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Forage production and orchard floor management through grass/legume intercropping in apple based agroforestry systems

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Abstract
The present investigation was initiated at the experimental farm of ICAR-Central Institute of Temperate Horticulture, Jammu and Kashmir, India in 2016 and 2017 for evaluation of forage grass/legume mixtures as a means of orchard floor management and for augmenting forage resource availability in apple based agroforestry systems. The treatments consisted of perennial temperate grasses (tall fescue and orchard grass) and legumes (white and red clover) both under sole as well as in combination. The experiment consisted of nine treatments replicated thrice in a randomised block design. The results revealed that growth parameters in terms of trunk girth, trunk cross-sectional area, fruit yield and yield efficiency were found to be higher in legume as sole and grass/legume combination treatments than control (clean cultivation) and grasses as sole. *Tall fescue + red clover* (T_5) recorded maximum green as well as dry fodder yield followed by *orchard grass + red clover*. Whereas, lowest green fodder and dry fodder yield was recorded in Apple + *white clover*. Results under present investigation also revealed that various soil physico-chemical properties were significantly higher under red clover treatment followed by white clover and grass/legume combinations, while lowest values were recorded under grasses under sole and clean cultivation. It may be concluded that grass/legume intercropping not only augments forage availability but also is an effective strategy for proper orchard floor management, thus enhancing system productivity as a whole.

Keywords: Forage production, grass/legume intercropping, orchard floor management, agroforestry systems

Introduction
Agroforestry is often defined as an economically viable land-use option on the environmental rehabilitation and sustainable agricultural development (Djalilov *et al*. 2016) [10]. It encompasses sustainable approaches to land-use management where both agricultural crops and tree crops combine into an integrated production system to get maximum benefits (Nair, 1998) [22]. Griffith (2000) [13] considers agroforestry as an ecologically sustainable land-use option alternative to the prevalent subsistence farming patterns for conservation and development. The last twenty years have witnessed an intensification and expansion of research relevant to smallholder agroforestry systems (Leakey *et al*. 2012) [18].
Livestock husbandry plays a significant role in the economy of the Himalayan people. In animalhusbandry about 65-75% expenditure is incurredin feeds and fodder (Singh 2009).Among the fruittree based agroforestry system, the hortipasturesystems have been recognized as sustainable landuse option because of its high productivity andenvironmental benefits even under fragile agroecosystems (Shukla *et al* 2014).Yield and quality of forage in agroforestry systems can be improved by introducing shade-tolerant grass and legume species in appropriate mixtures. The management of these systems can present a challenge regarding the selection of the proper grass and legume species as well as the maintenance of the optimum balance between the two species in the grass–legume stand.
The importance of horticulture in improving the productivity of the land, generating employment, improving economic conditions of the farmers and entrepreneurs, enhancing exports and above all, providing nutritional security can hardly be overemphasized (Ahmad and Verma, 2011) [1]. Among the Himalayan states, Jammu and Kashmir has emerged asleading apple producing state in the country and during last decade the area under crop has increased 16times, production by about 60 times and productivity by about five times (Bhat

et al., 2013) [7]. Although, Jammu and Kashmir is the state where yield of commercially important apple varieties is highest in the country (11.29 tha^{-1}) yet it compares poorly to the yields obtained by advanced countries which is 60 tha^{-1}(Anonymous, 2009) [4]. Jammu & Kashmir comprises three main physicalregions viz., outer Himalayas facing with sub-tropicaland intermediate type of climate (Jammu region), lesser Himalayas or temperate zone (Kashmir region) and inner Himalayas or cold arid zone i.e. Ladakh region (Ahmad and Verma, 2011) [1]. There is considerable area available under orchards (3.55 lakh hectares) and the inter spaces between fruit trees could be used for production of fodder by growing perennial grasses and legumes for enhancing forage availability and ensuring proper orchard floor management.

The orchard floor represents a substantial portion of the orchard agroecosystem, but it has generally received less research and management attention than tree horticulture and pest/disease management. Yet opportunities exist to improve orchard sustainability through manipulation of the orchard floor (Granatstein and Sanchez, 2009) [12]. Effective orchard soil management isalso key orchard production practice for profitable andsustainable tree fruit production (Derr, 2001) [9]. Proper orchard floor management is vital to the health and productivity of fruit trees, with management practices impacting tree growth, fruit yield, and fruit quality. Current recommended orchard floor management practices consist of maintaining a vegetation-free tree row and a grass cover crop in the alleyway (Dabney *et al*., 2001; Merwin, 2004) [8, 21]. Kuhn and Pedersen (2009) [15] showed that clover and grass mixtures increased shoot growth and yield in two varieties of apples. Cultivation of annual crops decreases soil organic matter and increases soil erosion potential, especially on sloping landscapes. Perennial crops maintain a continuous soil cover, increase water infiltration, reduce soil erosion, and improve overall soil quality. Therefore, planting forage species in the alleys may not only protect the soil resource by improving soil quality but also provide a source of income during orchard establishment.

