyrus pyrifolia* (7) *Musa* sp., (8) fruit trees.	(1) (Gunaga, 2017; Sureshbhai *et al.*, 2017; Toppo *et al.*, 2016), (2) (Handa and Newaj, 2017; Verma *et al.*, 2017), (3) (Singh, 1987), (4) (Singh, 1987), (5) (Anand *et al.*, 2016), (6) (Rani *et al.*, 2016), (7) (Bhusara, 2014), (8) (Hymavathi *et al.*, 2010).
Hevea brasiliensis	(1) *Ananas comosus,* (2) *Manihot esculenta,* (3) *Dioscorea floribunda,* (4) *Amomum villosum,* (5) *Passiflora edulis,* (6) *Piper nigrum.*	(1) (He *et al.*, 2012; Kumar *et al.*, 2012; Malézieux *et al.*, 2009; Rajasekharan and Veeraputhran, 2002), (2) (Rajasekharan and Veeraputhran, 2002), (3) (Rao *et al.*, 2004), (4) (Rao *et al.*, 2004), (5) (Newman, 1985), (6) (Newman, 1985).
	(1) *Musa* spp., (2) *Coffea* sp., (3) *Carica papaya*, (4) *Cocos nucifera,* (5) *Citrus reticulata.*	(1) (Newman, 1985; Rajasekharan and Veeraputhran, 2002; Ranashinghe and Newman, 1993; Rani *et al.*, 2016), (2) (Newman, 1985; Ranashinghe and Newman, 1993), (3) (Newman, 1985; Ranashinghe and Newman, 1993), (4) (Kumar *et al.*, 2012; Newman, 1985), (5) (Khaunkuab *et al.*, 2008).
Poplar spp.	(1) *Brassica juncea,* (2) *Solanum tuberosum,* (3) *Allium cepa,* (4) *Capsicum* sp., (5) *Solanum melongena,* (6) *Solanum lycopersicum,* (7) *Zea mays* (sweet corn), (8) *vegetables*	(1) (Ghimire, 2010), (2) (Devender *et al.*, 2012), (3) (Yadav, 2006), (4) (Yadav, 2006), (5) (Yadav, 2006), (6) (Yadav, 2006), (7) (Bhushan and Khare, 2018), (8) (Jose *et al.*, 2008).
	(1) *Prunus* spp., (2) *Psidium guajava,* (3) *Mangifera indica,* (4) *Citrus* spp., (5) *Pyrus communis.*	(1) (Dhillon *et al.*, 2012, 2010; Sangwan *et al.*, 2015), (2) (Dhillon *et al.*, 2012, 2010; Sangwan *et al.*, 2015), (3) (Handa and Newaj, 2017; Verma *et al.*, 2017), (4) (Dhillon *et al.*, 2012, 2010; Sangwan *et al.*, 2015; Verma *et al.*, 2017), (5) (Dhillon *et al.*, 2012).
Eucalyptus	(1) *Manihot esculenta,* (2) *Vigna* spp., (3) *Capsicum* sp., (4) *Brassica oleracea, B. chinensis* (5) *Coriandrum sativum,* (6) *Solanum melongena,* (7) *Cicer arentinum,* (8) *Solanum tuberosum,* (9) *Solanum lycopersicum*, (10) vegetables.	(1) (Dhyani *et al.*, 2013; Singh, 1989), (2) (Asati *et al.*, 2007; Nissen and Midmore, 2002), (3) (Schroth, 1995), (4) (Vinaya and Suresh, 1988), (5) (Sureshbhai *et al.*, 2017), (6) (Sureshbhai *et al.*, 2017), (7) (Asati *et al.*, 2007), (8) (Asati *et al.*, 2007), (9) (Asati *et al.*, 2007), (10) (Upadhyay and Yadava, 2009).
	(1) *Mangifera indica,* (2) *Theobroma cacao,* (3) *Litchi chinensis,* (4) *Pouteria sapota,* (5) *Citrus lemon,* (6) *Pyrus pyrifolia*	(1) (Verma *et al.*, 2017), (2) (Handa and Newaj, 2017; Lakaria *et al.*, 2012; Verma *et al.*, 2017), (3) (Upadhyay and Yadava, 2009), (4) (Sureshbhai *et al.*, 2017), (5) (Sureshbhai *et al.*, 2017), (6) (Rani *et al.*, 2016).
Populus tomentosa, P. euramericana, P. deltoides, P. nigra	(1) *Brassica alba, B. nigra*, *B. oleracea*, (2) *Citrullus lanatus* (3) *Cicer arietinum,* (4) *Cucurbita pepo,* (5) *Dacus carota,* (6) *Vicia faba,* (7) *Pisum sativum,* (8) *Vigna* sp., (9) *Solanum tuberosum,* (10) *Solanum lycopersicum*, (11) *Capsicum* sp.	(1) (Asati *et al.*, 2007; Burgess *et al.*, 2005; Sangwan, 2014; Singh, 1989), (2) (Jiang and Qin, 2007; Tolunay *et al.*, 2007), (3) (Asati *et al.*, 2007; Tolunay *et al.*, 2007), (4) (Akbulut *et al.*, 2003), (5) (Tolunay *et al.*, 2007), (6) (Burgess *et al.*, 2005), (7) (Burgess *et al.*, 2005), (8) (Chauhan *et al.*, 2013), (9) (Asati *et al.*, 2007; Chaturvedi *et al.*, 2001), (10) (Asati *et al.*, 2007), (11) (Asati *et al.*, 2007).
	(1) *Coffea* spp., (2) *Malus* spp., (3) *Pyrus pyrifolia*	(1) (Kumar *et al.*, 2012), (2) (Dhakar *et al.*, 2013; Kumar *et al.*, 2012), (3) (Rani *et al.*, 2016).
Grewia optiva	(1) *Withania somnifera,* (2) *Cicer arietinum,* (3) *Solanum tuberosum,* (4) *Brassica oleracea,* (5) *Solanum lycopersicum,* (6) *Capsicum* sp.	(1) (Verma and Thakur, 2010), (2) (Asati *et al.*, 2007), (3) (Asati *et al.*, 2007), (4) (Asati *et al.*, 2007), (5) (Asati *et al.*, 2007), (6) (Asati *et al.*, 2007).
	(1) *Prunus* spp., (2) *Coffea* sp., (3) *Malus domestica,* (4) *Mangifera indica*	(1) (Bijalwan, 2012; Verma and Thakur, 2010), (2) (Dhyani *et al.*, 2013) (3) (Bijalwan, 2012), (4) (Verma and Thakur, 2010).
Bambusa spp.	(1) *Vigna unguiculata, Vigna umbellata,* (2) *Cucumis sativus, (3) Lablab purpureus,* (4) *Solanum nigrum,* (5) *Ocimum basilicum,* (6) *Momordica charantea,* (7) *Capsicum frutescens,* (8) *Manihot esculenta*	(1) (Behera *et al.*, 2016), (2) (Christanty *et al.*, 1997), (3) (Christanty *et al.*, 1997), (4) (Christanty *et al.*, 1997), (5) (Christanty *et al.*, 1997), (6) (Christanty *et al.*, 1997), (7) (Christanty *et al.*, 1997), (8) (Christanty *et al.*, 1997).
	(1) *Psidium guajava,* (2) *Mangifera indica*	(1) (Hymavathi *et al.*, 2010), (2) (Christanty *et al.*, 1997).
Alnus japonicum A. nepalensis A. rubra	(1) *Zea mays*, (2) *Amomum subulatum* (3) *Vigna radiata,* (4) *Solanum tuberosum,* (5) *Capsicum* sp. (6) *Colocasia* spp., (7) *Ananas comosus,* (8) *Phaseolus multiflorus*	(1) (Seiter and Horwath, 1999; Stelen, 1997), (2) (Ranashinghe and Newman, 1993; Singh, 1989), (3) (Paningbatan, 1986), (4) (Handa and Newaj, 2017), (5) (Handa and Newaj, 2017), (6) (Handa and Newaj, 2017), (7) (Chauhan *et al.*, 1993), (8) (Dhakar *et al.*, 2013).

intercropping system generally adopted in rubber cultivation in India (6.7 x 3.4 m) allows intercropping with a variety of crops during the initial three years. Integration of other crops with rubber is not commonly practiced in older plantations due to the limited light availability and concerns of unfavourable effect on the performance of rubber (Jessy *et al.*, 2017). *Ananas comosus, Manihot esculenta,* and *Piper nigrum* are some annual vegetables cultivated in *H. brasiliensis* alley cropping.

Glomus deserticola significantly increased *M. esculenta* biomass accumulation and nutrient yield of alley crop. Root tuber nutrient yield for nitrogen, potassium and phosphorus was significantly increased by *G. deserticola* inoculation (Okon, 2011). The results showed that, under this pattern, the pineapple was able to grow and develop normally, and the fruit quality of Tainong NO. 16 pineapple slightly declined, without a significant difference. On the other hand, there was not any negative effect on the rubber's growth and development (He *et al.*, 2012). Table 2 shows other vegetable crops and fruit tree in *H. brasiliensis* alley cropping.

Populus deltoides: Poplar (*Populus deltoides*) is a fast-growing, deciduous, and tall tree (Thakur *et al.*, 2012), and is rated among the most promising species for the energy generation because of its minimum fertilizer requirement and its ability to grow on unfertile marginal lands (Rawat *et al.*, 2013). It is highly suitable for horti-agroforestry system (Devender *et al.*, 2012), by permitting enough sunlight for cultivation of horticultural crops, and intercropping results in increased growth rate of poplar due to frequent irrigation. Chauhan *et al.* (2013) concluded that *Curcuma longa* and *Vigna radiata* initially showed better performance in yield and yield contributing parameters under partial shade, and decreased as poplar canopy advanced with the age of tree.

Akbulut *et al.* (2003) concluded that *Cucurbita pepo* in *Populus euramericana* alley cropping might contribute to increasing beneficial arthropod diversity compared with monocrops. Dhillon *et al.* (2012) concluded that growth increment of poplar was significantly higher when planted with fruit crops (*Psidium guajava*, *Citrus reticulata*, *Pyrus communis*, *Prunus persica*, *Prunus americana*) as compared to sole poplar planting. Table 2 shows other vegetable crops and fruit tree in *Populus deltoides* alley cropping, and other wood trees.

Fruit trees

The production of horticultural trees as intercrops was found to be more effective for improvement in soil fertility and productivity (Verma *et al.*, 2017). Fruit trees have a long gestation period (4-5 years) to provide income; so the interspaces can be used for cultivation of crops profitably till the main crop develop canopy (Gunaga, 2017). One of the main motivations for farmers to simultaneously grow a variety of vegetables and fruits is to reduce the overall risk on production through a diversification effect (Paut *et al.*, 2018), and helps in strengthening the farmers economy (Gupta and Arora, 2015). 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, however, there is need of synchronization of cultural practices adapted for intercrops with the requirements of fruit trees (Singh *et al.*, 2018).

Mangifera indica: Mango (*Mangifera indica* L.) belongs to *Anacardaceae* family (Lieb *et al.*, 2019), and the tree takes 10-12 years to grow and attain its full production potential (Kumar *et al.*, 2008). It can be intercropped with vegetable crops (Musvoto and Campbell, 1995) to efficiently utilize resources such as water, and light (Swain *et al.*, 2012). Intercropping, besides providing income to the grower, suppresses weed growth, improves soil fertility and prevents leaching of nutrients and erosion of soil, achieves higher gross return per unit area (Kumari *et al.*, 2016). The light intensity below the mango trees decreased with the increasing tree age, the decrease was more pronounced at a distance of 3 m from the trunk, 5 x 5 m (Ali *et al.*, 2018) to 10 × 10 m (Swain, 2014) recommended spacing. The changing light profile within the orchard due to the growing plant canopy influence the choice of intercrop to be grown at different ages (Das *et al.*, 2017).

