02 RESEARCH ACHIEVEMENTS

P-2 : CONSERVATION MEASURES FOR SUSTAINABLE PRODUCTION SYSTEM

P-2.1: RESOURCE CONSERVATION MEASURES FOR ARABLE LANDS

Evaluating the effect of organic amendments on resource conservation and productivity of rainfed semi-arid vertisols (M. Prabhavathi and S.L. Patil-Ballay)

The field experiment was laid out during 2017-18 to know the effect of organic amendments on resource conservation and productivity of winter sorghum under rainfed semi-arid Vertisols. The experiment consists of five treatments, viz. T_1: Recommended rate of fertilizers (RRF) + FYM @ 5 t ha^{-1} (control/farmer's practice), T_2: T_1 + Biochar at 2.5 t ha^{-1}, T_3: T_1 + Biochar at 5.0 t ha^{-1}, T_4: T_1 + Biochar at 10 t ha^{-1} and T_5: T_1 + Biochar at 20.0 t ha^{-1}, was laid out in an RBD (plot size: 8 m × 5.4 m) with four replications. The soil is clayey, with pH 8.52, EC 0.25 dS m^{-1}, and available N, P and K contents being medium, medium and high, respectively. During 2017, a total of 709.5 mm runoff producing rainfall was received in 14 storms. Runoff varied from 151 to 319.8 mm across all the treatments, while soil loss ranged from 4.07 to 7.19 t ha^{-1} (Table 1). Both runoff and soil loss were lower under the treatment with biochar applied at 20 t ha^{-1}. Higher amount of potassium was lost through runoff as compared to nitrogen and phosphorus. Sorghum was sown on 19.9.2017 and harvested on 22.1.2018. Higher grain yield was recorded under the treatment T_4 (1.29 t ha^{-1}), wherein biochar was applied at 10 t ha^{-1} along with RRF, which was about 75% higher than T_1 (control, RRF). Similar was the trend observed in straw yield with 25.0 t ha^{-1} straw yield recorded under T_4. The organic carbon content in the sediments varied from 14.2 to 34.5 kg ha^{-1}, and the clay content also varied from 24.6 to 32.4% under different treatments.

Table 1: Effect of different rates of biochar application on runoff, soil and nutrient losses and sorghum yield

Treatment	Runoff (mm)	Soil loss (t ha^{-1})	Nutrient loss (kg ha^{-1})			Sedimentcontains		Sorghum yield	
			N	P	K	clay (%)	OC (kg ha^{-1})	Grain	Straw
								(kg ha^{-1})	
T_1	319.8	7.19	3.2	1.05	26.4	32.4	34.5	728	1688
T_2	265.0	6.84	2.9	0.96	23.2	30.5	29.4	982	2063
T_3	217.7	6.15	2.4	0.72	19.1	28.1	25.2	1141	2313
T_4	192.4	5.23	2.3	0.60	15.5	26.3	20.4	1287	2500
T_5	151.0	4.07	1.8	0.47	11.7	24.6	14.2	1175	2375
CD ($P = 0.05$)								360	384

Effect of varying water regimes on Zn and N dynamics and rice productivity in saline vertisols (M. Prabhavathi and H. Biswas-Ballary)

A field experiment was conducted to study the effect of water regimes and nutrient combinations (Zn & N) on rice (cultivar - TRY 3 with high Zinc use efficient index) productivity and quality in saline Vertisols during 2017-18. The soil was clayey with pH 8.3, electrical conductivity (EC) 5.3 dS m^{-1}, organic carbon 0.24%, available N 194 kg ha^{-1}, available P 20.2 kg ha^{-1}, available K 414 kg ha^{-1} and available Zn 0.58 mg kg^{-1}. Fertilizer treatments consisted of Zn and N each at 3 levels which were applied in the form of $ZnSO_4$ and Urea. Three irrigation regimes *viz.,* continuous flooding (CF), Alternate wetting and drying (AWD) and saturated soil culture (SSC) were treatments that were imposed from 10 days after transplanting to maturity. The AWD regime plots were irrigated when water levels in field water tube (perforated PVC tube) drops below 15 cm from the surface whereas in SSC regime, plots were maintained at 1 cm of ponded water depth a day after the disappearance of water. The experimental design was a split plot with three replications. Results show that Greater plant height of 57.4 cm was recorded in continuous flooding (M_1) and lower plant height of 52.2 cm was observed in saturated soil culture (M_3) (Table 2). Among different combinations of zinc and nitrogen application $Zn_{37.5}$ N_{150} (S_6) recorded greater plant height of 63.3 cm.

Among the different treatment combinations, AWD moisture regime with $Zn_{37.5}$ N_{150} (S_6) produced taller plants at tillering stage (72.9 cm). Higher leaf area index (LAI) of 2.47 and 3.72 was recorded in M_1 and S_6, respectively (Table 1). Among different treatment combinations, M_1S_6 recorded higher LAI of 4.73 and more number of tillers hill^{-1} (11.7). Water management practices had not showed any significant influence on chlorophyll index at panicle initiation stage. Among nutrient applications, S_6 treatment recorded significantly higher chlorophyll index (11.51) and lower chlorophyll index was observed in S_4 (3.68) treatment. Paddy yield was not significantly influenced by water management practices (Table 2). Greater yield was noticed with M_3 and was at par with M_1 and M_2. Among nutrient applications, S_6 treatment recorded significantly higher yield (6111 kg ha^{-1}) and lower yield was observed in S_4 (1667 kg ha^{-1}) treatment. Application of zinc and N and adoption of water saving irrigation techniques in place of continuous flooding in paddy cultivation improved plant growth and chlorophyll content index apart from saving water under water scarce situations in Tungabhadra canal area.

Table 2: Effect of moisture regime and nutrient application on Paddy yield and plant height and leaf area index at tillering stage

Treatments	Plant height (cm)				Leaf area index				Paddy yield (kg ha^{-1})			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	43.4	41.3	46.2	43.6	1.82	2.56	2.14	2.17	1800	2133	2467	2133
S_2	59.5	59.0	54.3	57.6	2.71	2.25	2.47	2.47	3733	4400	4867	4333
S_3	69.5	59.5	60.6	63.2	1.94	3.30	3.20	2.81	6467	4533	6733	5911
S_4	42.7	49.7	43.0	45.1	1.74	2.25	1.08	1.69	2000	1467	1533	1667
S_5	61.6	53.9	53.0	56.8	0.70	1.05	2.77	1.51	6467	5267	5733	5822
S_6	65.3	72.9	51.7	63.3	4.73	3.06	3.36	3.72	5867	6067	6400	6111
S_7	44.6	48.0	46.2	46.3	2.59	1.59	2.38	2.18	1533	2367	2333	2078
S_8	68.7	51.5	55.9	58.7	2.45	3.55	1.76	2.59	5200	6067	6267	5844
S_9	61.3	66.6	58.7	62.2	3.56	2.29	2.25	2.69	6467	5933	5267	5889
Mean	57.4	56.1	52.2		2.47	2.43	2.38		4393	4248	4622	
CD (*P=0.05*)	M=5.7 ; S=6.18; M×S=S				M= 1.51 ; S= 1.46; M×S= NS				M= 834 ; S= 1343; M×S= NS M at S= 2336; S at M= 2327			

