Fruit-forage Integrated Systems for Diversification and other Ecosystem Services

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Abstract: The interspaces (alleyways) in fruit orchards aregenerally not utilized for cultivation of perennial forage crops by a majority of farmers. These alleyways are often occupied by weeds or kept bare or clean with repeated tillage. The weeds may act as alternate/collateral hosts, thereby harboring pests and pathogens that may harm the fruit trees. In addition to this, the frequent tillage may subject the soil to erosion losses. Intercropping of perennial forage grasses and/or legumes with fruit crops is thus beneficial for not only providing high quality forage but also for providing various ecosystem services.Owing toan ever burgeoning population, degraded grasslands,shortage of fodder, and inability of farmers to earmark adequate land for fodder production, it becomes imperative to exploit the interspaces in fruit orchards. Yield and quality of forages can be increased by cultivating forage grasses and legume species in appropriate mixtures. The present study was conducted in order to evaluate the performance of several perennial temperate forage grass/legume combinations as an effective approach for weed management, soil fertility enhancement, and increased forage resource availability in apple/almond-based horti-pastoral systems in the northwestern Himalayan region of India during 2015 to 2020. The treatments consisted of various temperate perennial grasses (tall fescue, orchard grass, little seed canary grass, and timothy) and temperate perennial legumes (red and white clover) arranged in a randomised block design with three replications. In apple-based hortipasture, maximum yields were obtained with tall fescue + red clover (12.1 t/ha dry fodder yield) followed by orchard grass + red clover (10.45 t/ha dry fodder yield). Data on the effect of forage crops on soil fertility showed that organic carbon (%) varied significantly in various combinations, with maximum soil organic carbon being observed in red clover + apple (0.92%) followed by white clover + apple (0.89%). However,minimum soil organic carbon was observed in control plot (clean cultivation). In the almond-based hortipastoral system, canary grass + red clover recorded maximum green fodder yield (46.90 t/ha) and dry fodder yield (12.56 t/ha) followed by tall fescue + red clover and orchard grass+ red clover combinations. The treatment canary grass + red clover + almond recorded minimum weed density (10.64 m^{-2}) and maximum weed control efficiency (79.85%) compared to control plots (natural vegetation, 90.64 m^{-2}). Therefore, for achievingcomplementary benefits of high quality fodder, soil fertilityenhancement, and suppression of weeds, interculture of perennial grass-legume mixtures is recommended in fruit orchards.

Introduction

Livestock and horticulture sectors are highly significant in increasing the productivity of land, creating employment, enhancing economic conditions of the farming community and agripreneurs, and ensuring nutritional security. Interspaces of fruit orchards are an important niche area for cultivation of perennial forage crops and can augment fodder resource availability and provide other ecosystem services likesuppressing weeds, enhancing soil fertility, increasing nutrient cycling, etc. (Ahmad et al. 2018). The large intervening spaces in the orchards are seldom used for inter-culture of perennial forage crops by the majority of farmers and are often occupied by weeds or kept bare with repeated tillage. This vacant space with weeds may act as a breeding place for various pests and pathogens that are inimical to the fruit crops. The repeated tillage may subject the orchard floor to erosion losses. Horti-pastoral systems (orchard + pasture+ livestock) where in the inter-spaces between fruit trees are utilized for cultivation of grasses and grass/legume mixtures have been recognized as a sustainable land use option because of their high productivity and environmental benefits even under fragile agro-ecosystems (Shukla et al. 2014; Ahmad et al. 2021). Yield and quality of forage crops in these integrated systems can be enhanced by introduction of grass and legume species in optimum mixtures. This approach becomes more important due to increased population pressure, poor productivity of grassland resources, skewed forage supply, and farmers' inability to spare adequate land for fodder production. However, information on fruit tree-forage crop integrated systems in temperate regions is inadequate; therefore, this research was carried out to explore optimum tree-pasture combinations for increasing diversification and sustainability of such systems.