For mango, selective intercrops have been recommended for adoption up to 8-10 years (Negi, 2000), or up to 15 years of age of mango plantation (Swain, 2014). *Solanum melongena* L. is a common intercrop (Singh *et al.*, 2011). On the other hand, leguminous intercrops were used for improved availability of soil nutrients caused by nitrogen fixation, reduction in soil and nutrients erosion, and incorporation and decomposition of intercrop residues in soil of the orchard (Pradhan *et al.*, 2018). Table 3 shows vegetables crops and fruit tree in *Mangifera indica* alley cropping.

Psidium guajava: Guava (*Psidium guajava*), an important fruit in tropical regions (Etemadipoor *et al.*, 2019), belongs to the family *Myrtaceae.* It grows on different soils and in both humid and dry climates (Hiwale, 2015), and is a small tree (Hoseinifar *et al.*, 2019). The inter-row space in guava orchards is underutilized in the early growing period, may be used for growning intercrops (Singh *et al.*, 2016). Intercropping with vegetables can fetch better returns besides generating more employment (Mitra, 2005). The plant starts bearing 3 years after planting and reach their maximum bearing capacity within 6-7 years after planting (5 x 5 planting recommended) (Bhatt *et al.*, 2016).

Selection of suitable intercrops in the guava orchard to improve the soil fertility status mainly depends upon the agro-climatic condition of the area where the crop is grown (Swain, 2016). Guava plants have responded well to especially tuber crops (Singh *et al.*, 2016). Table 3 shows other vegetables crops and fruit tree in *Psidium guajava* alley cropping.

***Citrus* spp.**: *Citrus* is a large genus that includes several major cultivated species, including *Citrus sinensis* (sweet orange), *C. reticulata* (tangerine and mandarin), *C. limon* (lemon), *C. grandis* (pummelo) and *C. paradisi* (grapefruit) (Xu *et al.*, 2013). The intercropping of perennial lemon with vegetables has enhanced the profitability in the irrigated areas (Dubey *et al.*, 2016), intercropping of legumes in citrus orchards is beneficial for the citrus production. Intercrop improves fruit production of the orchard as compared to non-intercropped orchard (Gill *et al.*, 2018). As intercrop, citrus (4 x 4 recommended spacing) (Vijaykumar *et al.*, 2018) provides income to the growers, controls weed population, checks soil erosion, conserves soil moisture and organic matter and protects the soil from leaching of nutrients (Hnamte *et al.*, 2013).

Leguminous crops and ginger is beneficial in terms of economic returns (Lachungpa, 2004); other authors recommended *Cucumis melo*, and *Brassica oleracea* (Dubey *et al.*, 2016), *Capsicum* spp., *Curcuma longa, Ocimum basilicum*, *Vigna unguiculata, Abelmoschus esculentus* and *Cucumis melo,* to be compatible with citrus intercrop (Aiyelaagbe, 2001). Table 3 shows other vegetables crops and fruit tree in *Citrus* alley cropping.

Further studies: Agroforestry seems to be a viable and

Table 3. Fruit tree and annual vegetable

Fruit tree	Annual vegetable	Reference
Citrus sp., *C. sinensis.*, *C. reticulata*	(1) *Legumes crops*, (2) *Cicer arietinum*, (3) *Coriandrum sativum, (4) Capsicum annum,* (5) *Fagopyrum esculentum,* (6) vegetables, (7) *Zingiber officinale*, (8) *Colocasia esculenta,* (9) *Manihot esculentam*, (10) *Solanum lycopersicum*, (11) *Solanum tuberosum.*	(1) (Blair *et al.*, 2016; Workman *et al.*, 2003), (2) (Goswami *et al.*, 2014a; Hnamte *et al.*, 2013; Jose *et al.*, 2008), (3) (Sureshbhai *et al.*, 2017), (4) (Bhatt and Misra, 2003; Bhoyar *et al.*, 2016; Goswami *et al.*, 2014a), (5) (Gogoi, 2015), (6) (García *et al.*, 2018; Jalón *et al.*, 2018; Verma *et al.*, 2017; Workman *et al.*, 2003), (7) (Tabin *et al.*, 2015), (8) (Goswami *et al.*, 2014b; Hnamte *et al.*, 2013), (9) (Goswami *et al.*, 2014a; Hnamte *et al.*, 2013), (10) (Goswami *et al.*, 2014a; Hnamte *et al.*, 2013), (11) (Goswami *et al.*, 2014a).
Mangifera indica	(1) *Capsicum annum, (*3) *Manihot esculenta,* (4) *Vitis* spp., (5) *Coriandrum sativum,* (6) *Brassica oleraceae,* (7) *Ipomea batatas,* (8) *Chrysopongon fulvus,* (9) *Heteropogon contortus,* (10*) Cenchrus* spp., (11) *Vigna* spp.,	(1) (Bhoyar *et al.*, 2016; Bhusara, 2014; Chaturvedi *et al.*, 2001), (3) (Harrison and Harrison, 2016), (4) (Kumar *et al.*, 2012), (5) (Sureshbhai *et al.*, 2017), (6) (Sureshbhai *et al.*, 2017), (7) (Chaturvedi *et al.*, 2001), (8) (Jha and Chaturdevi, 1995), (9) (Jha and Chaturdevi, 1995), (10) (Jha and Chaturdevi, 1995), (11) (Mirjha and Rana, 2016).
Prunus domestica., *P. armeniaca,* *P. pérsica,* *P. avium*	(1) *Pisum sativum,* (2) *Solanum lycopersicum,* (3) *Fragaria* sp., (4) *Zea mays (sweet corn),* (5) *Cucurbita* sp., (6) *Capsicum* sp., (8) *Vitis vinífera,* (9) vegetables, (10) *Cicer arietinum*, (11) *Brassica napus,* (12) *Vigna* sp.	(1) (Bhutia *et al.*, 2015; Jose *et al.*, 2008; Williams and Gordon, 1992), (2) (Jose *et al.*, 2008; Williams and Gordon, 1992), (3) (Jose *et al.*, 2008; Williams and Gordon, 1992), (4) (Blair *et al.*, 2016), (5) (Williams and Gordon, 1992), (6) (Juárez and Fragoso, 2014), (8) (Nerlich *et al.*, 2013), (9) (Tolunay *et al.*, 2007), (10) (Jose *et al.*, 2008), (11) (Nerlich *et al.*, 2013), (12) (Shah *et al.*, 2017) .
Artocarpus heterophyllus, A. altilis	(1) *Ananas comosus,* (2) *Manihot esculenta*, (3) *Ipomoea batatas,* (4) Vegetables	(1) (Gogoi, 2015; Harrison and Harrison, 2016; Hasan *et al.*, 2008), (2) (Harrison and Harrison, 2016), (3) (Chaturvedi *et al.*, 2001), (4) (Verma *et al.*, 2017).
Zizyphus mauritiana	(1) *Cyamopsis tetragonoloba*, (2) *Vigna* spp., (3) *Manihot esculenta*	(1) (Korwar and Pratibha, 2005; Meghwal and Henry, 2006; Sharma, 1996, 2014), (2) (Korwar and Pratibha, 2005; Sharma, 1996), (3) (Meghwal and Henry, 2006).
Malus spp.	(1) *Legumes crops,* (2) *Rubus* spp., (3) *Ribes nidigrolaria,* (4) *Fragaria* sp., (5) (*Zea mays*), (6) *Vigna* spp. *(7)* (Anjulo, 2009), *Cicer arietinum,* (8) *Solanum lycopersicum*	(1) (Blair *et al.*, 2016), (2) (Rivera *et al.*, 2004), (3) (Rivera *et al.*, 2004), (4) (Sereke *et al.*, 2014), (5) (Schroth *et al.*, 1995; Tolunay *et al.*, 2007), (6) (Verma *et al.*, 2017), (7) (Anjulo, 2009), (8) (Anjulo, 2009).
Sysigium spp.	(1) *Vigna* spp., (2) *Brassica nigra*	(1) (Chaturvedi *et al.*, 2001; Pareek and Awasthi, 2008), (2) (Rizvi *et al.*, 2011).
Psidium guajava	(1) *Vigna* spp., (2) *Capsicum* sp., (3) *Cyamopsis tetragonoloba*, (4) *Piper nigrum,* (5) *Vigna* spp., (6) *Curcuma longa,* (7) vegetables	(1) (Das *et al.*, 1993; Dhakar *et al.*, 2013; Krishnan, 2016; Sharma *et al.*, 2017; Yadav, 2017), (2) (Bhoyar *et al.*, 2016; Verma *et al.*, 2017), (3) (Meena, 2015), (4) (Gogoi, 2015)., (5) (Pareek and Awasthi, 2008; Sharma, 2011), (6) (Bhatt *et al.*, 2006; Hembram, 2014; Jain and Sharma, 2011), (7) *(Verma et al.*, 2017)
Musa sp.	(1) *Ipomoea batatas,* (2) *Manihot esculenta,* (3) *Vigna* sp., *Vigna radiata*, (4) *Colocasia esculenta* (5) *Zingiber officinale,* (6) *Curcuma longa,* (7) *Dolichos lablab,* (8) *Abelmoschus esculentus,* (9) *Ananas comosus,* (10) *Telfairia occidentalis,* (11) vegetables	(1) (Balasubramanian and Egli, 1986; Kanmegne and Degrande, 2002; Nedunchezhiyan *et al.*, 2012), (2) (Balasubramanian and Egli, 1986; Kanmegne and Degrande, 2002), (3) (Aiyelaagbe and Kintomo, 2002; Balasubramanian and Egli, 1986), (4) (Balasubramanian and Egli, 1986), (5) (Rahman *et al.*, 2012), (6) (Rahman *et al.*, 2012), (7) (Rahman *et al.*, 2012), (8) (Rahman *et al.*, 2012), (9) (Ranashinghe and Newman, 1993), (10) (Aiyelaagbe and Jolaoso, 1992), (11) (Verma *et al.*, 2017).
Pyrus sp., *Pyrus silvestris*	(1) *Pisum sativum,* (2) legumes, (3) *Vigna* spp., (4) *Manihot esculenta*, (5) *Solanum tuberosum*, (6) *Colocasia esculenta*, (7) *Capsicum annuum*, (8*) Zingiber officinale*, (9) *Solanum lycopersicum*	(1) (Jose *et al.*, 2008; Nerlich *et al.*, 2013), (2) (Nerlich *et al.*, 2013), (3) (Goswami *et al.*, 2014b), (4) (Goswami *et al.*, 2014b), (6) (Goswami *et al.*, 2014a), (7) (Goswami *et al.*, 2014a), (8) (Goswami *et al.*, 2014a), (9) (Goswami *et al.*, 2014a).
Morus alba	(1) *Cicer arietinum,* (2) *Solanum tuberosum,* (3) *Brassica oleracea,* (4) *Brassica nigra,* (5) *Solanum lycopersicum,* (6) *Capsicum* sp., (7) *Solanum tuberosum*	(1) (Asati *et al.*, 2007), (2) (Asati *et al.*, 2007), (3) (Asati *et al.*, 2007), (4) (Asati *et al.*, 2007), (5) (Asati *et al.*, 2007), (6) (Asati *et al.*, 2007), (7) (Benavides, 2002).
Cocos nucifera	(1) *Ipomoea batatas,* (2) *Piper nigrum*, (3) tuber crops, (4) *Capsicum* sp., (5) *Maranta arundinacea,* (6) *Ananas comosus,* (7) *Manihot esculenta*	(1) (Chaturvedi *et al.*, 2001; Nedunchezhiyan *et al.*, 2012), (2) (Gogoi, 2015; Kumar *et al.*, 2012), (3) (Bavappa, 1990a, 1990b) (4) (Bavappa, 1990a), (5) (Bavappa, 1990a), (6) (Peng *et al.*, 1999), (7) (Kumar, 2006)
Coffea arabica L.	(1) *Lycopersicum esculentum,* (2) *Vigna sesquipedalis,* (3) *Capsicum* sp. (4) *Passiflora edulis,* (5) *Ipomoea batatas*	(1) (Iijima *et al.*, 2003), (2) (Iijima *et al.*, 2003), (3) (Nuberg and Evans, 1993), (4) (Ranashinghe and Newman, 1993), (5) (Nedunchezhiyan *et al.*, 2012).
Carica papaya	(1) *Abelmoschus esculentus,* (2) *Citrullus lanatus,* (3) *Ipomoea batatas,* (4) *Solanum gilo,* (5) *Solanum lycopersicum*	(1) (Aiyelaagbe and Jolaoso, 1992), (2) (Aiyelaagbe and Jolaoso, 1992), (3) (Aiyelaagbe and Jolaoso, 1992), (4) (Aiyelaagbe and Jolaoso, 1992). (5) (Kumar *et al.*, 2000).

economically feasible solution for the farmers to meet the challenges of food, nutrition, energy, employment and environmental security (Verma *et al.*, 2017). Further studies should be carried out related to water use efficiency, biofertilizers, weed management, technical support, integration of fruit trees and vegetables of high commercial value, biological control, mechanized harvesting, integration of indigenous fruit trees and indigenous vegetables, carbon credits, birds, predators, bees, policies, credits, and subsidies to increase global food production and conserve the environment.