M_1: Continuous flooding, M_2: Safe AWD, M_3: Saturated soil culture, S_1: Zn_0N_0; S_2: Zn_0N_{125}; S_3: Zn_0N_{150}; S_4: $Zn_{37.5}$ N_0; S_5: $Zn_{37.5}$ N_{125}; S_6: $Zn_{37.5}$ N_{150}; S_7: $Zn_{50}N_0$; S_8: Zn_{50} N_{125}; S_9: Zn_{50} N_{150}

***In-situ* moisture conservation practices under aonla based agro-forestry system for sustainable production in red soils of Bundelkhand (**Dev Narayan, RS Yadav-Datia)

The study was initiated in 2010 to evolve a suitable for *in-situ* rain water harvesting practice for higher growth and yield of Aonla in agri-horti system in red soils of Bundelkhand. Four treatments viz. i) farmer's practice of aonla planting with 0.027 m^3 pit, ii) Pit filled up to 0.75 m with 1 m^3 pit, iii) crescent shape micro-catchment with 1 m^3 pit and iv) V- Shape micro-catchment with 1 m^3 pit at 2.00 per cent slope plots (14 m x 21 m) were laid in RBD with four replications. Six aonla plants (7m x 7m) in each plot were accommodated and black gram- Indian mustard cropping system was followed.During the year 2017, black gram was sown July 1 and harvested on September 26, 2017. The rainfall received during crop period was 421 mm, of which 308 mm with seven runoff producing storms occurred. The results of seven years indicated that the runoff, soil and nutrient losses (N, P and K) reduced significantly under different treatments over farmer's practice of aonla planting (Table 3). Runoff in terms of per cent of rainfall reduced by 2.00, 5.00 and 16.0 per cent under pit filled up to 0.75 m, crescent shaped and V-shaped micro-catchment respectively, over farmer's practice of aonla planting. Similarly, the soil loss reduced by 17.0, 28.0 and 55.0 per cent under pit filled up to 0.75 m, crescent shaped and V-shaped micro-catchment, respectively, over farmer's practice of aonla planting. While, Organic Carbon reduced by 32.0, 50.0 and 64.0 per cent, N reduced by 22.0, 39.0 and 39.0 per cent, P reduced by 11.0, 33.0 and 33.0 per cent and K reduced by 11.0, 22.0 and 33.0 per cent under pit filled up to 0.75 m, crescent shaped and V-shaped micro-catchment, respectively, over farmer's practice of aonla planting. The fruit yield of aonla and seed yield of inter crops increased under *in-situ* rain water harvesting practice (Table 4). The grain yield of black gram increased by 25.0, 54.0 and 73.0 per cent under pit filled up to 0.75 m, crescent shaped and V-shaped micro-catchment, respectively, over farmer's practice of aonla planting. The seed yield of Indian mustard increased by 38.0, 15.0 and 64.0 per cent under pit filled up to 0.75 m, crescent shaped and V-shaped micro-catchment, respectively, over farmer's practice of aonla planting. The fruit yield of aonla also increased by 9, 4 and 36% under pit filled up to 0.75 m, crescent shaped and V-shaped micro-catchment, respectively, over farmer's practice of aonla planting. Irrespective of water conservation measures, soil analysis revealed that mean soil organic carbon (5.22 g kg^{-1} soil) at 0-15 cm soil depth under canopy of aonla found higher as compared to open canopy (4.62 g kg^{-1} soil). There was no perceptible impact of canopy cover of the tree on availability of P and K. Soil pH under canopy was found slightly lower by 0.07 units compared to open canopy.

Table 3: Runoff soil loss and Nutrient loss as influenced by different treatments during 2017 and mean of 7 years

Treatment	Runoff				Soil loss ($t\ ha^{-1}$)		Nutrient loss ($kg\ ha^{-1}$)							
	(mm)		(%)				OC		N		P		K	
	2017	Mean (7 yr)	2017	Mean (7 yr)	2017	Mean (7 yr)	2017	Mean (7 yr)	2017	Mean (7 yr)	2017	Mean (7 yr)	2017	Mean (7 yr)
Farmer's practice	61.2	122	19.9	26.7	1.21	2.66	4.40	11.5	1.80	4.10	0.90	1.90	2.70	5.70
Pit filled up to 0.75 m	60.3	106	19.6	22.6	1.03	1.99	3.00	8.60	1.40	3.40	0.80	1.60	2.40	5.00
Crescent shape	58.3	96.1	18.9	20.8	0.89	1.73	2.20	7.50	1.10	3.00	0.60	1.50	2.10	4.30
V shape	51.3	83.4	16.7	17.7	0.56	1.26	1.60	5.50	1.10	2.80	0.60	1.30	1.80	3.70
C.D. (P=0.05)	6.00	-	2.00	-	0.14	-	0.50	-	0.20	-	0.10	-	0.40	-

Table 4: Seed yield of inter crops (black gram and Indian mustard) and fruit yield of aonla as influenced by different treatments

Treatment	Yield of inter crops ($kg\ ha^{-1}$)				Fruit yield of aonla ($q\ ha^{-1}$)
	Black gram		Indian mustard		
	2017	Mean (7 yr)	2017	Mean (7 yr)	2017
Farmer's practice	109	265	523	985	70.0
Pit filled up to 0.75 m	136	316	719	1194	76.1
Crescent shape	168	347	599	1156	73.0
V shape	190	392	859	1412	95.3
C.D. (P=0.05)	NS	-	NS	-	NS

Restoration of shifting cultivated lands for resource conservation and sustainable production in Eastern Ghats.(D.C.Sahoo, P.P. Adhikary, Praveen and Karma Beer –Koraput**)**

The study conducted on restoration of shifting cultivated land to develop management/restoration strategy for resource conservation and sustainable production in Eastern *Ghats*. The experiment carried out with different treatment measures along with control (farmers practice) for two scenarios *viz*., currently under shifting cultivation and shifting cultivated area currently under fallow for restoration. Predominant crop of the region "*Ragi*" was transplanted as the test crop in the shifting cultivated area currently under cultivation. The results indicated that Better grain yield found among the treatments (11.1-13.5 q/ha) and significantly (CD (0.05) = 2.53) higher than control (7.1 q/ha). However, maximum grain yield is found in Earthen bunding + BP of *Gliricidia sepium* (13.5 q/ha) *followed by* Earthen bunding with vegetative barrier of sambuta + BP of *Gliricidia sepium* (12.3 q/ha) and Earthen bunding + Pigeon pea + BP of *Gliricidia sepium)* (11.9 q/ha) and found statistically non-significant among the treatments *may be due to the establishing phase of the conservation measures.* Similar result also found in biomass yield. Statistically non-significant with maximum biomass yield is found in Earthen bunding + BP of *Gliricidia sepium* (25.0 q/ha) *followed by* Earthen bunding + Sambuta + BP of *Gliricidia sepium* (23.3 q/ha) and Earthen bunding + Pigeon pea + BP of *Gliricidia sepium* (22.0 q/ha). Minimum runoff of 8.2% was observed in Earthen bunding with vegetative barrier of sambuta + BP of *Gliricidia sepium* followed by Earthen bunding with BP of *Gliricidia sepium* (10.4 %) and highest runoff of 18.8 % in control plot (Fig.1a) under the shifting cultivated plots. The wider difference between control and treated plots shows the positive impact of conservation measures in reducing runoff. Soil loss follows similar trend to runoff with minimum (6.4 t/ha) from the plot under *ragi* with vegetative barrier of sambuta and *Gliricidia sepium* on earthen bund. The soil loss (6.4-9.3 t/ha) from all the treated plots is in the decreasing trend over years and maximum (14.5 t/ha) in control (Fig.1b).