The integrated approach of growing grasses and fodder crops under agroforestry systems is one of the vital alternatives to augment fodder production. Intercropping of perennial forage grasses and/or legumes with fruit crops is fruitful for high forage and fruit production (Kumar and Choubey 2008*)*. Due to increased population, poor productivity of grassland resource and deficit in forage supply and farmers inability to spare their cultivated land for forage production, it is essential to utilize the interspaces in the horticultural tree plantation as an important niche area for augmentation of forage resource availability (Ahmad *et al*, 2017) [2]. However, in formation on tree and alley crop interactions intemperate agroforestry including contributions by intercropped herbaceous legumes to soil quality andconservation is inadequate, therefore, research aimedat exploring new species is needed to optimizeproduction and sustainability of these systems (Jose *et al*. 2004) [14]. The majority of research on cover crops has focused on their role in cereal crop rotations (Sainju and Singh 1997; Macdonald *et al*. 2005) [27, 19] and little information is available on their role in fruit production.

Scanty information is available on the effect of forage grasses and legumes on orchard productivity. In view of this, the present investigation was carried out to evaluate various temperate grass/legume combinations under apple-based hortipastoral systems with twin objectives of forage production and orchard floor management.

Materials and Methods

A field experiment was conducted during 2016 and 2017 on 15-year old *apple* (cultivar 'Red Gold') orchard established at 4 m × 4 m spacing at the experimental farm (33° 59'23.9" N latitude, 74° 48'0.2" E longitude; 1636 m above mean sea level) of ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, India to study the effect of grass/legume mixtures (tall fescue, orchard grass, red and white clover grown as sole as well as in combinations with clean cultivation as control) on forage production, apple tree growth/yield and soil physico-chemical properties. The region is characterized by temperate climate. During experimental period, mean annual precipitation was 960mm ± 282.15, of which almost half was received from December to April. The soil was clay loam in texture with silt constituting largest fraction, neutral in reaction (pH 6.95), bulk density (g/cm^3) of 1.23, SOC concentration (0.68 %), adequate available N (490.76 kg ha^{-1}), low available Olsen P (10.4 kg ha^{-1}) and rich in available K (390 kg ha^{-1}). The experiment consisted of 9 treatment combinations. These treatments were evaluated under randomized block design with 3 replications. The rooted slips of tall fescue and orchard grass were transplanted in November-December, 2015 at 75 x 30 cm and red and white clover seed @ 5 kg/ha was sown in lines between 2 rows of grass under apple tree (plot size of 12 m x 12 m per replication). Application of 5 kg FYM and 200 g N, 100g P_2O_5 and 150 g K_2O to each tree during both years was done and the dose was increased every year in same proportion. For pasture,30 kg N and 60 kg P_2O_5 and 30 kg K_2O/ha of fertilizers were applied each year.Various growth characteristics of apple trees, like trunk girth, trunk cross-sectional area and yield efficiency of each experimental plot were calculated by using the formulae suggested by Westwood (1993) [38]. Fruit yield was calculated by weighing all the fruits harvested individually from each experimental tree and average yield was expressed as kg/ha. 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 (Ram *et al*., 2006) [26]. Soil samples for each plot were obtained by digging three profiles up to 30 cm. Composite samples from all sub plots were obtained for 0-30 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. The pH of soil was determined by Basak and Das (1998) [6]. The bulk density (g cm^{-3}) and organic carbon content were estimated by the methods given by Singh (1980) [33] and Walkley and Black (1934) [37], respectively. Available nutrients, like, nitrogen, phosphorus and potassium in soil were determined by the methods given by Subbiah and Asija (1956) [35], Merwin and Peech (1950) [20] and Olsen *et al*. (1954) [24], respectively.

The experimental data was subjected to two-way analysis of variance to determine variations and differences between treatments. Treatment mean comparisons were made using least significant difference at p= 0.05 level.