Discussion

The legumes have great potential for inclusion in horticulture (Zaki *et al.*, 2017) in various ways, for example, fix atmospheric nitrogen, nitrogen green manure, transform and increase the soil mineral N pool (Del Grosso *et al.*, 2006), reduce resilience on mineral forms of N fertilizer (Seran and Brintha, 2010), and reduce the environmental damage through NO_3 leaching and N_2O emission (Meena *et al.*, 2018). It is a natural mini-nitrogen manufacturing factory in the field and can play a vital role in increasing indigenous nitrogen production (Ghosh *et al.*, 2007), seven times faster compared to natural forests (Pavlidis and Tsihrintzis, 2018). Legume green manuring improves SOC, nutrient availability, physicochemical and biological properties of soil, and crop productivity (Meena *et al.*, 2018). It can help improving the soil physical environment, increasing soil microbial activity, restoring organic matter, and also has smothering effect on weed, and solubilizing insoluble P in soil (Hymavathi *et al.*, 2010) for bacterial phytase enzymes activity for release as free phosphorus over time (Blair *et al.*, 2016), so nitrogen and phosphorus efficiency is higher (Khan *et al.*, 2017).

The excessive application of chemical fertilizers has enormously increased (especially nitrogen), which has been designated as a severe environmental threat especially of air and groundwater pollution (Khan *et al.*, 2017). Among the pollutants, nitrates, and phosphoric compounds from agricultural activities are the most common and hazardous to environment and human health (Pavlidis and Tsihrintzis, 2018). Alley cropping is a strategic tool for food and wood production and environment protection. Legume tree offers advantages to the horticultural crops, and mitigates challenges mainly related to the growing population, climate changes and loss of biodiversity (Ribeiro *et al.*, 2018).

Smallholder farmers are inclined to intercrop young timber trees with well-fertilized annuals to confer nutrient and weeding benefits to the trees while gaining a short-term return on the land (Nissen and Midmore, 2002). Recommended principles for designing the cropping system based on this approach include: selecting species for complementary functional traits, developing complex trophic levels, and reproducing ecological succession (Lovell *et al.*, 2017; Malézieux, 2012). Agroforestry systems can be significant sink of atmospheric carbon (C) due to their fast growth and high productivity (Tiwari *et al.*, 2017). Under the Kyoto Protocol's Article 3.3, A&R (afforestation and reforestation) with agroforestry as a part has been recognized as an option for mitigating greenhouse gases (Sureshbhai *et al.*, 2017), and the potential of C sequestration is dependent on the tree component (Nair *et al.*, 2009; Sureshbhai *et al.*, 2017).

The selection of fruit and vegetable species must be prioritized for regional economic potential and specific interactions between crops (Lovell *et al.*, 2017). The success towards ecologically and economically sound agroforestry systems lies in identification of compatible tree-crop units under varying spatial arrangements and limited solar energy available underneath (Thakur *et al.*, 2018). Satisfactory growth and yields of both woody and crop plants can be achieved in the microenvironment of the agroforestry land-use system that is established, a microenvironment that varies considerably with time (Lin *et al.*, 1998).

The modification in microclimate is one of the important features of agroforestry (Kumar *et al.*, 2018). Alley cropping provides climate change adaptation potential and ecological benefits by buffering alley crops to weather extremes, diversifying income to hedge financial risk, increasing biodiversity, reducing soil erosion, and improving nutrient and water use efficiency (Wolz and DeLucia, 2018). It has potential to address the problems of food insecurity especially in developing countries and conservation of natural resources (Gunaga, 2017), reducing vulnerability, increasing resilience of farming systems and buffering households against climate-related risk in addition to providing livelihood security (Sureshbhai *et al.*, 2017).

Trees can maintain the stability of internal microclimates, and are strong assets for extreme weather adaption (Wu *et al.*, 2016). The presence of trees modifies site microclimate in terms of temperature, water vapor content or partial pressure, and wind speed, among other factors, and, temperature reductions can help reduce heat stress of associated crops (Jose *et al.*, 2004). Temperature reductions in the alleys can help to reduce heat stress of crops by lowering rates of foliar evapo-transpiration and soil evaporation (Jose *et al.*, 2008). In vegetable crops, photosynthetically active radiation and temperature are reduced, while the humidity is increased (Chauhan, 2016; Sangwan *et al.*, 2017), water use efficiency and carboxylation efficiency under shade conditions are essential factors (Sangwan *et al.*, 2015).

Appropriate selection of tree and vegetable combination promises the success of plantation. *Mangifera indica, Psidium guajava, Citrus* spp., *Leucaena* spp., *Gliricidia sepium, Cajanus cajan, Populus* spp., *Eucalyptus,* and *Hevea brasiliensis,* are the main tree used. *Fabaceae, Brassicaceae, Solanaceae* families and tuber crops are the main associated vegetable crops.

Climate change and its variability pose significant challenges influencing the performance of horticulture crops. The extreme weather events of hot and cold wave conditions have been reported to cause considerable damage to many fruit crops. The various impacts need to be addressed in concerted and systematic manner in order to prepare the horticulture sector to face the imminent challenges (Malhotra, 2017). Diversifying nature of alley cropping allows farmers to make the best use of their land by maximizing the crop yields as well as diversify income, and help in increasing resilience to global threat of climate change (Gunaga, 2017).

References

Abd-allah, M., L. El-Juhany and F. Hassan, 1999. Growth and mineral content of a woody legume trees (*Leucaena leucocephala*) and two citrus species in mixed culture. *Proc. Third Symp. Biol. Nitrogen Fixat. Mediterr. Basin.* November 21-25, 1999. El-Arish, North Sinai Governorate, Egypt.

Abugre, S. and K. Twum, 2011. Using *Cajanus Cajan* in biomass transfer technology to increase yield of tomato (*Lycopersicon esculentum*). *J. Sci. Technol.,* 31: 1-10.

Adekunle, O.K. 2009. Population dynamics of *Meloidogyne incognita* and three other phytonematodes on okra cultivars planted in alleys of *Leucaena leucocephala* and *Gliricidia sepium*. *Plant Pathol.,* 38: 211-215.

Adinya, I., S. Afu and J. Ijoma, 2010. Economic meltdown and decline in pineapple production: Determinants of production inefficiency of pineapple-based alley cropping practices in Cross River State. *J. Anim. Plant Sci.*, 20: 107-116.

Aiyelaagbe, I.O. and A. Kintomo, 2002. Nitrogen response of fluted pumpkin (*Telfairia occidentalis*) grown sole or intercropped with banana. *Nutr. Cycl. Agroecosystems,* 64: 231-235.

Aiyelaagbe, I.O. and M.A. Jolaoso, 1992. Growth and yield response of papaya to intercropping with vegetable crops in southwestern Nigeria. *Agrofor. Syst.*, 19: 1-14.

Aiyelaagbe, I.O. 2001. Productivity of an intercropped sweet orange orchard in southwestern Nigeria. *Biol. Agr. & Hort.* 18: 317-325.

Akbulut, S., A. Keten and W.T. Stamps, 2003. Effect of alley cropping on crops and arthropod diversity in Duzce, Turkey. *J. Agron. Crop Sci.,* 189: 261-269.

Akinnifesi, F., B. Kang and D. Ladipo, 1998. Structural root form and fine root distribution of some woody species evaluated for agroforestry systems. *Agrofor. Syst.*, 42: 121-138.

Akondé, T., N. Steinmüller and D. Leihner, 1997. Alley cropping on an Ultisol in subhumid Benin Part 3: nutrient budget of maize, cassava and trees. *Agrofor. Syst.*, 37: 213-226.

Ali, M.M., M.M. Rahman, S. Islam, M.A. Islam, M.R. Alam, M.S Bari and M.N. Nahar, 2018. Varietal performance of turmeric under mango based agroforestry system. *J. Plant Sci.,* 9: 995-997.

Alves, S.M., A.C. de Souza, R.D. Ribeiro and D.L. de Almeida, 2004. Balanço do nitrogênio e fósforo em solo com cultivo orgânico de hortaliças após a incorporação de biomassa de guandu. *Pesqui. Agropecu. Bras.*, 39: 1111-1117.

Amara, D.S., N. Sanginga, S.K. Danso and D.S. Suale, 1996. Nitrogen contribution by multipurpose trees to rice and cowpea in an alley cropping system in Sierra Leone. *Agrofor. Syst.,* 34, 119-128.

Anand, R., N. Khare, S. Dwivedi, M. Singh and R. Umrao, 2016. Studies on adoption of traditional agroforestry among the farmers in district Sonbhadra, Uttar Pradesh. *Indian For.,* 142: 144-150.

Anjulo, A. 2009. *Component Interactions and Their Influence on the Production of Apple Based Agroforestry System in Wet Temperate Zone of Himachal Himalayas*. Ph.D. Diss., Parmar University of Horticulture & Forestry. 2009. 100 pp.

Asati, B., J. Tomar and P. Asati, 2007. Agrihorticulture develoment in north eastern region. *Himal. Ecol.,* 15: 22-30.

Atayese, M., O. Awotoye, O. Osonubi and K. Mulongoy, 1993. Comparisons of the influence of vesicular-arbuscular mycorrhiza on the productivity of hedgerow woody legumes and cassava at the top and the base of a hillslope in alley cropping systems. *Biol. Fertil. Soils,* 16: 198-204.

Atta-Krah, A. 1990. Alley farming with *Leucaena*: effect of short grazed fallows on soil fertility and crop yields. *Exp. Agric.,* 26: 1-10.

Balasubramanian, V. and A. Egli, 1986. The role of agroforestry in the farming systems in Rwanda with special reference to the Bugesera-Gisaka-Migongo (BGM) region. *Agrofor. Syst.*, 4: 271-289.

Balasubramanian, V. and L. Sekayange, 1991. Effects of tree legumes in hedgerows on soil fertility changes and crop performance in the semi-arid highlands of Rwanda. *Biol. Agr. & Hort.,* 8: 17-32.

Barreto, A. and M. Fernandes, 2001. Cultivo de *Gliricidia sepium* e *Leucaena leucocephala* em alamedas visando a melhoria dos solos dos tabuleiros costeiros. *Pesqui. Agropecu. Bras.,* 36: 1287-1293.

Bavappa, K.V., 1990a. Agronomic desirability of coconut based farming systems. Proc. Coconut based farming systems. Asian Pacific Coconut Community. p. 57-67.

Bavappa, K.V., 1990b. An up to date research profile on coconut based farming systems. Proc. of XXVII COCOTECH Meeting on Coconut Based Farming Systems. Asian and Pacific Coconut Community, Jakarta, Indonesia. p. 90.

Bayard, B., C. Jolly and D. Shannon, 2007. The economics of adoption and management of alley cropping in Haiti. *J. Environ. Manag.,* 84: 62-70.