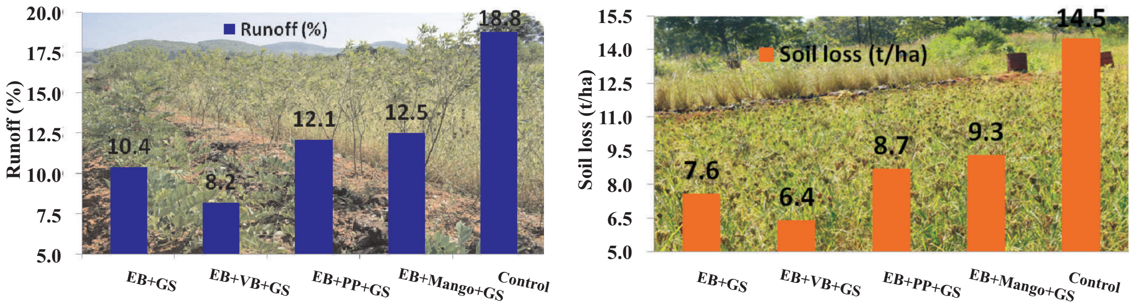


Fig.1a&b: Runoff and soil loss from cultivated plots

In the shifting cultivated fallow plots, runoff varies from minimum of 11.3% (Earthen bunding with vegetative barrier of sambuta + BP of *Gliricidia sepium)* to maximum of 19.3 % in control. The plots treated in combination of earthen bunding with *Gliricidia sepium and Gliricidia sepium* + mango also produced runoff close to minimum with 14.3 and 15.7 % respectively. The variation in soil loss among treatments (5.3-7.1 t/ha) is considerable less in comparison to the cultivated plots may due to undisturbed surface. The soil loss followed a similar trend to runoff with minimum (5.3 t/ha) in vegetative barrier of sambuta and *Gliricidia sepium* on earthen bund and maximum from control (11.5 t/ha) (Fig 2a&b).

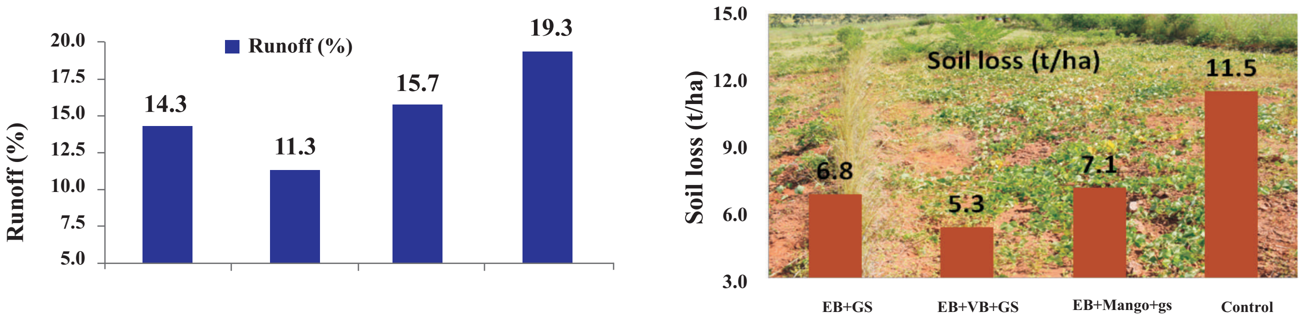


Fig.2a&b: Runoff and soil loss under fallow plots

Jhola kundi **based vegetable farming with soil moisture conservation practices for increasing profitability of tribal farmers in Eastern Ghats High Land Region** (Karma Beer, Ch. J.P. Dash and P. Jakhar- Koraput)

Study was initiated during 2017 with the objective of assessing the water availability in Jhola kundi during the post monsoon seasons for cultivation of vegetables with soil moisture conservation practices in tribal belt of Odisha. *Jhola* kundis at different location along the *Jhola* systems were selected and recuperation test of *Jhola* kundis have been conducted on monthly basis. From the recuperation study carried out during the month of December 2017 in jhola khundi with diameter of 4.5 m located at the research farm, it was observed that the total recovery period (up to depth of 2.68 m) was 18185 minutes (or 12.6 days). The initial water level depth was not obtained because of rainwater. The recuperation rate of *Jhola* kundi is 6.02 m^3/day, which is only 10 m away from *Jhola* (Fig. 3). In another recuperation test conducted at Rajbidai village having *Jhola* kundi of 2.1 diameters during December 2017, it was observed that the total recovery period (depth of 1.77 m) was 5772 minutes (or 4 days). The recuperation rate of *Jhola kundi* is 2.00 m^3/day (Fig. 4), which is about 75 m away from *Jhola* system.

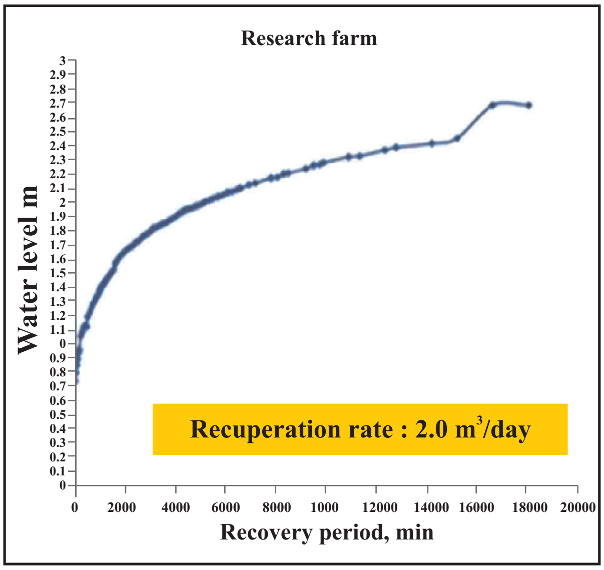


Fig. 3 : Recovery period of Rajbidai *Jhola* Kundi

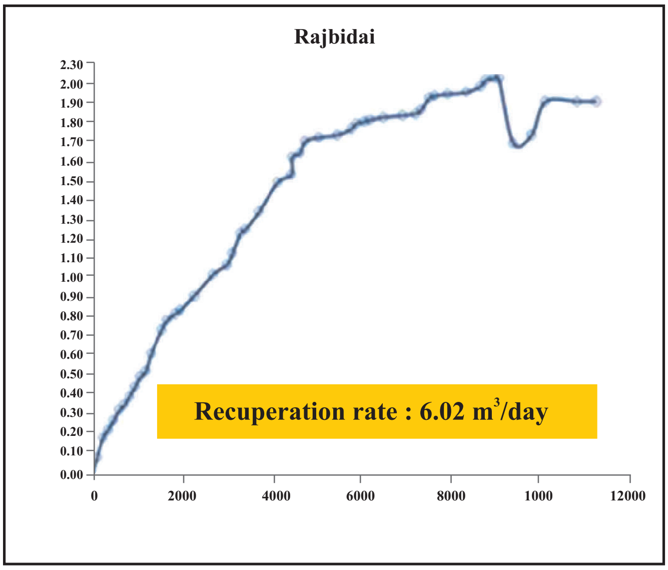


Fig. 4 : Recovery period of research farm *Jhola* Kundi

Conservation tillage systems for enhancing productivity and resource-use efficiency in rainfed area of South-eastern Rajasthan (Kuldeep Kumar, B L Mina, Shakir Ali and Ashok Kumar-Kota)