Methods and Study Site

This study was carried out from 2015 to 2020 in two fruit orchards (apple and almond). In apple orchard (15 year old orchard; spacing: 4 m x 4 m), treatments consisted of two temperate perennial grasses (tall fescue and orchard grass) and two perennial legumes (red and white clover) whereas in almond orchard (5 year old orchard; spacing: 5 m x 5 m), the treatments consisted of tall fescue, orchard grass, little seed canary grass and timothy) and one perennial legume (red clover) that were arranged in a randomised block design with three replications. The study was conducted in the experimental field of ICAR-IGFRI Regional Research Station, Srinagar ($33^0$59'12'' N longitude and 74˚47'52'' E latitudes and 1650 m above mean sea level). The climate is temperate with mild summers and generally wet, frozen with moderate to heavy snowfall winters. The maximum temperature observed was as high as 35°C during July and August months, while sub-freezing temperatures and frost were common during the winters (December to February). The soil was a silt clay loam with 9.1% sand, 57.5% silt, and 33.4% clay. Soil pH was neutral (6.75) with a bulk density of 1.28 g/cm^3, 0.685% soil organic carbon, 282.76 kg ha^{-1} available N, 10.4 kg ha^{-1} available Olsen P, and 384.65 kg ha^{-1}available K. The grass-rooted slips of little seed canary grass, tall fescue, timothy and orchard grass were transplanted in November-December, 2015 at 75 x 30 cm and red and white clover were seededat 5 kg/ha in lines between 2 rows of grass inboth apple (plot size of 12 m x 12 m per replication) and almond (plot size of 15 m x 15 m per replication) orchards.A total of 5 kg farmyard manure, 200 g N, 100g $P_2O_5$and 150 g K_2O was applied to each fruit tree. For the forages, 80 kg N, 60 kg $P_2O_5$and 40 kg K_2O fertilizerwas applied per hectare per year.

Plant and soil sampling: At the time of 50% heading of forage, each plot (1m x 1m) was harvested using hand sickle and intercrops were separated and weighed to have green forage weight. A 500 g sample of chopped forage was kept in an oven at 65°C till constant dry weight. The forage quality was determined after the samples were dried and crushed to a fine powder. Soil samples for each plot were obtained by digging three profiles up to 40 cm. Composite samples from all sub plots were obtained for 0-40 cm depth. Samples were air dried in shade, grinded with wooden pestle, passed through 2 mm sieve and stored in cloth bags for further laboratory analysis. Soil organic carbon was determined by Walkley Black Rapid Titration method (Jackson, 1958).

Weed dynamics: The observations on weed were recorded before first cut and the total vegetation present in 1 m x1 m random quadrants was cut and separated species wise.Weed species were identified and counted separately and expressed as number of weeds/m2 (Palsaniya et al, 2015). Weed control efficiency (WCE) was calculated using WCE = ((WDWc - WDWi)/WDWc) x 100, where WDWc is the weed dry weight in control treatment and WDWi is the weed dry weight in intercropped plot (Singh et al, 2013).

Statistical analysis: The pooled data was subjected to analysis of variance and LSD ($P<0.05$) was used to compare means among various treatment combinations followingSnedecor and Cochran (1994).

Table 1: Effect of forage grasses and/or legumes on green fodder yield (t/ha), dry fodder yield (t/ha), and soil organic carbon (%) in apple orchard.

Treatments	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Soil organic carbon (%)
T_1: White clover+apple	16.35	5.92	0.890
T_2: Red clover+ apple	22.84	6.84	0.920
T_3: Tall fescue+ apple	27.60	8.4	0.713
T_4: Orchard grass+ apple	25.54	7.86	0.720
T_5: Tall fescue + white clover+ apple	27.31	10.65	0.800
T_6: Tall fescue + red clover+ apple	32.74	12.1	0.800
T_7: Orchard grass + white clover+ apple	26.45	8.12	0.793
T_8: Orchard grass + red clover+ apple	29.74	10.45	0.803

T_9: Control (Clean cultivation)	0.00	0.00	0.660
SEm ±	0.75	0.01	0.01
$CD_{0.05}$	2.33	0.036	0.03

Results and Discussion

Intercropping of forage grasses with either red or white clover in an apple-based hortipasture system produced significantly higher total green and dry forage yields in comparison to the treatments wherein grasses and legumes were intercropped as monocultures. However, maximum yield was obtained with tall fescue + red clover (12.1 t/ha dry fodder yield) followed by tall fescue + white clover (10.65 t/ha) and orchard grass + red clover (10.45 t/ha dry fodder yield) when intercropped with apple. Lesser forage yields were obtained when legumes were grown as monocultures, with lowest value in white clover + apple (5.92 t/ha dry fodder yield). Higher yield in grass/legume combinations might be because of greater diversity and complementarity leading to increased herbage dry matter yields than in monocultures (Sturludottir *et al.*, 2013). Data on the effect of forage crops on soil fertility showed that soil organic carbon (%) varied significantly with maximum soil organic carbon being observed in red clover + apple (0.92%) followed by white clover + apple (0.89%). Lowest organic carbon was observed in control plot (clean cultivation). However, comparatively better soil organic carbon contents were observed in grass/legume combinations (although lower than pure legume monocultures). The increase in soil organic carbon in grass and/or legume combinations might be due to addition of more plant residues into the soil, increased turnover of minute rootlets of grasses/legumes, consequent decay and disintegration of roots (Waisel et al. 2002; Ahmad et al. 2018).