Behera, S., A.K. Mahapatra, P.J. Mishra, S. Pattanayak and D. Panda, 2016. Performance of bamboo based agri-silvicultural systems in north Odisha, India. *Int. J. Bio-Resource Stress Manag.,* 7: 218-221.

Bellow, J., P.K. Nair, and T.A. Martin, 2008. Tree-crop interactions in fruit tree-based agroforestry systems in the western highlands of Guatemala. p.111-131. In: *Toward Agroforestry Design.* Jose S. and A.M. Gordon (Eds.). Springer, Dordrecht.

Benavides, J.E., 2002. Utilization of mulberry in animal production systems, Mulberry for animal production. Proc. FAO Animal Production and Health Paper. FAO, Rome.

Bhatt, B., B. Parmar, L.J. Bordoloi and B. Bhattacharyya, 2016. Impact of agroforestry systems on soil and nutrient conservation in the eastern Himalayas, India*. Int. J. Bio-resource Stress Manag.,* 7: 575-581.

Bhatt, B., M. Sachan and K. Singh, 2006. Production potential of traditional agroforestry systems of Meghalaya: a case study. p. 337-349. In: A*groforestry in northeast India*: *oportunities and challengues.* Bhatt B.P. and K.M. Bujarbaruah (eds.). ICAR Research Complex for NEH Region, India.

Bhatt, B.P. and L.K. Misra, 2003. Production potential and cost-benefit analysis of agrihorticulture agroforestry systems in northeast India. *J. Sustain. Agric.,* 22: 99-108.

Bhoyar, S., H. Deshmukh, R. Mahajan, N. Sharma, B. Bohra and D.N. Nalgel, 2016. Traditional agroforestry systems practiced in lower hills of Melghat region, Chikhaldara tehsil, Maharashtra, India. *Bioved*, 27: 131-140.

Bhusara, J. 2014. *Productivity and carbon Sequestration under Prevalent Agroforestry Systems in the Valsad District.* Ph.D. Thesis. Aspee College Of Horticulture And Forestry, Navsari Agricultural University, Navsari, 4-110 pp.

Bhusara, J.B., M.J. Dobriyal, N.S. Thakur, R.L. Sondarva and D.H. Prajapati, 2018. Growth and yield performance of green gram under *Melia composita* plantations. *J. Pharmacogn. Phytochem*., 7: 1490-1494.

Bhushan, A. and N. Khare, 2018. Effect of organic manure and spacing on the growth and yield performance of baby corn under poplar based agroforestry system. *Int. J. Curr. Microbiol. App. Sci.,* 7: 3015-3019.

Bhutia, P.L., C.L. Thakur, S. Sarvade, D.R. Bhardwaj, R. Kaushal and K.G. Bhutia, 2015. Varietal performance of pea (*Pisum sativum*) under peach based agroforestry system in mid hill conditions of Himachal Pradesh. *Indian J. Agrofor.,* 17: 14-17.

Bijalwan, A. 2012. Land-use and vegetation pattern in traditional agroforestry systems in mid-hills of Garhwal Himalaya. *J. Progress. Agric.,* 3: 6-13.

Blair, W., X. Wu, D. Bhandari, X. Zhang, J. Hao, B. Devendra, X. Zhang and H. Junjie, 2016. Role of legumes for and as horticultural crops in sustainable agriculture. In: *Org. Farming Sustain. Agric*. Nandwani D. (ed.). Springer, Cham. p. 185-211.

Böhringer, A. and D.E. Leihner, 1996. A comparison of alley cropping and block planting systems in sub-humid Bénin. *Agrofor. Syst.*, 35: 117-130.

Brook, R. 1992. Early results from an alley cropping experiment in the humid lowlands of Papua New Guinea. *Nitrogen Fixing Tree Rpt.*, 10: 73-79.

Budelman, A. 1990. Woody legumes as live support systems in yam cultivation. *Agrofor. Syst*., 10: 47-59.

Budelman, A. and E. Pinners, 1987. The value of *Cassia siamea* and *Gliricidia sepium* as “insitu” support systems in yam cultivation: Experiences from a farm-based trial. Proc. International Workshop *Gliricidia sepium* (Jacq.) Walp.: Management and Improvement. Iturrialba, Costa Rica, pp. 90-91.

Burgess, P.J., L.D. Incoll, D.T. Corry, A. Beaton and B.J. Hart, 2005. Poplar (*Populus* spp.) growth and crop yields in a silvoarable experiment at three lowland sites in England. *Agrofor. Syst*., 63: 157-169.

Chaturvedi, O., D. Das and A. Jha, 2001. Household fuel situation and agroforestry in north Bihar, plains a diagnostic. *Range Manag. Agrofor.,* 22: 94-105.

Chaturvedi, O.P., J.C. Dagar, A.K. Handa, R. Kaushal and V.C. Pandey, 2018. Agroforestry Potential for Higher Productivity from Degraded Ravine Watersheds. In: *Ravine Lands*: *Greening for Livelihood and Environmental Security.* Dagar J. and Singh A. (eds.). Springer Singapore, Singapore. pp. 335-360.

Chauhan, D., A. Desai and S. Dhyani, 1993. Sustainable silvi-horti-pastoral system for Meghalaya. *Indian J. Hill Farming*, 6: 109-112.

Chauhan, K., 2016. *Effect of tree leaf mulch on pearl millet (Pennisetum glaucum L.) in guava (Psidium guajava L.) based agri-horti system in Vindhyan.* M.Sc. Thesis. Agroforestry, Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi. 100 pp.

Chauhan, S.K., W.S. Dhillon, N. Singh and R. Sharma, 2013. Physiological behaviour and yield evaluation of agronomic crops under agri-horti-silviculture system. *Int. J. Plant Res.*, 3: 1-8.

Chen, W.J., X. Wang, S. Yan, X. Huang and H.M. Yuan, 2019. The ICE-like transcription factor HbICE2 is involved in jasmonate-regulated cold tolerance in the rubber tree (*Hevea brasiliensis*). *Plant Cell Rep.*, 38: 699-714.

Christanty, L., J.P. Kimmins and D. Mailly, 1997. Without bamboo, the land dies: a conceptual model of the biogeochemical role of bamboo in an Indonesian agroforestry system. *For. Ecol. Manag.,* 91: 83-91.

Dalal, V., N. Kaushik, K. Bhardwaj, K. Rajesh and M. Suleman, 2015. Soil properties under different agri-silvi-horticultural systems in coarse textured soils of north-west India. *Ann. Biol.*, 31: 257-260.

Das, B., M. Dhakar, P. Sarkar and S. Kumar, 2017. Performance of mango (*Mangifera indica*) based agri-horticultural systems under rainfed plateau conditions of eastern India. *Indian J. Agric. Sci.*, 87: 521-527.

Das, S.K., S. Sharma, K.L. Sharma, N. Saharan, N.N. Nimbole and Y.V. Reddy, 1993. Land use options on a semi-arid Alfisol. *Am. J. Altern. Agric.*, 8: 34-39.

de Paula, P., E. Campello and J. Guerra, 2015. Decomposição das podas das leguminosas arbóreas *Gliricidia sepium* e *Acacia angustissima* em um sistema agroflorestal. *Cienc. For.*, 25: 791-800.

Deb, J.C., S. Phinn, N. Butt and C.A. McAlpine, 2017. Climatic-induced shifts in the distribution of teak (*Tectona grandis*) in tropical Asia: Implications for forest management and planning. *Environ. Manage.,* 60: 422-435.

Del Grosso, S.J., W.J. Parton, A.R. Mosier, M.K. Walsh, D.S. Ojima and P.E.Thornton, 2006. Daycent National-Scale Simulations of Nitrous Oxide Emissions from Cropped Soils in the United States. *J. Environ. Qual.,* 35: 1451-1455.

Devender, C., A. Afzal and J.N. Bhatia, 2012. Assessment of agroforestry based two-tier-cropping system in Ambala district of Haryana. *Agric. Updat.*, 7: 210-213.

Dhakar, M.K., B.B. Sharma, K. Prajapat and K.P. Kheti, 2013. Fruit crop-based cropping system: a key for sustainable production. *Pop. Kheti*, 1: 39-45.

Dhewa, J. and S. Daniel, 2017. Effect of different levels of phosphorus and sulphur on yield and quality of green gram (*Vigna radiata* L.) under teak (*Tectona grandis* L.) based agroforestry system. *Int. J. Farm Sci.,* 7: 1799-1802.

Dhillon, W.S., S.K. Chauhan, N. Jabeen, C. Singh and N. Singh, 2012. Growth performance of intercropping system components and nutrient status of soil under horti-silvicultural system. *Int. J. Environ. Resour.,* 1: 31-38.

Dhillon, W.S., S.K. Chohan, N. Singh, C.S Rattan and D. Singh, 2010. Pre-bearing behaviour of some fruit crops under horti-silviculture system. *Indian J. Hort.*, 67: 311-314.

Dhyani, S.K. and A.K. Handa, 2013. Agroforestry in India and its Potential for Ecosystem Services. In: *Agroforestry Systems in India*: *Livelihood Security & Ecosystem Services. Advances in Agroforestry.* Dagar J., A. Singh and A. Arunachalam (eds.). Springer, New Delhi. p. 345-365.

Dubey, S.K., N. Sharma, J.P. Sharma, A. Sharma and N. Kishore, 2016. Assessing citrus (lemon) based intercropping in the irrigated areas of northern plains of Haryana. *Indian J. Hort.,* 73: 441-444.

Duguma, B., B.T. Kang and D.U. Okali, 1988. Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an alfisol. *Agrofor. Syst.,* 6: 19-35.

Dyal, S., S. Grewal and S. Singh, 1996. An agri-silvi-horticultural system to optimize production and cash returns for Shivalik foothills. *Indian J. Soil Conserv.,* 24: 150-155.

Ernst, S., 1994. *Potential of alley cropping maize and cassava in south Benin*: *West Africa*: *evaluation of the establishing-phase.* Verlag Ukrich E. Grauer. Germany.

Escaño, C. and S. Tababa, 1998. *Fruit Production and the Management af Slopelands in the Philippines.* Forestry and Natural Resources Research and Development, Paseo del Valmayor, Los Baños, Philippines.

Etemadipoor, R., A. Ramezanian, A. Mirzaalian and M. Shamili, 2019. The potential of gum arabic enriched with cinnamon essential oil for improving the qualitative characteristics and storability of guava (*Psidium guajava*) fruit. *Sci. Hort.,* 251: 101-107.

Evensen, C.I., T.S. Dierolf and R.S. Yost, 1995. Decreasing rice and cowpea yields in alley cropping on a highly weathered oxisol in west Sumatra, Indonesia. *Agrofor. Syst.*, 31: 1-19.

Fagbola, O., O. Osonubi and K. Mulongoy, 1998. Growth of cassava cultivar TMS 30572 as affected by alley-cropping and mycorrhizal inoculation. *Biol. Fertil. Soils*, 27: 9-14.

Fagbola, O, O. Osonubi and K. Mulongoy, 1998. Contribution of arbuscular mycorrhizal (AM) fungi and hedgerow trees to the yield and nutrient uptake of cassava in an alley-cropping system. *J. Agric. Sci.,* 131: 79-85.

Fanish, S. and Priya, 2013. Review on benefits of agro forestry system. *Int. J. Educ. Res.*, 1: 1-12.

Firoz, Z., K. Nasiruddin and M. Mondal, 2012. Effect of different hedgerow species and nitrogen level on the soil properties and yield of okra (*Abelmoschus esculentus* L.). *Bangladesh J. Agric. Res.*, 37: 159-169.

Fujita, K., Y. Kai, M. Takayanagi, H. El-Shemy, J.J. Adu-Gyamfi and P.K. Mohapatra, 2004. Genotypic variability of pigeonpea in distribution of photosynthetic carbon at low phosphorus level. *Plant Sci.,* 166: 641-649.