Conservation agriculture is generally referred to a way of practicing agriculture that primarily includes less tillage, incorporation of crop residue and follow-up of better crop rotation. The key features of these technologies include: (i) minimum soil disturbance by adopting no-tillage and minimum traffic for agricultural operations, (ii) leave and manage the crop residues on the soil surface, and (iii) adopt spatial and temporal crop sequences to derive maximum benefits from inputs and minimize adverse environmental impacts. When the residues are retained on soil surface in combination with zero-tillage, the enhanced biological processes lead to improved soil quality. A considerable amount of research work on conservation agriculture has been done in India and South Asia under irrigated ecosystem, but very little information is available in rainfed

Table 5: Mustard (*Rabi*) and soybean (kharif) yield, Runoff and soil loss during monsoon 2017 as affected by tillage and residue management

Treatments	Runoff (mm)	Runoff (% of rainfall)	Soil loss (t/ha)	Yield (kg/ha)	
				Mustard (2016-17)	Soybean (2017)
T_1. Conventional tillage (Farmer Practice)	36.8	7.94	1.46	1042	1085
T_2. Conventional tillage (Farmer Practice) + Residue Retention	30.8	6.65	0.68	1086	1061
T_3. Zero tillage	41.6	8.98	1.06	838	713
T_4. Zero tillage + Residue Retention	39.3	8.48	0.88	939	794
T_5. Reduced Tillage (No Primary tillage)	33.0	7.13	1.30	990	888
T_6. Reduced Tillage + Residue Retention	25.6	5.53	0.60	1027	924
T_7. Broad Bed and Furrow	38.9	8.40	1.68	1114	1079
T_8. Broad Bed and Furrow + Residue Retention	30.4	6.57	1.05	1134	1093
T_9. Permanent Broad Bed and Furrow	47.6	10.28	0.99	1029	904
T_{10}. Permanent Broad Bed and Furrow + Residue Retention	43.8	9.46	0.84	1106	869

conditions particularly in semi-arid situations. Therefore, a project has been initiated from 2015 at ICAR-IISWC, Research Centre, Kota to explore the feasibility of double cropping under rainfed ecosystem through resource-conserving practices. Soybean and mustard was grown as experimental crops during *Kharif* and *Rabi* season, respectively. The experiment was laid down in randomized block design with 10 treatments consisting of a combination of tillage, land configuration and residue management of previous crop. Residue of previous crops i.e. residue of soybean @1.5 t/ha in mustard crop and residue of mustard @ 3.0 t/ha in soybean crop was retained.

During monsoon 2017 the Kota region received total 463 mm *rainfall which is lower than* average seasonal rainfall of this region. The rainfall consisted of 2-3 intense storms in the month of August. Results show that reduced tillage with retention of residue of previous crop resulted in minimum runoff and soil loss. Permanent Broad Bed and Furrow produced maximum value of runoff while maximum value of soil loss was observed in broad bed and furrow treatment (Table 5). Rainfed mustard crop was raised on residual soil moisture after giving a light pre sowing irrigation to ensure proper germination just after harvesting of *Kharif* soybean. Maximum mustard yield was obtained with broad bed and furrow treatment while zero tillage recorded lowest yield among all the treatments. During Kharif season of 2017 maximum soybean yield was recorded with broad bed and furrow in combination with residue retention of previous crop while zero tillage with no residue retention recorded lowest soybean yield. Maximum mustard yield was obtained in BBF+residue retention treatment followed by Permanent BBF+residue while zero tillage recorded lowest mustard yield during Rabi season of 2016-17.

Resource conservation and productivity enhancement through organic and inorganic amendments in soybean-mustard cropping system (I.Rashmi, B.L.Mina, Kuldeep K, Shakir Ali, Ashok Kumar-Kota)

A field experiment was carried out in 2017-18 at Research farm, Kota to study the effect of organic and inorganic amendments in soybean mustard cropping system on resource conservation and crop productivity in soybean mustard cropping system. Eight treatments of soybean – mustard cropping system are T1: Control; T2: Recommended Dose of Fertilizer (RDF) (Soybean-Mustard); T3: RDF + Gypsum; T4: RDF + FYM (10t/ha); T5: RDF + Mulches (previous crop residues will be used as per requirement); T6: RDF+ Gypsum + Mulch; T7: RDF+ Gypsum + FYM; T8: RDF + Gypsum + Mulches + FYM. Results show that Among the different treatments soybean grain yield ranged from 728.5 to 1798 kg/ha and straw yield ranged from 1769 to 2744.3 kg/ha. Maximum grain production was observed in T6 treatment (RDF+ Gypsum + Mulch) as shown in the Table 6. Application of gypsum and mulch showed significant effect on soybean yield. Rainfall received during crop period was 495 mm of which 220 mm rainfall produced four runoff storm events. Meagre rainfall (<5mm) was received during the first two weeks after sowing, and after 4^{th} week 3 runoff events were recorded. After 5^{th} week of crop sowing again meagre rainfall (5-6mm) was received. Runoff varied from 5.8 to 6.8 % of rainfall produced by runoff (table 1). Similarly soil loss ranged from 85 to 116 kg/ha. Among the various treatments, T6: RDF+ Gypsum + Mulches followed by T8: RDF+ Gypsum + Mulches + FYM showed least runoff and soil loss. The highest runoff, soil and nutrient loss was observed in control plots with no application of amendments. Application of crop residue as mulch alongwith FYM and gypsum was effective in reducing runoff and soil loss over control treatment.

Table 6: Runoff, soil and nutrient loss under different treatments during 2017-18

Treatments	Runoff (mm)	Runoff (%)	Soil loss (kg ha^{-1})	Nutrient loss (kg/ha)			Yield(kg ha^{-1})	
				N	P	K	Grain	Stover
T1	14.9	6.8	115.6	0.86	0.02	2.9	728.5	1769.3
T2	14.2	6.5	98.5	0.72	0.02	5.2	1189.6	2033.0
T3	13.6	6.2	89.5	0.89	0.02	4.10	1319.5	2278.1
T4	13.3	6.1	92.1	1.1	0.02	5.17	1365.9	2339.1
T5	14.1	6.4	90.9	1.05	0.03	6.1	1542.5	2530.5
T6	12.6	5.8	84.5	0.81	0.02	4.11	1798.0	2744.3
T7	14.1	6.4	102.4	1.02	0.03	5.30	1396.0	2439.4
T8	13.3	6.1	85.5	0.74	0.01	4.27	1726.6	2578.0

Cover crops and reduced tillage for enhancing productivity and soil health in rainfed farming system in the hilly area (K. Kannan, V. Kasthuri Thilagam, P. Raja and O.P.S. Khola- Udhagamandalam)

A study was initiated during 2014 with objective of assessing the productivity of potato –carrot cropping sequence and soil health under reduced tillage and cover crop system with respect to climate resilience farming. The treatments included:

conventional tillage (M_1) and reduced tillage (M_2) in main plot and winter cover crops: No cover crops (S_1), Oats (S_2), Lupin (S_3), Buck wheat (S_4) and Mustard (S_5) as sub plot. During the reporting period, potato during I season (March to June) and carrot during II season (July to October) were taken up under two tillage treatments. Cover crops were sown during November 2017 and harvested during January to February, 2018 for cover crops.There was no significant effect on potato yield due to tillage treatment (Table 7). Higher yield of potato achieved with mustard followed by oats and buckwheat.