Results and discussion

Significant differences existed in yield of apple trees intercropped with different intercrops (Table 1). Maximum fruit yield was observed in leguminous crops like red (37.45 t/ha in 2017) and white clover (36.85 t/ha) followed by grass/legume combinations, while as lower fruit yield was observed in strong feeder crops like grasses as sole and clean cultivation in both the years. The data in table 1 also revealed that highest trunk girth was observed in treatment T_2 (intercropping with red clover) followed by treatment T_1 (intercropping with white clover), while as lowest trunk girth was recorded in treatments T_3 and T_4 (grass as sole) which was statistically at par with clean cultivation. Use of leguminous crops like red and white clover and their intercropping with grasses increased the trunk cross-sectional area as compared to the control (clean cultivation) and grasses as sole during both years of experimentation. Highest yield efficiency was observed in apple trees intercropped with red clover followed by white clover. The lower values of yield efficiency of apple trees were recorded when intercropped with grasses and under clean cultivation in both the years. This might be due to the reason that legumes increase the absorptive capacity of water and nutrients in upper fertile layers of soils owing to the process of biological nitrogen fixation. They also maintain slightly higher temperature which could essentially help in uptake of nutrients and increase the root concentration on the surface soils. The production can also be influenced by species, orchard site, pruning procedures, pests and diseases and above all the rootstocks. These findings are in congruence with Neilson and Hogue (1985) [23] and Gao *et al*. (2013) [23].

Data presented in table 2 revealed that the intercropping of grasses with with either red or white clover produced significantly higher total green and dry forage yields in both the years of experimentation as compared to sole stand of both grass and legume. Maximum yield was obtained by the treatment combination of tall fescue + red clover followed by orchard grass + red clover during both years. Higher yield in grass/legume combinations were also obtained by Kumar *et al*. (2005) [16] and Sharma *et al*. (2009) [30]. A mixture experiment carried out in Northern Europe and Canada revealed that mixing red and white clover with timothy (*Phleum pratense* L.) and smooth meadow grass (*Poa pratensis* L.) had positive diversity effect leading to increased herbage dry matter yield than in monocultures (Sturludottir *et al*., 2013) [34].

Various orchard floor management practices under present investigation (table 3) had no significant effect on soil pH which is in conformity with the findings of Raina (1991) [25] who studied the effect of mulching, herbicides, legumes and clean cultivation on growth, yield and leaf nutrient status of Royal Delicious apple trees and recorded no significant change in soil pH.

It is clear from the data presented in table 3 that organic carbon (%) varied significantly under different agroforestry systems, maximum soil organic carbon (0.85 %) was found in T_2 (Red clover + Apple) followed by T_1 (White clover + Apple), which, however remained statistically at par with the organic carbon contents as observed in the grass/legume combinations and differed significantly from all other agroforestry systems including clean cultivation (T_9). Organic carbon content is affected by leaf litter, higher rate of turnover of minute rootlets, death and decomposition of roots and exudation of organic chemicals and hence organic carbon of soil will also increase (Waisel *et al*., 1991) [36]. The lower values of bulk density in the soils during 2017 can be ascribed to higher soil organic carbon content in these systems except clean cultivation. These findings are in agreement with the findings of Senneh (2007) [28], who also reported higher values of bulk density in cultivated soil in comparison to grass land and forest ecosystems.

The present study revealed that highest available soil N was observed under red clover followed by white clover and grass/legume combinations when intercropped with apple trees. The lowest available soil N was observed with clean cultivation and grasses as sole treatments. This might be due to the reason that continuous cultivation causes greater loss of N from the soil and damage the root system. Available soil phosphorus was higher under red clover treatment followed by white clover, while lowest available soil phosphorus was recorded under feeder crops like grasses as sole and clean cultivation. This might be due to the reason that clovers have deep roots from which they draw the nutrients, partly for their own requirement and partly for the tree requirement. It has also been reported that under sod culture the roots are infected with vesicular arbuscular mycorhizae which can improve phosphorus uptake. These results are in congruence with Wheeler (1970) [39] and Atkinson and White (1980) [5] who while studying the nutrient requirements of fruit trees observed highest available soil P under clover treatments as compared to the clean cultivation. Available soil K also followed similar trend in both years of experimentation. This might be due to the reason that the competition for nutrients by the crop itself as well as by trees was found less under intercropping system with legumes than control (clean cultivation) and grasses as sole.

With deterioration of pasture lands and no significant expansion of other forage resources, there is an increase in the demand of green fodder, especially during the winter (Ahmad *et al*., 2016) [3]. Orchard floor management practices involving grasses and legumes (hortipastoral systems) are important to augment forage resource availability and improve orchard floor.It can be concluded that apple trees intercropped with, red and white clover and their combinations with grasses like, tall fescue and orchard grass resulted in better productivity and increase in soil physico-chemical properties and proved to be beneficial for sustainable fruit and livestock development.

Plate 1: Photographs showing different apple based agroforestry systems at ICAR-CITH experimental farm, India. White clover + Apple (A), Tall fescue + Apple (B), Orchard grass + Apple (C), Harvesting of forages under cut and carry system (D), Tall fescue + red clover + Apple (E) and Control plot without grasses/legumes (F).