García, S., P.J. Burgess, A. Graves, G. Moreno, J. McAdam, E. Pottier, S. Novak, V. Bondesan, R. Mosquera, J. Crous, J.H. Palma, J.A. Paulo, T.S. Oliveira, E. Cirou, Y. Hannachi, A. Pantera, R. Wartelle, S. Kay, N. Malignier, P. Van Lerberghe, P. Tsonkova, J. Mirck, M. Rois, A.G. Kongsted, C. Thenail, B. Luske, S. Berg, M. Gosme and A. Vityi, 2018. How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders. *Agrofor. Syst.*, 92: 829-848.

Ghimire, T. 2010. *Effect of fertility levels on mustard (Brassica juncea) productivity under varying poplar tree densities.* Ph.D. Thesis. Govind Ballabh Pant University of Agriculture and Technology. 344 pp.

Ghosh, P.K., K.K. Bandyopadhyay, R.H. Wanjari, M.C. Manna, A.K. Misra, M. Mohanty and A.S. Rao, 2007. Legume effect for enhancing productivity and nutrient use-efficiency in major cropping systems, an Indian perspective: A Review. *J. Sustain. Agric.*, 30: 59-86.

Ghuman, B.S., R. Lal and W. Shearer, 1991. Land clearing and use in the humid Nigerian tropics: 1. Soil physical properties. *Soil Sci. Soc. Am. J.,* 55: 178-183.

Gichuru, M.P. and B.T. Kang, 1989. *Calliandra calothyrsus* in an alley cropping system with sequentially cropped maize and cowpea in southwestern Nigeria. *Agrofor. Syst*., 9: 191-203.

Gill, M.S., S. Khehra and N. Gupta, 2018. Impact of intercropping on yield, fruit quality and economics of young kinnow mandarin plants. *Appl. Nat. Sci.*, 10: 954-957.

Gogoi, B., 2015. Soil productivity management and socio-economic development through agroforestry in north-east India. *Asian J. Sci. Technol.*, 6: 2048-2053.

Goswami, S., K.S. Verma and R. Kaushal, 2014a. Biomass and carbon sequestration in different agroforestry systems of a Western Himalayan watershed. *Biol. Agric. Hort.*, 30: 88-96.

Goswami, S., K.S. Verma and R. Kaushal, 2014b. Impact of component variability on biomass production and soil organic carbon in traditional agroforestry systems. *Biol. Agric. Hort.,* 143: 550-556.

Gunaga, R. 2017. Crop biomass and yield patterns of dominant agroforestry systems of Navsari district, Gujarat, India. *Indian J. Agrofor.*, 19: 72-78.

Gupta, R.D., and S. Arora, 2015. Agroforestry as Alternate Landuse System for Sustaining Rural Livelihoods in Himalayan Ecosystem. In: *Adv. Soil Water Resour. Manag. Food Livelihood Secur. Chang. Clim*. S. Bhan and S. Arora (eds.). Soil Conservation Society of India, New Delhi.

Hanada, T. 1990. Cultivation of temperate vegetables in the tropics. *Trop. Agric. Res. Ser.*, 23: 182-191.

Handa, A. and R. Newaj, 2017. Agroforestry systems and technologies for different agro-climatic regions of India. In: *Forestry Technologies - A Complete Value Chain Approach*. K. T. Parthiban (ed.). India. 177-193 pp.

Harrison, S. and R. Harrison, 2016. Financial modelling of mixed-species agroforestry systems in Fiji and Vanuatu, based on traditional tree species. 110-125 pp. In: *Smallscale and Community Forestry and the Changing Nature of Forest Landscapes.* Sunshine Coast, Australia.

Harun-Ur, R., H. Iwasaki, S. Parveen, S. Oogai, M. Fukuta, M.A. Hossain, T. Anai and H. Oku, 2018. Cytosolic cysteine synthase switch cysteine and mimosine production in *Leucaena leucocephala*. *Appl. Biochem. Biotechnol.,* 186: 613-632.

Hasan, M.K., M.M. Ahmed and M.G. Miah, 2008. Agro-economic performance of jackfruit-pineapple agroforestry system in madhupur tract. *Agric. Rural Dev.*, 6: 147-156.

He, S., Z.W. Luo, M. Hua, X.H. Wang, X.H. Li, F. He and H.Y. Fan, 2012. Study on young rubber/Tainong NO. 16 pineapple intercropping pattern. *Guangdong Agric. Sci.*, 13: 16-24.

Hembram, J., 2014. *Production potential of turmeric under different cultural practices in guava based agrihorticulture practice of agroforestry.* Ph.D. Thesis. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur College of Agriculture Jabalpur (MP). 119 pp.

Hiwale, S., 2015. Guava (*Psidium guajava*). pp. 213-224. In: *Sustainable Horticulture in Semiarid Dry Lands.*, New Delhi, Springer India.

Hnamte, V., B. Gopichand and F. Lalnunmawia, 2013. Study on economic feasibility of intercropping of lemon (*Citrus limon*) with vegetables in the hilly terrain of Mizoram. *Sci. Vision,* 13: 40-44.

Honda, M.D., K.L. Ishihara, D.T. Pham and D. Borthakur, 2019. Highly expressed genes in the foliage of giant leucaena (*Leucaena leucocephala* subsp. *glabrata*), a nutritious fodder legume in the tropics. *Plant Biol.,* 1-10.

Hoseinifar, S.H., A. Sohrabi, H. Paknejad, V. Jafari, M. Paolucci and H. Van Doan, 2019. Enrichment of common carp (*Cyprinus carpio*) fingerlings diet with *Psidium guajava*: The effects on cutaneous mucosal and serum immune parameters and immune related genes expression. *Fish Shellfish Immunol.*, 86: 688-694.

Hulugalle, N. and B. Kang, 1990. Effect of hedgerow species in alley cropping systems on surface soil physical properties of an Oxic Paleustalf in south-western Nigeria. *J. Agric. Sci.*, 114: 301-307.

Hy, N., N. Dang, P. Van Bien, T. Dung, N. Cach and T. Phien, 2002. Cassava agronomy research in Vietnam. Proc. 7th Regional Workshop, held in Bangkok, Thailand. p. 204-211.

Hymavathi, H., A. Kandya and L. Patel, 2010. Beneficial effects of multiple plantation patterns in agroforestry systems. *Indian For.,* 136: 465-475.

Iijima, M., Y. Izumi, E. Yuliadi, A. Sunyoto and M. Utomo, 2003. Erosion control on a steep sloped coffee field in Indonesia with alley cropping, intercropped vegetables, and no-tillage. *Plant Prod. Sci.*, 6: 224-229.

Insaidoo, T. and S. Quarshie, 2007. Evaluation of the effect of hedgerow intercropping using *Leucaena leucocephala* and fertilizer application on growth and yield of garden eggs (*Solanum melongena*). *J. Sci. Technol.* 27: 62-70.

Isaac, L., C.W. Wood and D.A. Shannon, 2003. Pruning management effects on soil carbon and nitrogen in contour-hedgerow cropping with *Leucaena leucocephala* on sloping land in Haiti. *Nutr. Cycl. Agroecosystems*, 65: 253-263.

Jain, K.K. and H.L. Sharma, 2011. Growth characters of turmeric under guava based agri-horticulture system: An exploratory study. *J. Trop. For.,* 27: 12-16.

Jakhar, P., B.S. Naik, D. Barman, H.C.H. Gowda, A. Dass, S. Sudhishri and K.P. Gore, 2010. Evaluation of conservation potential of multitier cropping systems in Eastern Ghat highland zone of Orissa. *Indian J. Soil Conserv.,* 38: 188-193.

Jalón, S.G., A. Graves, J.H. Palma, M. Upson, A. Williams and P. Burgess, 2018. Modelling and valuing the environmental impacts of arable, forestry and agroforestry systems: a case study. *Agrofor. Syst.,* 92: 1059-1073.

Jessy, M.D., P. Joseph and S. George, 2017. Possibilities of diverse rubber based agroforestry systems for smallholdings in India. *Agrofor. Syst.,* 91: 515-526.

Jha, A. and O. Chaturdevi, 1995. Biomass of *Leucaena leucocephala* and the yield of intercrops under alley cropping. *Int. Tree Crop. J.*, 8: 177-181.

Jiang, Y. and G. Qin, 2007. Effect of tree-crop intercropping on a young *Populus tomentosa* plantation. *Front. For. China,* 2: 174-178.

Jose, S., S. Allen and P. Nair, 2008. Tree-crop interactions: lessons from temperate alley-cropping systems. pp. 15-36. In: *Ecological Basis of Agroforestry*. Rani, D., R. Kumar, S. Jose and H. Singh (Eds.), Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL, U.S.A.

Jose, S., A.R. Gillespie and S.G. Pallardy, 2004. Interspecific interactions in temperate agroforestry. *Agrofor. Syst.*, 61: 237-255.

Juárez, D. and C. Fragoso, 2014. Comunidades de lombrices de tierra en sistemas agroforestales intercalados, en dos regiones del centro de México. *Acta zoológica Mex.,* 30: 637-654.

Kaba, J.S., S. Zerbe, M. Agnolucci, F. Scandellari, A.A. Abunyew, M. Giovannett and M. Tagliavini, 2019. Atmospheric nitrogen fixation by gliricidia trees (*Gliricidia sepium*) intercropped with cocoa (*Theobroma cacao*). *Plant Soil*, 435: 323-336.

Kang, B.T. 1993. Alley cropping: past achievements and future directions. *Agrofor. Syst.*, 23: 141-155.

Kang, B.T., H. Grimme and T.L. Lawson, 1985. Alley cropping sequentially cropped maize and cowpea with *Leucaena* on a sandy soil in Southern Nigeria. *Plant Soil*, 85: 267-277.

Kanmegne, J. and A. Degrande, 2002. From alley cropping to rotational fallow: Farmers' involvement in the development of fallow management techniques in the humid forest zone of Cameroon. *Agrofor. Syst.*, 54: 115-120.

Kass, D., 1987. Alley cropping of annual food crops with woody legumes in Costa Rica. P*roc. Advances in Agroforestry Research*, *CATIE*. 197-208.

Kass, D. L., J. S. Araya, J. O. Sanchez, L.S. Pinto and P. Ferreira, 1992. Ten years experience with alley farming in Central America. *Plant and Soil*, 63: 165-179.

Kaushik, N. and V. Kumar, 2003. Khejri (*Prosopis cineraria*)-based agroforestry system for arid Haryana, India. *J. Arid Enviroments,* 55: 433-440.

Kaushik, N., A. Tikkoo, P.K. Yadav, R.P. Deswal and S. Singh, 2017. Agri-Silvi-Horti Systems for Semiarid Regions of North-West India. *Agric. Res.,* 6: 150-158.

Khan, A.A., M. Sajid, A. Iqbal, Z.H. Khan, B. Islam, F. Ali, K. Ali, A. Ahmed, M. Sajjad, M. Arif, W. Ali and F. Shah, 2017. Improving yield and mineral profile of tomato through changing crop micro-environment. *Fresenius Environ. Bull.*, 26: 4911-4918.

Khaunkuab, N., S. Suvannalert, R. Chotiphan, L. Namphech, J. Sinphai and J. Chaiburi, 2008. Study on intercropping system between turmeric (*Curcuma longa*) in para rubber and fruit plantation on upper southern area. Proc. Asetsart University Annual Conference, Bangkok (Thailand).

Korwar, G.R. and G. Pratibha, 2005. Existing and improved agroforestry systems in low rainfall areas of India. Proc. Sustain. Agric. Syst. Drylands. Niamey, Niger. p. 3-16.

Krishnan, T. 2016. *Effect of inorganic and organic fertilizer on growth and yeild of green gram (Vigna radiata) under guava (Psidium guajava) based agri-horti system*. M.Sc. Thesis. Banaras Hindu University, Varanasi. 3-93 pp.

Kumar, B., 2006. Agroforestry : the new old paradigm for Asian food security. *J. Trop. Agric.,* 44: 1-14.