Table 7: Potato yield under tillage and cover crop treatments

Treatments	Potato yield (t ha^{-1})		
	Conventional tillage	Reduced tillage	Main plot Mean
No cover crop	19.1	18.1	18.6
Fodder oats	23.5	21.6	22.6
Lupin	22.7	18.8	20.8
Buckwheat	21.6	21.5	21.5
Mustard	22.8	22.4	22.6
Main plot Mean	22.0	20.5	
CD(P=5%) Tillage :NS Cover crop: 2.16			

The days to 50% flowering of different cover crops were 55, 62, 75 and 100 days for buckwheat, mustard, fodder oats and lupin. At 50 % flowering, cover crops were cut to the ground level and kept as mulch. The highest biomass at (3.2 t ha^{-1}) quickest time (55 days) was achieved with buckwheat and the highest biomass at flowering was recorded in oats(4.8 t ha^{-1}), followed by mustard (4.3t ha^{-1}). The highest N (76.8 kg), P (17.2 kg) addition per hectare due to cover crops incorporation was observed in fodder oats & K (27.5 kg) in mustard under reduced tillage (Table 8). Higher soil moisture was observed under reduced tillage and cover crops compared to the conventional tillage and without cover crop.

Table 8: Biomass Yield and nutrient addition by cover crops

Cover crops	Biomass Yield (t ha^{-1})		Nutrient addition (kg ha^{-1})					
	CT	RT	CT			RT		
			N	P	K	N	P	K
Buck wheat	2.9	3.2	46.4	14.9	9.5	51.2	16.3	10.5
Lupin	2.1	1.8	34.4	11.4	13.4	29.5	9.7	11.5
Mustard	4.1	4.3	61.5	15.9	26.2	64.5	16.7	27.5
Oats	4.5	4.8	72	16.2	24.3	76.8	17.2	25.9

The highest cover crop residue cover at the time of planting potato was found in mustard followed by fodder oats.

P-2.2: RESOURCE CONSERVATION MEASURES FOR NON-ARABLE LANDS

Improvisation of Soil Working Techniques for Enhancing Tree Establishment under Rainfed Conditions of North-Western Himalayas (D.V. Singh, J. Jayaprakash, D.M. Kadam and Vibha Singhal-D.Dun)

In North-Western Himalayas, majority of tree planting in degraded areas suffers from major problem of water scarcity during lean period. Also, farmers encounter the problem of low survival rate of fruit saplings due to moisture deficiency occurred during dry season. Therefore, a study was initiated during 2016-17 as an action research project in order to develop effective soil working technique which can counter water scarcity problem and enhance tree establishment under rainfed conditions of North-Western Himalayas. It has been widely reported that in sub-surface soil, moisture is retained even during dry period but there is restricted supply of oxygen and nutrients. These issues have been attempted to address through an innovative method of sub-surface planting. In this method of soil working technique, planting has been tried, 20-30 cm below the soil surface through a low quality PVC pipe for keeping the saplings' stems not in contact with surface soil.In Dhanpau-Lakhwar area, two field experiments on forestry had conducted, one each on southern and northern aspects. These sites were selected in consultation with Eco-Task Force and *Van Panchayat Samiti*. Experiment on agri-horticulture was conducted at farmer's field in Pasauli village. For forestry species, *Ritha* was planted on northern aspect with seven treatments while *Bahera* on southern aspect was planted with eight treatments during last year. Under agri-horticulture, mango was planted with six treatments. These field experiments have been laid in Randomized Block Design (R.B.D.) with three replications.

Sub-surface planting of mango sapling

Sub- surface planting of Ritha sapling

During the period of report, data on tree survival, plant height and collar diameter have been recorded for both forestry species and depicted in Fig. 5 to 6. It is pertinent to note that *Ritha* had 100 per cent survival rate under all seven treatments due better moisture availability on northern aspect. Since *Bahera* is planted on southern aspect, the survival rate was varied from 94.4 to 100 % but the difference was not significant. It is also observed that application of hydrogel had shown negative effect on both plant height and collar diameter in *Ritha* whereas in case of *Bahera* only plant height was negatively affected by hydrogel application. Generally in both the plantations, higher values of survival rate, plant height and collar diameter were observed in treatments where sub-surface planting through PVC pipe was introduced.

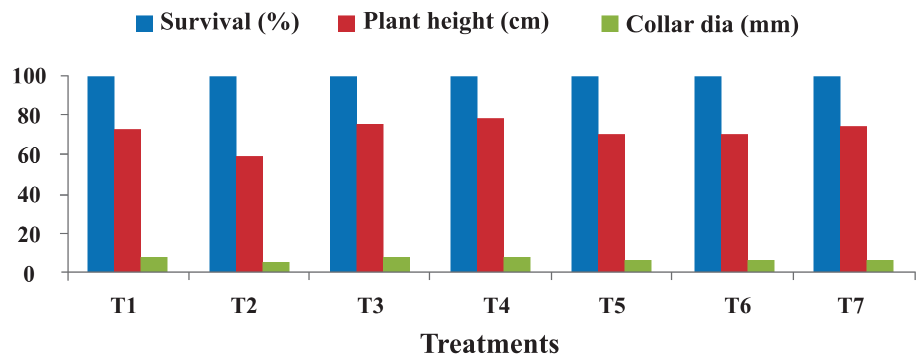


Fig- 5. Plant growth of *Ritha* after one year of planting under different treatments

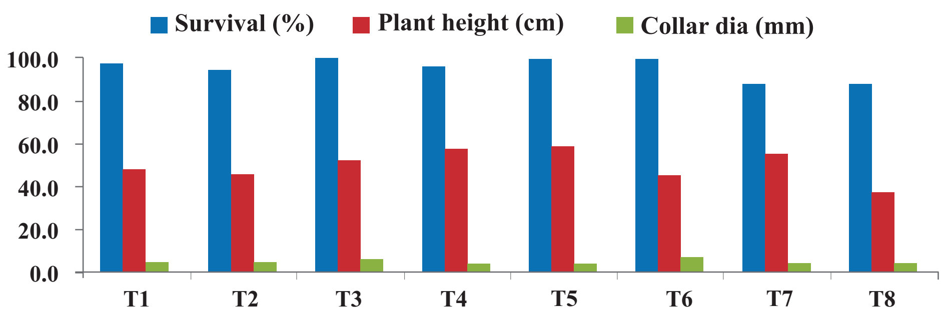


Fig -6: Plant growth of *Bahera* after one year of planting under different treatments

Data on different growth parameters like plant height, collar diameter, number of leaves, number of branches and plant survival have been recorded for mango planted under agro-forestry system and presented in Table 9. It could be seen from this table that significantly higher plant height, collar diameter and number of leaves were observed under all three treatments (T3, T5 and T6) where modified sub-surface planting through PVC pipe was adopted. Also, highest plant survival of 95.8 to 100 % was observed in these treatments but this parameter did not vary significantly.