Table 2. Green fodder yield (t/ha), dry fodder yield (t/ha),weed density (per m^2), and weed control efficiency (%) as influenced by forage grass and/or legume treatment in an almond-based hortipasture.

Treatments	**Green fodder yield (t/ha)**	**Dry fodder yield (t/ha)**	**Weed density (no/m^2)**	**Weed control efficiency (%)**
T_1 (Tall fescue + almond)	35.50	8.45	18.42	66.45
T_2 (Orchard grass + almond)	32.47	7.18	20.45	62.35
T_3(Little seed canary grass + almond)	37.54	8.50	14.65	74.65
T_4(Timothy + almond)	22.82	6.10	58.65	51.25
T_5(Red clover + almond)	23.12	6.12	54.14	42.10
T_6(Tall fescue + red clover + almond)	39.12	10.21	14.24	69.25
T_7(Orchard grass + red clover + almond)	38.35	9.06	15.58	68.64
T_8(Little seed canary grass + red clover + almond)	46.90	12.56	10.64	79.85
T_9(Timothy + red clover + almond)	28.63	7.97	34.32	57.64
T_{10} (Natural pasture + almond)	10.42	3.50	90.64	0.00
SEm ±	0.35	0.03	0.03	0.68
$CD_{0.05}$	1.09	0.09	0.09	2.03

For the almond-based system, the highest green fodder yield (46.90 t/ha) and dry fodder yield (12.56 t/ha) was observed when little seed canary grass was intercropped with red clover in association with almond fruit trees. This was followed by tall fescue intercropped with red clover (39.12 t/ha green fodder yield and 10.21 t/ha dry fodder yield) and orchard grass intercropped with red clover (38.35 t/ha green and 9.06 t/ha dry fodder). Lowest green and dry fodder yields were observed incontrol treatment (natural pasture). Higher forage yields were observed with grass-legume mixtures compared to either sole grass or sole legume treatments, except in the case of little seed canary grass + almond. This might be attributed to little seed canary grass being a more productive, stable, and reliable species compared to most of the temperate perennial grasses such as orchard grass, tall fescue, and brome grass as little seed canary grass possesses better long term persistence, an efficient and deep root system, and good drought tolerance (Watson et al. 2000). The increased yield in little seed canary grass, tall fescue, orchard grass and timothy intercropped with red clover might be owing to their better compatibility with red clover and more vigorous growth which led to improvement in all the growth and yield attributes that was eventually reflected in higher forage yield (Zemenchik et al. 2001; Ahmad et al. 2018). In case of weed dynamics, little seed reed canary grass + red clover had the lowestweed density (10.64 m^{-2}), while maximum weed density was observed in the control treatment(90.64 m^{-2}) followed by timothy (58.65 m^{-2}) and red clover (54.14 m^{-2})grown in monoculture. Little seed canary grass + red clover exhibited the highest weed control efficiency (79.85 %)followed by little seed canary grass + almond, tall fescue + red clover (69.25 %) and orchard grass + red clover (68.64 %). The increased weed controlling efficiency in perennial grasses and their mixtures with legumesmight be owing to quick and better occupation of the interspaces, vigorous growth, and better resource utilization that reduces germination of weed seeds and lessens the chances of weed seedling establishment (Teasdale, 1998; Ahmad et al. 2021).

Conclusions and/or Implications

Most of the apple and almond orchards in the northwestern Himalayan region are rainfed and have slow growth during establishment.The interspaces in these orchards often not only go without any productive use, but also become filled with weeds that reduce the yield of fruit trees and interfere with various orchard operations. Therefore, in order to ensure optimum ecosystem services in the from of adequate and nutritious fodder supply, improving soil fertility, and suppressing weeds, intercropping of temperate perennial forage grass and/or legume mixtures is recommended in apple (tall fescue/orchard grass + red/white clover) and almond orchards (little seed canary grass/tall fescue/orchard grass/timothy + red clover).

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