Kumar, B., A. Kumar and S.K. Dhyani, 2012. South Asian Agroforestry: Traditions, Transformations, and Prospects. In: *Agroforestry-The Future of Global Land Use.* Nair P. and D. Garrity (eds). Springer, Dordrecht. p. 359-389.

Kumar, D., V. Pandey and V. Nath, 2008. Effect of organic mulches on moisture conservation for rainfed turmeric production in mango orchard. *Indian J. Soil Conserv.,* 36: 188-191.

Kumar, M., S. Kumar, A. Uthappa and S. Kalappurakkal, 2018. Influence of *Prosopis cineraria* on microclimate conditions under agroforestry system in arid region of India. *Indian J. of Agroforestry,* 20: 35-39.

Kumar, M., N.S. Thakur, K. Bardhan and J.B. Bhusara, 2017. Effect of teak (*Tectona grandis*)-*Ocimum* spp. based silvi-medicinal systems on growth and physiological parameters of *Ocimum* spp. *International Journal of Farm Sciences*, 7: 8-14.

Kumar, M., N.S. Thakur and H.T. Hegde, 2015. Growth, herb yield and financial flows from *Ocimum* spp. intercropped under teak (*Tectona grandis*)-*Ocimum* spp. based silvi-medicinal system in Gujarat, India. *Int. J. Innov. Hort.*, 4: 113-118.

Kumar, P., P. Dwivedi and A. Hemantaranjan, 2016. Physiological and biochemical properties of *Gliricidia*: its cultivation a scope for remunerative venture for farmers. In: *Plant Stress Tolerance Physiological & Molecular Strategies.* A Hemantaranjan (ed). Banaras Hindu University, India. Scientific Publishers. p. 359-365.

Kumar, S., V. Swaminathan and S. Sathiamoorthy, 2000. Effect of spacing, nutrition and intercrops on yield and quality of papaya (*Carica papaya*). *Res. Crop.*, 1: 58-62.

Kumari, S., S. Kavita and R. Kumar, 2016. Yield and profitability of vegetable based intercrops in mango mother plant orchard. *Adv. Life Sci.,* 5: 2278-3849.

Kuntashula, E., P.L. Mafongoya, G. Sileshi and S. Lungu, 2004. Potential of biomass transfer technologies in sustaining vegetable production in the wetlands (DAMBOS) of eastern Zambia. *Exp. Agric.,* 40: 37-51.

Lachungpa, K., 2004. Intercropping of agri/horti crops with special reference to mandarin (*Citrus reticulata*) in Sikkim (India). Proc. Australian Agronomy Conference.

Lakaria, B.L., M.K. Patne, P. Jha and A.K. Biswas, 2012. Soil organic carbon pools and indices under different land use systems in vertisols of central India. *J. Indian Soc. Soil Sci.,* 60: 125-131.

Lal, R. 1989. Potential of agroforestry as a sustainable alternative to shifting cultivation: concluding remarks. *Agrofor. Syst.,* 8: 239-242.

Lasco, R.D., R.F. Sales, R. Estrella, S.R. Saplaco, A.S. Castillo, R.V. Cruz and F.B. Pulhin, 2001. Carbon stock assessment of two agroforestry systems in a tropical forest reserve in the Philippines. *Philipp. Agric. Sci.,* 84: 401-407.

Lawson, T. and B. Kang, 1990. Yield of maize and cowpea in an alley cropping system in relation to available light. *Agric. For. Meteorol.,* 52: 347-350.

Leihner, D.E., R. Ernst-Schaeben, T.P. Akondé, N. Steinmuller and N. Steinmüller, 1996. Alley cropping on an Ultisol in subhumid Benin. Part 2: Changes in crop physiology and tree crop competition. *Agrofor. Syst.,* 34: 13-25.

Liasu, M., M. Atayese and O. Osonubi, 2006. Effect of mycorrhiza and pruning regimes on seasonality of hedgerow tree mulch contribution to alley-cropped cassava in Ibadan, Nigeria. *African J. Biotechnol.,* 5: 14-19.

Lieb, V.M., L.K. Schuster, A. Kronmüller, H.G. Schmarr, R. Carle and C.B. Steingass, 2019. Fatty acids, triacylglycerols, and thermal behaviour of various mango (*Mangifera indica*) kernel fats. *Food Res. Int.*, 116: 527-537.

Lin, B., 2007. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. *Agric. For. Meteorol.,* 144: 85-94.

Lin, C., R. McGraw, M. George and H. Garret, 1998. Shade effects on forage crops with potential in temperate agroforestry practices. *Agrofor. Syst.*, 44: 109-119.

Lose, S., T. Hilger, D. Leihner and J. Kroschel, 2003. Cassava, maize and tree root development as affected by various agroforestry and cropping systems in Benin, West Africa. *Agric. Ecosyst. Enviroment*, 100: 137-151.

Lovell, S., C. Dupraz, M. Gold, S. Jose and R. Revord, 2017. Temperate agroforestry research: considering multifunctional woody polycultures and the design of long-term field trials. *Agrofor. Syst.*, 92: 1397-1415.

Mafongoya, P. and O. Jiri, 2016. Nutrient dynamics in wetland organic vegetable production systems in eastern Zambia. *Sustain. Agric. Res.*, 5: 37749-37754.

Majumdar, D. 2011. Pulse crop production: principles and technologies. PHI Learning Privated Limited, New Delhi.

Malézieux, E. 2012. Designing cropping systems from nature. *Agron. Sustain. Dev.,* 32: 15-29.

Malézieux, E., Y. Crozat, C. Dupraz, M. Laurans, D. MakowskI, H. Ozier, B. Rapidel and S. de Tourdonnet, 2009. Mixing plant species in cropping systems: concepts, tools and models: a review. *Sustain. Agric.*, 29: 43-62

Malhotra, S.K., 2017. Horticultural Crops and Climate Change-A Review. *Indian J. Agric. Sci.,* 8: 12-22.

Mappaona, S., M. Kitou, S. Yoshida, M. Kitou, S. Mappaona and M. Kitou, 1994. Yield response of cabbage to several tropical green manure legumes incorporated into soil. *Soil Sci. Plant Nutr.,* 40: 415-424.

Marak, M.K. and A.M. Wani, 2018. Pollen morphology and viability in *Gliricidia sepium*. *J. Pharmacognosy Phytochemistry*, 7: 19-22.

Martin, A., C. Béral and Y. Capowiez, 2019. Agroforestry has an impact on nocturnal predation by ground beetles and opiliones in a temperate organic alley cropping system. *Biol. Control,* 129: 128-135.

Matthews, R.B., S.T. Holden, J. Volk and S. Lungu, 1992. The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia I. Chitemene and Fundikila. *Agrofor. Syst.,* 17: 219-240.

McDonald, M.A., P.A. Stevens and J.R. Healey, 2003. Soil fertility under *Calliandra calothyrsus* hedgerows and other land-use treatments following forest clearance in Jamaica. *Agrofor. Syst.,* 57: 127-135.

Meena, B.L., R.K. Fagodiya, K. Prajapat, M.L. Dotaniya, M.J. Kaledhonkar, P.C. Sharma, R.S. Meena, T. Mitran and S. Kumar, 2018. Legume Green Manuring: An Option for Soil Sustainability. In: *Legumes for Soil Health and Sustainable Management.* Meena R., A. Das, G. Yadav and R. Lal (eds). Springer Singapore, Singapore. pp.387-408.

Meena, H., 2015. *Influence of sowing environments and bio-regulators on clusterbean (Cyamopsis tetragonoloba) under guava (Psidium guajava L.) based agri-horti system.* M. Sc. Thesis. Institute of Agricultural Sciences, Banaras Hindu University. 150 pp.

Meghwal, P.R. and A. Henry, 2006. Economic evaluation of different agro-horticulture systems under rainfed condition of arid zone. In: *Legumes in Dry Areas*. D. Kumar, A. Henry, K.P.R (ed). Vittal. Scientific Publisher Jodhpur, India .

Mercado, A.R., G. Arcinal, C. Duque, M. Palada and M. Reyes, 2008. Vegetable-agroforestry (VAF) system: Understanding vegetable-tree interaction is a key to successful farming enterprise. Sustainable Agriculture and Natural Resource Management (SANREM). Virginia, U. E.

Mirjha, P.R. and D.S. Rana, 2016. Yield and yield attributes, system productivity and economics of mango (*Mangifera indica*)-based intercropping systems as influenced by mango cultivars and nutrient levels. *Indian J. Agron.,* 61: 307-314.

Mitra, S. K., M.R. Gurung and P.K. Pathak, 2007. Guava production and improvement in India: An overview. Proc. International Workshop on Tropical and Subtropical Fruits. 59-66 pp.

Mittal, S.P. and P. Singh, 1989. Intercropping field crops between rows of *Leucaena leucocephala* under rainfed conditions in northern India. *Agrofor. Syst.,* 8: 165-172.

Montero, F.M., M.A. López, M. Jiménez, V.M. Cetina, D.E. Platas and C.J. López, 2017. *Gliricidia sepium* and fertilization affect growth, nutrient status, and incidence of *Hypsipyla grandella* in a *Cedrela odorata* plantation. *Agrofor. Syst.,* 93: 813-823.

Moura, A.G., A.D. Aguiar, T.D. Agostini and E.G. Moura, 2017. Food quantity and quality of cassava affected by leguminous residues and inorganic nitrogen application in a soil of low natural fertility of the humid tropics. *Bragantia*, 76: 406-415.

Murray, G.F. and M.E. Bannister, 2004. Peasants, agroforesters, and anthropologists: A 20-year venture in income-generating trees and hedgerows in Haiti. *Agrofor. Syst.,* 61: 383-397.

Musvoto, C. and B.M. Campbell, 1995. Mango trees as components of agroforestry sytsems in Mangwende, Zimbabwe. *Agrofor. Syst.,* 32: 247-260.

Nair, P.R., S. Viswanath and P.A. Lubina, 2017. *Cinderella* agroforestry systems. *Agrofor. Syst.*, 9: 901-917.

Narain, P., R.K. Singh, N.S. Sindhwal and P. Joshie, 1997. Agroforestry for soil and water conservation in the western Himalayan Valley Region of India 1. Runoff, soil and nutrient losses. *Agrofor. Syst.,* 39: 175-189.

Nedunchezhiyan, M., S. K. Jata and G. Byju, 2012. Sweet potato-based cropping systems. *Fruit, Veg. Cereal Sci. Biotechnol.*, 6: 11-16.

Negi, S.S. 2000. Mango production in India. Proc. VI International Symposium on Mango. pp. 69-78.

Nehdi, I.A., H. Sbihi, C.P. Tan and S.I. Al-Resayes, 2014. *Leucaena leucocephala* seed oil: Characterization and uses. *Ind. Crops Prod.,* 52: 582-587.

Nerlich, K., S. Graeff and W. Claupein, 2013. Agroforestry in Europe: a review of the disappearance of traditional systems and development of modern agroforestry practices, with emphasis on experiences in Germany. *Agrofor. Syst.*, 87: 475-492.

Newman, S.M. 1985. A survey of interculture practices and research in Sri Lanka. *Agrofor. Syst.*, 3: 25-36.

Newman, S.M., K. Bennett and Y. Wu, 1997. Performance of maize, beans and ginger as intercrops in *Paulownia* plantations in China. *Agrofor. Syst.*, 39: 23-30.

Ngambeki, D. 1985. Economic evaluation of alley cropping *Leucaena* with maize-maize and maize-cowpea in southern Nigeria. *Agric. Syst.,* 17: 243-258.

Nissen, T. and D. Midmore, 2002. Stand basal area as an index of tree competitiveness in timber intercropping. *Agrofor. Syst.*, 54: 51-60.

Nissen, T.M., D.J. Midmore and A.G. Keeler, 2001. Biophysical and economic tradeoffs of intercropping timber with food crops in the Philippine uplands. *Agric. Syst.*, 67: 49-69.

Nolte, C., T. Tiki, S. Badjel and J. Gockowski, 2005. Groundnut, maize and cassava yields in mixed-food crop fields after *Calliandra* tree fallow in southern Cameroon. *Exp. Agric.*, 41: 21-37.