Table -9: Plant growth and survival of mango under different treatments

Treatment	PlantHeight(cm)	Collar dia at 45 cm h (mm)	No. of leaves	No. of branches	Survival %
T1	67.2	10.3	55.3	4.7	85.6
T2	77.6	14.6	56.3	5.3	86.6
T3	100.1	18.9	93.3	9.3	100.0
T4	83.9	15.2	66.0	7.7	94.4
T5	97.3	15.8	92.7	11.3	100.0
T6	103.0	15.1	89.0	9.7	95.8
C.D. (at 5%)	16.3	4.2	10.7	NS	NS

Evaluation of traditional minor millet based agroforestry systems under recommended agri-silvicultural practices of North Western Himalayas: (Harsh Mehta, J.M.S Tomar and D.Mandal-D. Dun)

The experiment was laid out in August 2009 by planting 324 saplings of improved provenances of *Grewia optiva* and *Morus alba* which are the major agroforestry tree species of the North Western Himalayas primarily grown by small and marginal farmers for green tree fodder. High yielding provenances of bhimal viz. I.C. Bhaintan, I.C. Chamba and I.C. Malas were planted (54 each). Likewise 54 saplings of high yielding provenances of mulberry (S1, S146 and S1635) were planted in run off size plots 45x15 meter with uniform plant and row spacing of 5.0 x 4.25 m.Initial recordings were taken for 324 bhimal and mulberry plantations at the time of planting in respect of different growth parameters like plant height, collar diameter, as given in Fig 7&8. The mean annual increments in respect of plant height in Bhimal and mulberry were 95.88 and 104.63 cm respectively leading to very rapid growth of plants. Similarly the mean annual increments in respect of collar diameter in Bhimal and mulberry were **2.18** and 2.53 cm respectively.

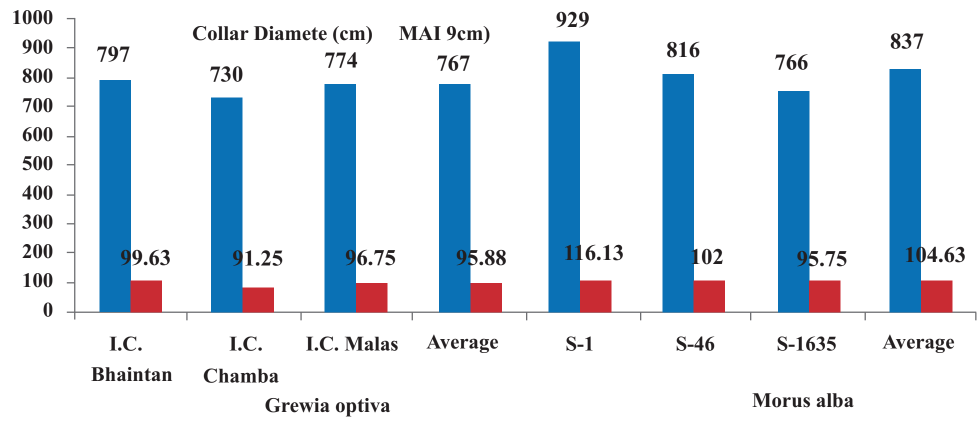


Fig- 7. Plant height and Mean Annual Increment (cm) of *Grewia optiva* and *Morus alba* in 2017.

The average productivity (Table 10) of improved varieties of finger millet and barnyard millet was 14.26 and 13.4 q ha^{-1} in comparison to 13.3 q ha^{-1} and 11.4 q ha^{-1} recorded in local varieties. The average productivity of finger millet and barnyard millet under *Grevia optiva* was 11.09 and 101.0 qha-1 while it was 9.40 and 8.54 q ha-1 under *Morus alba*, showing tree crop interactions.

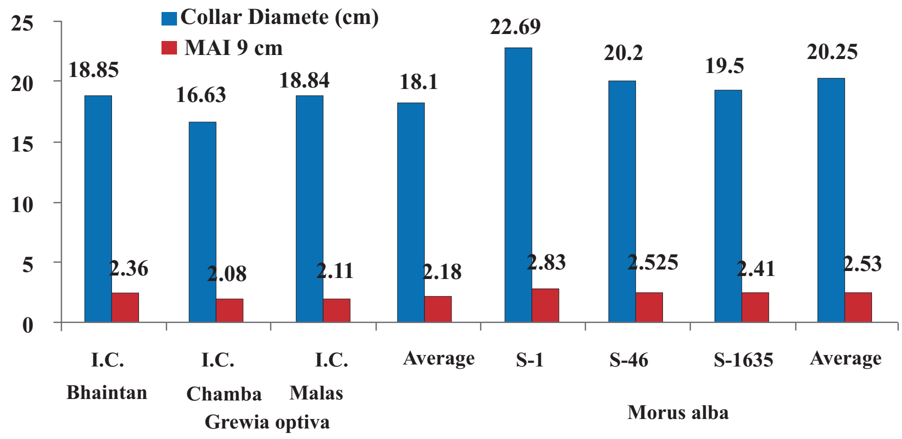


Fig -8. Collar diameter and Mean Annual Increment (cm) of *Grewia optiva* and *Morus alba* in 2017.

Table- 10. Average productivity of finger millet and barnyard millet under different agroforestry trees in kharif 2017

Crops →	**FINGER MILLET**	**Yield (q ha^{-1})**	**BARNYARD MILLET**	**Yiel (q ha^{-1})**
	Finger millet (PRM 1)	14.26(7.1 %)	Barnyard millet (PRJ 1)	13.4 (17.5%)
	Finger millet(Local)	13.3	Barnyard millet (Local)	11.4
	Av. productivity	14.25	Av. productivity	12.4
↓ Trees *Grewia optiva*	Finger millet (VR708) under *Grewia optiva*	11.85	Barnyard millet (VL Madira 207) under *Grewia optiva*	11.62
	Finger millet(Local) under *Grewia optiva*	10.32	Barnyard millet (Local) under *Grewia optiva*	9.57
	Av. productivity under *Grewia optiva*	11.09(22.2 %)	Av. productivity under *Grewia optiva*	10.10(18.5%)
Morus alba	Finger millet (VR708) under *Morus alba*	9.7	Barnyard millet (VL Madira 207) under *Morus alba*	8.67
	Finger millet (Local) under *Morus alba*	9.1	Barnyard millet (Local) *Morus alba*	8.40
	Av. Productivity Under *Morus alba*	9.40(34.0%)	Av. productivity under *Morus alba*	8.54(31.1%)

Recording of runoff and soil loss (Fig.9) in different land uses indicated that tree crop combinations were quite effective in controlling the runoff and soil loss. Mulberry and finger millet combination produced the minimum run off and soil loss followed by other tree crop combinations. Traditional crops alone were more effective than native trees.