Table 1: Effect of grasses and/or legumes on yield characters in apple cv. Red Gold

Treatments	Fruit Yield (Kg/tree)		Trunk girth (cm)		Trunk cross-sectional area (cm^2)		Yield efficiency (kg/cm^2)	
	2016	2017	2016	2017	2016	2017	2016	2017
T_1: White clover+Apple	30.45	36.85	38.20	39.90	116.18	126.75	0.262	0.291
T_2: Red clover+ Apple	31.20	37.45	39.20	41.00	122.34	133.84	0.255	0.280
T_3: Tall fescue+ Apple	27.45	27.45	37.10	37.40	109.59	111.37	0.251	0.246
T_4: Orchard grass+ Apple	27.78	28.75	37.20	37.50	110.18	111.96	0.252	0.257
T_5: Tall fescue + white clover+ Apple	28.75	33.16	38.00	39.70	114.97	125.48	0.250	0.264
T_6: Tall fescue + red clover+ Apple	28.65	32.62	37.20	38.80	110.18	119.86	0.260	0.272
T_7: Orchard grass + white clover+ Apple	28.46	32.65	37.40	39.10	111.37	121.72	0.256	0.268
T_8: Orchard grass + red clover+ Apple	28.84	32.45	37.20	38.90	110.18	120.48	0.262	0.269
T_9: Control (Clean cultivation)	26.45	27.40	36.10	37.20	103.76	110.18	0.255	0.249
$CD_{0.05}$	0.09	0.23	0.06	0.08	0.33	0.50	0.001	0.001

Table 2: Effect of grasses and/or legumes on green fodder and dry fodder yield

Treatments	Green fodder yield (t/ha)		Dry fodder yield (t/ha)	
	2016	2017	2016	2017
T_1: White clover+Apple	13.20	16.35	4.63	5.92
T_2: Red clover+ Apple	16.10	22.84	5.82	6.84
T_3: Tall fescue+ Apple	21.24	27.60	7.63	8.4
T_4: Orchard grass+ Apple	19.10	25.54	6.92	7.86
T_5: Tall fescue + white clover+ Apple	21.40	27.31	8.1	10.65
T_6: Tall fescue + red clover+ Apple	26.20	32.74	9.34	12.1
T_7: Orchard grass + white clover+ Apple	21.40	26.45	7.94	8.12
T_8: Orchard grass + red clover+ Apple	23.70	29.74	7.81	10.45
T_9: Control (Clean cultivation)	0.00	0.00	0.00	0.00
$CD_{0.05}$	0.04	2.33	0.031	0.036

Table 3: Effect of grass/legume combinations on soil physicochemical properties

Treatments	pH		Bulk density (g/cm^3)		Organic carbon (%)	
	2016	2017	2016	2017	2016	2017
T_1: White clover+Apple			1.31	1.28	0.750	0.890
T_2: Red clover+ Apple			1.30	1.27	0.763	0.920
T_3: Tall fescue+ Apple			1.29	1.28	0.700	0.713
T_4: Orchard grass+ Apple			1.31	1.29	0.690	0.720
T_5: Tall fescue + white clover+ Apple			1.30	1.28	0.710	0.800
T_6: Tall fescue + red clover+ Apple			1.29	1.28	0.720	0.800
T_7: Orchard grass + white clover+ Apple			1.31	1.28	0.723	0.793
T_8: Orchard grass + red clover+ Apple			1.30	1.28	0.730	0.803
T_9: Control (Clean cultivation)			1.29	1.29	0.693	0.660
$CD_{0.05}$	NS	NS	NS	0.001	0.04	0.03

Table 4: Effect of grass/legume combinations on soil nutrient availability

Treatments	Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2016	2017	2016	2017	2016	2017
T_1: White clover+Apple	447.08	492.180	15.68	16.940	441.90	449.403
T_2: Red clover+ Apple	444.67	505.453	16.84	17.920	446.56	454.063
T_3: Tall fescue+ Apple	375.15	393.650	12.94	13.240	405.32	412.823
T_4: Orchard grass+ Apple	392.64	394.200	12.92	14.100	408.34	415.843
T_5: Tall fescue + white clover+ Apple	412.66	432.350	14.24	16.320	433.90	441.403
T_6: Tall fescue + red clover+ Apple	413.44	428.320	14.94	16.940	437.48	444.983
T_7: Orchard grass + white clover+ Apple	410.80	424.383	14.32	16.360	431.56	439.063
T_8: Orchard grass + red clover+ Apple	415.41	428.650	14.92	16.403	432.69	440.193
T_9: Control (Clean cultivation)	378.52	379.787	11.89	11.740	413.11	420.613
$CD_{0.05}$	21.76	8.21	0.09	0.13	0.001	0.001

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