Nuberg, I.K. and D.G. Evans, 1993. Alley cropping and analog forests for soil conservation in the dry uplands of Sri Lanka. *Agrofor. Syst.,* 24: 247-269.

Odeny, D.A. 2007. The potential of pigeonpea (*Cajanus cajan*) in Africa. *Proc. Natural Resources Forum*. November, 2007. Blackwell Publishing Ltd.

Oelbermann, M., P. Voroney and D.C. Kass, 2004. *Gliricidia sepium* carbon inputs and soil carbon pools in a Costa Rican alley cropping system. *Int. J. Agric. Sustain.,* 2: 33-42.

Okon, I., 2011. Tree pruning regimes on three cassava genotypes. *Insight Bot.,* 1: 39-44.

Olasantan, F. 2000. Effect of nitrogen rate on okra and tomato in *Gliricidia* alley cropping system in South-western Nigeria. *Trop. Agric. Res. Ext.,* 3: 112-119.

Oliveira, A.T.M., C.S. São Bernardo, F.R. de Melo, M. dos Santos-Filho, C.A. Peres and G.R. Canale, 2019. Primate and ungulate responses to teak agroforestry in a southern Amazonian landscape. *Mamm. Biol.,* 96: 45-52.

Osonubi, O., M.O. Atayese and K. Mulongoy, 1995. The effect of vesicular-arbuscular mycorrhizal inoculation on nutrient uptake and yield of alley-cropped cassava in a degraded Alfisol of southwestern Nigeria. *Biol. Fertil. Soils,* 20: 70-76.

Oyetunji, O. and O. Osonubi, 2007. Assessment of influence of alley cropping system and arbuscular mycorrhizal (AM) fungi on cassava productivity in derived savanna zone of Nigeria. *World J. Agric. Sci.*, 3: 489-495.

Oyetunji, O.J., O. Osonubi and I.J. Ekanayake, 2003. Contributions of an alley cropping system and arbuscular mycorrhizal fungi to maize productivity under cassava intercrop in the derived savannah zone. *J. Agric. Sci.*, 140: 311-316.

Pachas, A.N., S. Sakanphet, O. Soukkhy, M. Lao, S. Savathvong, J.C. Newby, B. Souliyasack, B. Keoboualapha and M.J. Dieters, 2019. Initial spacing of teak (*Tectona grandis*) in northern Lao PDR: Impacts on the growth of teak and companion crops. *For. Ecol. Manage.,* 435: 77-88.

Palada, M.C., B.T. Kang and S.L. Claassen, 1992. Effect of alley cropping with *Leucaena leucocephala* and fertilizer application on yield of vegetable crops. *Agrofor. Syst.,* 19: 139-147.

Palm, C.A., 1995. Contribution of agroforestry trees to nutrient requirements of intercropped plants. In: *Agroforestry*: *Science, Policy and Practice*. Sinclair F.L. (eds). Springer, Dordrecht. pp. 105-124.

Pande, V.C., R.S. Kurothe, G. Kumar, H.B. Singh and S.P. Tiwari, 2018. Economic assessment of agri-horticulture production systems on reclaimed ravine lands in Western India. *Agrofor. Syst.,* 9: 195-211.

Pandey, S., M. Pandey, D. Jadeja, M. Tandel and D. Nayak, 2017. Growth and yield of ginger (*Zingiber officinale*) under Sapota-Jatropha based agroforestry systems in south Gujarat. *J. Pharmacogn. Phytochem.,* 6: 247-251.

Paningbatan, E., 1986. Alley cropping in the Philippines. Proc. of the First Regional Seminar on Soil Management under Humid Conditions in Asia and the Pacific, Khon Kaen, Thailand. pp. 385-395.

Pareek, O.P. and Awasthi, O.P., 2008. Horticulture-based farming systems for arid region. 12-22 p. In: *Diversification of Arid Farming System.* P. Narain, M.P. Singh, A. Kar, S. Katju and Praveen Kumar (eds.). Scientific Publishers, India.

Patel, S., M. Tandel, M. Desai, J. Pathak, L. Behera and M. Parmar, 2018. Economics of cucurbitaceous vegetable crops under teak (*Tectona grandis*) based silvi-horticultural system in South Gujarat. *Int. J. Chem. Stud*., 6: 119-123.

Paulino, G., D. Barroso, R. Lamonica and V. Árvore, 2011. Desempenho da *Gliricidia* no cultivo em aleias em pomar orgânico de mangueira e gravioleira. *Rev. Arvore*, 35: 781-789.

Paut, R., R. Sabatier and M. Tchamitchian, 2018. Benefits of diversified horticultural systems: assessment with the modern portfolio theory. Proc. International Farming Systems Association (IFSA) Symposium, Chania, Crete, Greece. 1-9 pp.

Pavlidis, G. and V.A. Tsihrintzis, 2018. Environmental benefits and control of pollution to surface water and groundwater by agroforestry systems: a Review. *Water Resour. Manag.*, 32: 1-29.

Peng, F., B. Huang, T. Juhana, F.R. Peng and B.L. Huang, 1999. Productivity and nutrient cycling in an agroforestry ecosystem for interplanting of pineapple and coconut. *J. For. Res.,* 10: 163-167.

Pradhan, S., P. Sahu, P. Panigrahi, K.G. Mandal and S.K. Ambast, 2018. Performance of intercropping in pre-bearing mango orchards under drip irrigation in a degraded land. *J. Appl. Nat. Sci.*, 10: 1124-1129.

Rahman, S.A., M.H. Imam, D.J. Snelder and T. Sunderland, 2012. Agroforestry for Livelihood Security in Agrarian Landscapes of the Padma Floodplain in Bangladesh. *Small-scale For.,* 11: 529-538.

Rajasekharan, P. and S. Veeraputhran, 2002. Adoption of intercropping in rubber smallholdings in Kerala, India: a tobit analysis. *Agrofor. Syst.,* 56: 1-11.

Ranashinghe, D. and S. Newman, 1993. Agroforestry research and practice in Sri Lanka. *Agrofor. Syst.*, 22: 119-130.

Rani, S., D.K. Benbi, A. Rajasekaran and S.K. Chauhan, 2016. Litterfall, decomposition and nutrient release patterns of different tree species in Taran Taran district of Punjab, India. *J. Appl. Nat. Sci.*, 8: 1260-1266.

Rao, M.R.M., M.C. Palada, B.N. Becker and B. Becker, 2004. Medicinal and aromatic plants in agroforestry systems. In: *New Vistas Agrofor.* Nair P.K.R., M.R. Rao and L.E. Buck (eds.). Springer, Dordrecht. p.107-122.

Rawat, R., B.K. Kumbhar and L. Tewari, 2013. Optimization of alkali pretreatment for bioconversion of poplar (*Populus deltoides*) biomass into fermentable sugars using response surface methodology. *Ind. Crops Prod.*, 44: 220-226.

Ribeiro, A., M. Silva, I. Moura, J. Ramalho and C. Máguas, 2018. The Potential Systems of Tree and Shrub Legumes in Agroforestry Systems. In: *Nitrogen in Agriculture*. Amanullah and Shah Fahad (eds.). IntechOpen. 223-239 p.

Rivera, T.M., M.F. Quigley and J.C. Scheerens, 2004. Performance of component species in three apple-berry polyculture systems. *HortScience*, 39: 1601-1606.

Rizvi, R.H., S.K. Dhyani, R.S. Yadav and R. Singh, 2011. Biomass production and carbon stock of poplar agroforestry systems in Yamunanagar and Saharanpur districts of northwestern India. *Curr. Sci.,* 100: 736-742.

Rosecrance, R.C., S. Rogers and M. Tofinga, 1992. Effects of alley cropped *Calliandra calothyrsus* and *Gliricidia sepium* hedges on weed growth, soil properties, and taro yields in Western Samoa. *Agrofor. Syst.*, 19: 57-66.

Salami, A.O., A.C. Odebode and O. Osonubi, 2005. The use of arbuscular mycorrhiza (am) as a source of yield increase in sustainable alley cropping system. *Arch. Agron. Soil Sci.,* 51: 385-390.

Salami, A.O. and O. Osonubi, 2003. Influence of mycorrhizal inoculation and different pruning regimes on fresh root yield of alley and sole cropped cassava (*Manihot esculenta*) in Nigeria. *Arch. Agron. Soil Sci.*, 49: 317-323.

Sampaio, L., J. Araújo, E. Sousa, A. Ferraz and A. Araujo, 2015. Pumpkin cultivation, supplemented with biofertilizer, in alleys cropping of leguminous trees. *Hort. Bras.,* 33: 40-44.

Sangwan, A., W. Dhillon, H. Singh, S. Chohan and P. Gill, 2015. Influence of horti-silviculture combinations on pre-bearing growth and physiological parameters of pear. *Indian J. Hort.,* 72: 21-27.

Sangwan, A.K. 2014. Physiological behaviour and yield evaluation of *Colocasia* under agri-horti-silviculture system. *HortFlora Res. Spectr.,* 3: 114-121.

Sangwan, A.K., W.S. Dhillon, S.K. Chauhan,N.P. Singh and M.K. Bath, 2017. Performance of garlic under agri-horti-silvicultural system in relation to physiological behaviour and yield. *Indian Journal of Ecology*, 43: 724-729.

Schroth, G. 1995. Tree root characteristics as criteria for species selection and systems design in agroforestry. In: *Agroforestry: Science, Policy and Practice*. Sinclair F.L. (eds.). Springer, Dordrecht. 125-143 p.

Schroth, G., P. Balle and R. Peltier, 1995. Alley cropping groundnut with *Gliricidia sepium* in Cote d'Ivoire: Effects on yields, microclimate and crop diseases. *Agrofor. Syst.,* 29: 147-163.

Schroth, G., U. Krauss, L. Gasparotto, J. Aguilar and K. Vohland, 2000. Pests and diseases in agroforestry systems of the humid tropics. *Agrofor. Syst.,* 50: 199-241.

Schroth, G. and F. Sinclair, 2003. *Trees, Crops and Soil fertility: Concepts and Research Methods.* CABI Publishing. UK.

Seiter, S. and W.R. Horwath, 1999. The fate of tree root and pruning nitrogen in a temperate climate alley cropping system determined by tree-injected 15 N. *Biol. Fertil. Soils*, 30: 61-68.

Seran, T. and Brintha, I., 2010. Review on maize based intercropping. *J. of Agron.,* 9: 135-145.

Sereke, F., A.R. Graves, D. Dux, J.H. Palma and F. Herzog, 2014. Innovative agroecosystem goods and services: key profitability drivers in Swiss agroforestry. *Agron. Sustain. Dev.,* 35: 759-770.

Shah, M.H., V. Dutt, S.J. Bhat, Z.A. Dar and M. Khanday, 2017. Characteristics of soil under greengram-plum based agroforestry system in Kashmir valley, India. *Int. J. Curr. Microbiol. App. Sci.,* 6: 1615-1622.

Shapo, H., Adam, H., 2008. Modification of microclimate and associated food crop productivity in an alley-cropping system in Northern Sudan. In: *Toward Agroforestry Design*. Jose S. and A.M. Gordon (eds.). Springer, Dordrecht. 97-109 pp.

Sharma, A.K. 1996. Arid Zone Agroforestry : Dimensions and Directions for Sustainable Livelihoods. Central Arid Zone Research Institute. Jodhpur, India.

Sharma, I., R. Singh, P. Tiwari and P. Sharma, 2017. Effect of different Spacing and Phosphorus levels on growth and yield parameters of Mungbean under guava based Agri-horti System. *J. Pharmacogn. Phytochem.*, 993-996.

Sharma, K.C. 2014. Production potential of fodder crops sequences in association with ber (*Zizyphus mauritiana*) under agri-horticulture system in hot arid ecosystem of western. *Range Manag. Agrofor.*, 35: 188-192.

Sharma, K.L. 2011. Effect of agroforestry systems on soil quality-monitoring and assessment. Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, India.