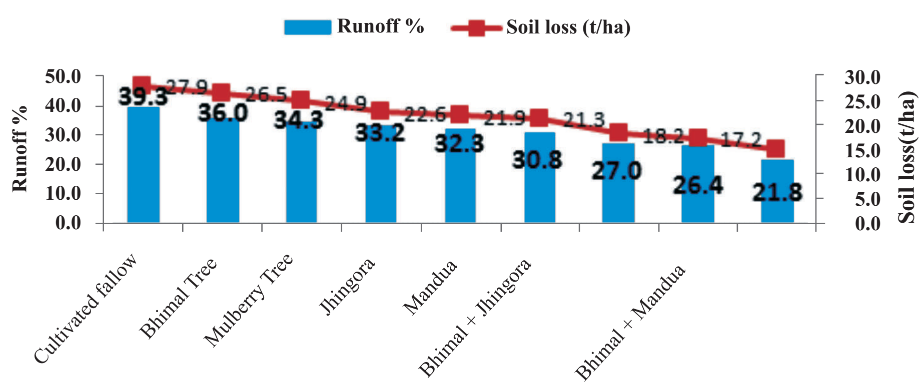


Fig- 9. Runoff and soil loss under different land uses

A

B

C

D


Finger millet grown in association with *Grewia optiva* (A) and *Morus alba* (B);
Barnyard millet grown in association with *Morus alba* (C) and *Grewia optiva* (D)

Efficacy of different soil and water conservation measures on bamboo productivity and resource conservation in Himalayan foothills (Rajesh Kaushal, Ambrish Kumar, J.M.S. Tomar and D.V. Singh-D. Dun)

The study was initiated in the year 2012 on steep sloping land (> 25%) in Timli Range of Kalsi Forest Divison near Mednipur village in District DehraDun for evaluating two species of bamboo - *D strictus* (DS) which is widely grown in foothills, while another *D hamiltonii* (DH) is being introduced as it has high productivity potential. Both the species were raised with soil conservation measures *viz*., Rectangular trenches (R), semicircular trench (S) and V-shaped ditches for improving soil moisture alongwith control (C). Growth parameters revealed that diameter and height growth were maximum in semicircular trenches in both the species (Fig 10). In DH height of clump varied from 10.8-12.7 m in different treatments while, culm diameter ranged from 5.7-6.4 cm. In DS height of clump varied from 4.5-6.0 m in different treatments while, diameter ranged from 4.03-4.99 cm. Number of new shoots were maximum 10.0 in *D. hamiltonii* when raised with S trenches. Biomass varied from 9.7 to 13.1 kg/culm in *D. hamiltonii* and 3.8-5.9 kg/culm in ***D strictus***. The maximum biomass was recorded in S trenches in both the species. Only one runoff event was recorded during the study period. Under different trenches, growth of lantana was significantly reduced. It was minimum under DH-S treatment. In 0-15 cm soil layer, soil pH, organic carbon and available P was reduced under all the treatments as compared to control. Available K however did not follow trend.

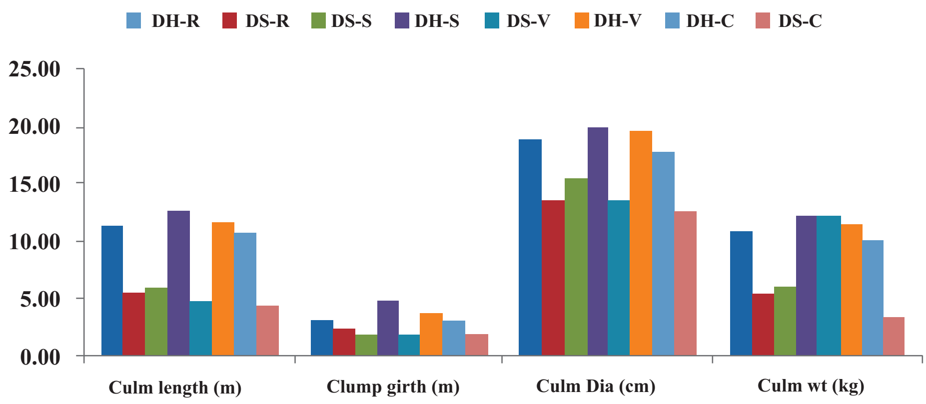


Fig-10: Effect of soil conservation measure on growth and biomass of bamboos

Development and characterization of quality planting material of MPT's for improving the productivity of degraded lands (Harsh Mehta, Rajesh Kaushal , Anand Gupta- D.Dun)

The study was initiated in the year 2012 with the aim of developing quality planting material of MPT's for improving the productivity of degraded lands. Screening provenances of Celtis australis and Bauhinia variegata under nursery and field conditions was initiated in 2013 and 2014. Planting materials of Celtis australis(Khirak) were collected from diverse locations of North-west Himalaya Uttarakhand, Himachal Pradesh and Jammu and Kashmir, from 10 districts viz., Kathua, Chamba, Kangra, Kullu, Shimla, Solan, Sirmour, Dehradun, Tehri, Almora and Nainital. Similarly for Bauhinia variegata (Kachnar), the planting materials were colleted from Uttarakhand and Himachal Pradesh with seven provenances viz., IC Ghatol, IC Sorus, IC Hamirpur, IC Bilaspur, IC Ranichauri and IC Dehradun. The healthy sapling of provenances were planted in the field conditions at the Selakui farm in randomized block design with three replications.Maximum plant height of 6.39 m was recorded in I.C. Solan. It was followed by I.C. Tehri (6.07 m) (Fig. 11). Maximum collar diameter of *Celtis australis* was recorded in I.C. Solan (12.77 cm) followed by I.C. Jammu (12.14 cm) (Fig. 12). Maximum DBH of *Celtis australis* was recorded in I.C. Tehri (8.05 cm) followed by I.C. Solan (7.85 cm) (Fig. 13). Likewise material of *Bauhinia variegata* is being evaluated. Under field conditions I.C. - Soras recorded the maximum plant height of 4.78 m followed by I.C. Ghatol (4.71). Maximum collar diameter of 10.1 cm was in I.C. Ghatol followed by I.C. Soras (9.68) (Fig. 14 &15). The maximum DBH of *Bauhinia variegata* was recorded in I.C. Ghatol (7.08 cm) followed by I.C. Soras (6.65 cm) (Fig. 16).

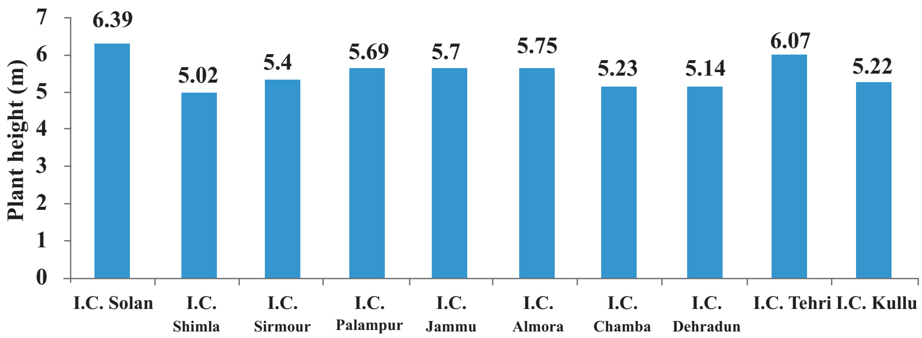


Fig- 11. Plant height (m) of different provenances of *Celtis australis* after three years of planting

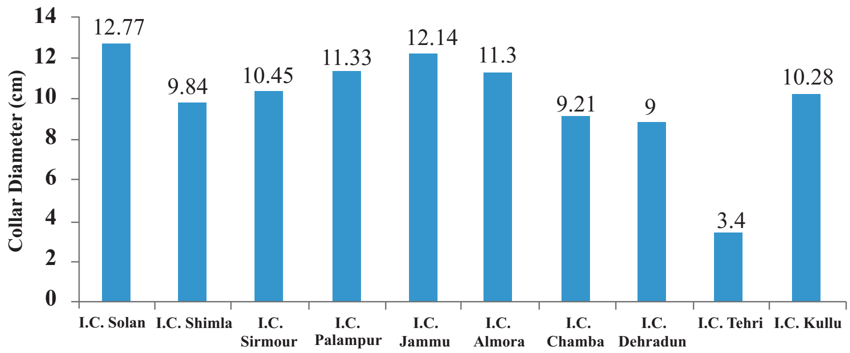


Fig- 12. Collar diameter (cm) of different provenances of *Celtis australis* after three years of planting.