Shukla, S., V. Pandey and V. Kumar, 2018. Agroforestry systems as a tool in sustainable rural development, food scarcity and income generation. *Indian For.*, 144: 435-441.

Singh, B. and G. Singh, 2015. Biomass production and carbon stock in a silvi-horti based agroforestry system in arid region of Rajasthan. *Indian For.,* 141: 1237-1243.

Singh, D.K., V.K. Sharma, J. Kumar, A. Mishra, S.K. Verma, T.N. Sieber and R.N. Kharwar, 2017. Diversity of endophytic mycobiota of tropical tree *Tectona grandis*. Spatio temporal and tissue type effects. *Sci. Rep.,* 7: 3745-3750.

Singh, G. 2009. Comparative productivity of *Prosopis cineraria* and *Tecomella undulata* based agroforestry systems in degraded lands of indian desert. *J. For. Res.,* 20: 144-150.

Singh, G. 1987. Agroforestry in the Indian subcontinent: past, present and future. In: Agroforestry: a decade of development. Steppler, H. and P. Nair (eds.). ICRAF, Nairobi, Kenya, pp.117-138.

Singh, P. 2016. Effect of shoot pruning intensity and sowing direction of mungbean (*Vigna radiata*) under bael (*Aegle marmelos*) based agri-horti system in vindhyan region. Ph.D. Diss. Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. 23-120 pp.

Singh, R. and R. Van den Beldt, 1989. Alley farming in the semi-arid regions of India. Proc. Alley Farming in the Humid and Subhumid Tropics. Ibadan, Nigeria, pp. 10-14.

Singh, S., M. Sharma and P. Singh, 2016. Intercropping- An approach to reduce fruit drop and improve fruit quality in guava. *J. Chem. Pharm. Sci.*, 9: 3182-3187.

Singh, S.K., S.K. and S. Singh, 2018. Vegetable crops as most efficient and economical intercrops: A brief review. *Plant Arch.,* 18: 923-929.

Singh, V.K., Kumar, M. and Singh, K., 2011. Increasing profitability of mango (*Mangifera indica*) orchard through intercropping. Proc. Global conference on augmenting production and utilization of mango: biotic and abiotic stresses. pp. 151-157.

Sondarva, R.L., M.B. Tandel, N.K. Patel, V.M. Prajapati, D.H. Prajapati and J.B. Bhusara, 2018. Effect of INM on growth and yield components of Brinjal (*Solanum melongena*) under teak (*Tectona grandis*) based silvi-horticultural system in South Gujarat. *Int. J. Chem. Stud.,* 6: 1224-1227.

Soreng, M. and N. Kerketta, 2017. Effect of organic manures on different plant varieties of chilli (*Capsicum annum*) under subabul (*Leucaena leucocephala*) based Horti silviculture system. *J. Med. Plant Stud.*, 5: 273-276.

Ssekabembe, C.K. 1985. Perspectives on hedgerow intercropping. *Agrofor. Syst.,* 3: 339-356.

Stelen, S. 1997. Intercropping trees in a vegetable production system: A holistic inquiry. Ph.D. Diss. Oregon State University, U.E.

Sureshbhai, P.J., N.S. Thakur, S.K. Jha and V. Kumar, 2017. Productivity and carbon sequestration under prevalent agroforestry systems in Navsari District, Gujarat, India. *Int. J. Curr. Microbiol. App. Sci.*, 6: 3405-3422.

Suttie, J. 2015. *Gliricidia sepium* (Jacq.). F.A.O. Rome, Italy.

Swain, S.C. 2016. Influence of intercropping systems on soil health, productivity and quality of guava (*Psidium guajava*) in Eastern India. *J. Plant Nutr.,* 39: 2037-2046.

Swain, S.C. 2014. Performance and profitability study of different mango based intercropping systems in Easternghat high land zone of Odisha. *J. Crop Weed,* 10: 170-178.

Swain, S.C., D.K. Dora, S.C. Sahoo, S.K. Padhi and D. Sanyal, 2012. Influence of mango-based intercropping systems on improvement of soil health under rainfed situation. *Soil Sci. Plant Anal.,* 43: 2018-2026.

Tabin, T., D. Balasubramanian and A. Arunachalam, 2015. Influence of canopy pruning on orange growth and rhizome yield of intercrop ginger under agri-horticulture system. *Indian J. Hill Farming,* 28.

Thakur, A.K., A. Saraswat and D.K. Srivastava, 2012. *In vitro* plant regeneration through direct organogenesis in *Populus deltoides* clone G48 from petiole explants. *J. Plant Biochem. Biotechnol.,* 21: 23-29.

Thakur, N.S., Jilariya, D.J., Gunaga, R.P. and S. Singh, 2018. Positive allelospoly of *Melia dubia* spatial geometry improve quantitative and qualitative attributes of *Aloe vera*. *Ind. Crops Prod.,* 119: 162-171.

Thakur, P., V. Dutt, S. Sehgal and R. Kumar, 2005. Diversification and improving productivity of mountain farming systems through agroforestry practice in Northwestern India. Proc. 9th North Am. Agrofor. Conf. Solan, India.

Tiwari, P., R. Kumar, L. Thakur, A. Salve and Y. Parmar, 2017. Agroforestry for Sustainable Rural Livelihood : A review. *J. Pure App. Biosci*., 5: 299-309.

Tolunay, A., H. Alkan, M. Korkmaz and S. Fliliz, 2007. Classification of Traditional Agroforestry Practices in Turkey. *Int. J. Nat. Eng. Sci.,* 1: 41-48.

Tonye, J. 1989. Alley cropping in Cameroon. Proc. Alley Farming in the Humid and Subhumid Tropics. Ibadan, Nigeria.

Tonye, J., B. Duguma and T. Tiki, 1994. Stepwise approach to alley cropping technology development and transfer in the forest zone of Cameroon. *Agrofor. Syst.*, 28: 269-278.

Toppo, P., A. Raj and M.K. Jhariya, 2016. Agroforestry systems practised in Dhamtari district of Chhattisgarh, India. *J. Applied Natural Science*, 8: 1850-1854.

Upadhyay, M. and M. Yadava, 2009. Agroforestry System Practiced in Nepal. Tribhuvan University. Institute of Forestry. Office of the Dean, Pokara.

Vanlauwe, B., N. Sanginga and Merckx, R., 1998. Recovery of *Leucaena* and *Dactyladenia* residue nitrogen-15 in alley cropping systems. *Am. Soc. Agron.,* 62: 453-460.

Varshney, R.K., R.V. Penmetsa, S. Dutta, P.L. Kulwal, R.K. Saxena, S. Datta, T.R. Sharma, B. Rosen, B., N. Carrasquilla, A.D. Farmer, A. Dubey, K.B. Saxena, J. Gao, B. Fakrudin, M.N. Singh, B.P. Singh, K.B. Wanjari, M. Yuan, R.K. Srivastava, A. Kilian, H.D. Upadhyaya, N. Mallikarjuna, C.D. Town, G.E. Bruening, G. He, G.D. May, R. McCombie, S.A. Jackson, N.K. Singh and D.R. Cook, 2010. Pigeonpea genomics initiative (PGI): an international effort to improve crop productivity of pigeonpea (*Cajanus cajan*). *Mol. Breed.*, 26: 393-408.

Verma, K.S. and N.S. Thakur, 2010. Economic analysis of ashwagandha (*Withania somnifera*) based agroforestry land use system in mid hill Western Himalayas. *Indian J. Agrofor*., 12: 62-70.

Verma, P., A. Bijalwan, M.J. Dobriyal, S.L. Swamy and T.K. Thakur, 2017. A paradigm shift in agroforestry practices in Uttar Pradesh. *Current Sci.,* 112: 509-515.

Vijaykumar, R., B. Mehera and N. Khare, 2018. Evaluate the organic manure for growth and economics for rice cultivation using system of rice intensification (SRI) method under citrus based agroforestry system. *J. Pharmacogn. Phytochem.,* 7: 1799-1802.

Vinaya, R.S. and K.K. Suresh, 1988. Agrisilvicultural studies-optimum species combination. *Int. Tree Crop. J.*, 5: 1-8.

Wadeesirisak, K., S. Castano, K. Berthelot, L. Vaysse, F. Bonfils, F. Peruch, K. Rattanaporn, S. Liengprayoon, S. Lecomte, S. and C. Bottier, 2017. Rubber particle proteins REF1 and SRPP1 interact differently with native lipids extracted from Hevea brasiliensis latex. *Biochim. Biophys. Acta - Biomembr.,* 1859: 201-210.

Weersum, K.F. 1982. Tree gardening and taungya on Java: examples of agroforestry techniques in the humid tropics. *Agrofor. Syst.*, 1: 53-70.

Williams, P.A. and A.M. Gordon, 1992. The potential of intercropping as an alternative land use system in temperate North America. *Agrofor. Syst.,* 19: 253-263.

Wilson, G.F., B.T. Kang and K. Mulongoy, 1986. Alley cropping: trees as sources of green-manure and mulch in the tropics. *Biol. Agric. Hort.,* 3: 251-267.

Wilson, G.F. and R. Swennen, 1989. Alley cropping: potential for plantain and banana production. Proc. Alley Farming in the Humid and Subhumid Tropics. Ibadan, Nigeria, pp. 10-14.

Wolz, K.J. and E.H. DeLucia, 2018. Alley cropping: Global patterns of species composition and function. *Agric. Ecosyst. Environ*., 252: 61-68.

Workman, S.W., S.C. Allen and S. Jose, 2003. Agroforestry potential in the southeastern United States: perceptions of landowners and extension professionals. *Agroforestry Syst.,* 59: 73-83.

Wu, J., W. Liu and C. Chen, 2016. Can intercropping with the world's three major beverage plants help improve the water use of rubber trees?. *J. Appl. Ecol.,* 53: 1787-1799.

Xu, Q., L.L. Chen, X. Ruan, D. Chen, A. Zhu, C. Chen and J. Chen, 2013. The draft genome of sweet orange (*Citrus sinensis*). *Nat. Genet.,* 45: 59-62

Yadav, B. S. 2006. *Performance of Vegetable Crops Uunder Poplar Based Agroforestry System*. Ph.D. Diss. Haryana Agricultural University, Hisar.

Yadav, A. 2017. *Effect of Inorganic and Organic Fertilizer on Growth and Yeild of Black Gram (Vigna mungo) under Guava (Psidium guajava) based Agri-Horti System*. Ph.D. Diss. Institute of Agricultural Sciences, BHU. Varanasi.

Yamoah, C., R. Grosz and E. Nizeyimana, 1989. Early growth of alley shrubs in the Highland region of Rwanda. *Agrofor. Syst.*, 9: 171-184.

Zaki, H., A. Mahmoud, Y. Abb, A. Hammad and M. Sayed, 2017. Studies on pea (*Pisum sativum*) growth and productivity under agroforestry system: 2. Yield and seed quality of pea under alley cropping system with two types of trees. *J. Basic Appl. Res.,* 3: 1-9.

Zaki, H., A. Mahmoud, Y. Abb, A. Hammad and M. Sayed, 2016. Studies on pea *(Pisum sativum*) growth and productivity under agroforestry system: 1. Vegetative growth, chemical composition and nodulation status of pea under. *J. Basic Appl. Res.,* 2: 596-605.

Zhang, Y., J. Leclercq, S. Wu, E. Ortega, S. Pointet, C. Tang, S. Hu and P. Montoro, 2019. Genome-wide analysis in *Hevea brasiliensis* laticifers revealed species-specific post-transcriptional regulations of several redox-related genes. *Sci. Rep.*, 9: 5701-5705.

Zu, Y., Y. Fu, W. Liu, C. Hou and Y. Kong, 2006. Simultaneous determination of four flavonoids in pigeonpea (*Cajanus cajan*) leaves using RP-LC-DAD. *Chromatographia*, 63: 499-505.

Received: July, 2019; Revised: August, 2019; Accepted: August, 2019