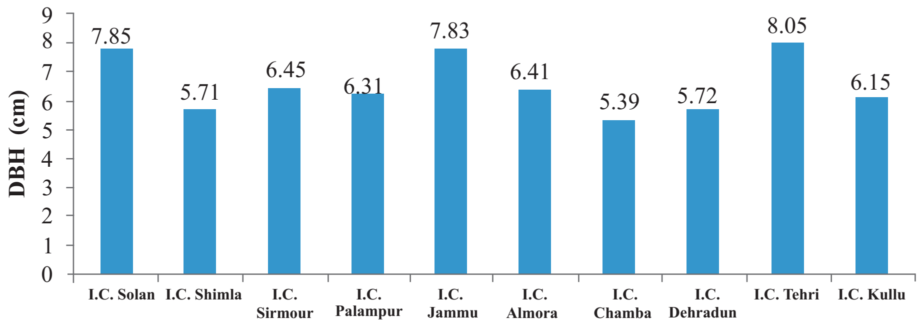


Fig-13. DBH (cm) of different provenances of *Celtis australis* after three years of planting.

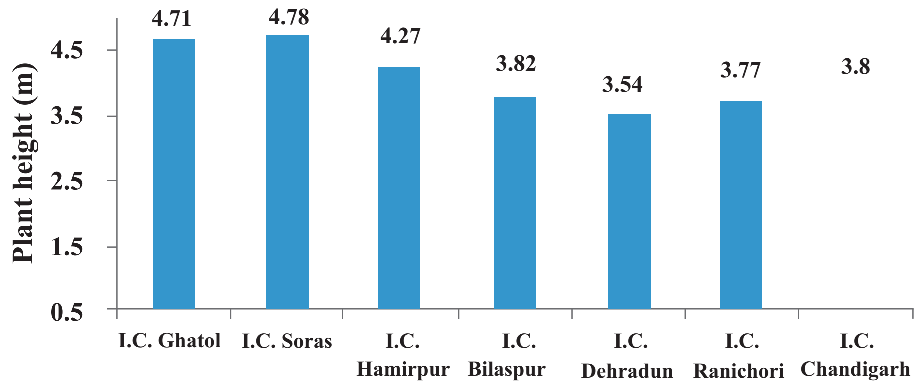


Fig-14. Plant height (cm) of different provenances of ***Bauhinia variegata*** after three years of planting.

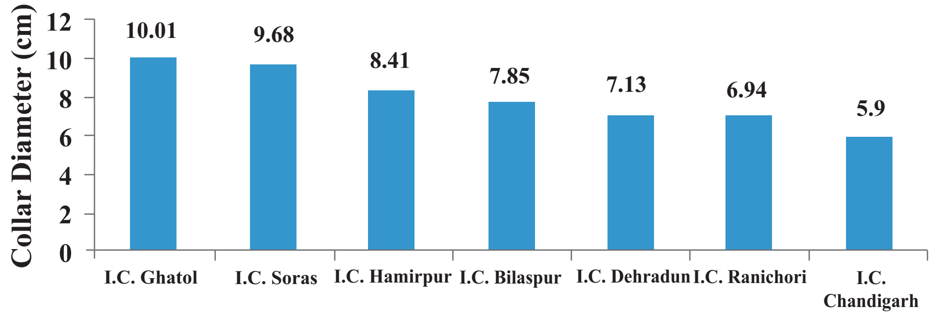


Fig-15. Collar diameter (cm) of different provenances of ***Bauhinia variegata*** after three years of planting.

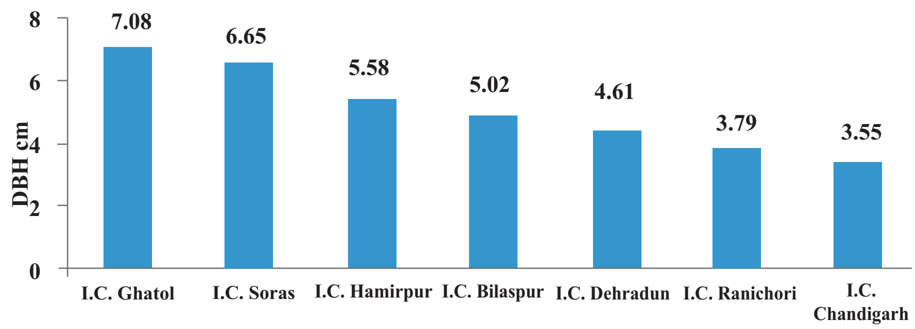


Fig-16. DBH (cm) of different provenances of ***Bauhinia variegata*** after three years of planting.

Evaluation of Bael and Olive Based Agro-forestry System with Soil Amendments in Doon Valley (J. Jayaprakash, A.C. Rathore, D.V. Singh and Harsh Mehta- D.Dun).

This experiment was started in 2015 with five objectives for production of fruit based land use system with various amendments under rainfed situation. Bael cv. NB-5 and olive cv. Barnea had been planted in 2015. The various treatment imposed were T1-Control, T2-Pressmud, T3-Rice husk, T4-Oil cake, T5-FYM, T6-Pressmud + stone mulching, T7- Rice husk + stone mulching, T8-Oil cake + stone mulching and T9-FYM+stone mulching. The results of the experiment are reported for 2016-17. Maximum plant height (65 cm) and collar diameter (1.8 cm) have been recorded in T_5 treatment which received only FYM application whereas minimum plant height (39.5 cm) and collar diameter (0.72 cm) under control treatment. Similarly, Bael plant recorded maximum plant height (73.5 cm with 1.45 cm collar diameter under T_8 treatment (Oil cake + stone mulching) and minimum plant height and collar diameter with control treatment (59.8 cm and 1.3 cm).

Soil fertility restoration and carbon sequestration potential of multipurpose indigenous tree species from western Himalayas (Vibha Singhal, Charan Singh and Trisha Roy-D.Dun**)**

The aim of the project is to to quantify the litter production of multipurpose agroforestry trees namely *Grewia optiva, Celtis australis*, *Bauhinia variegata* and *Ficus roxburghii* and to study the decomposition dynamics and its effect on the return of nutrients to the soil. 5 trees of each species in good form and health were selected .Litterfall traps(75 X75 cm) (4-5) were kept under the canopy of each tree for leaf litter collection at the end of each month. 250 leaf traps were placed under selected trees. Litter decomposition studies is being carried out by Litterbag method. followed the order *Grewia optiva* > *Celtis australis* > *Bauhinia variegata* > *Ficus roxburghii* .A uniform decomposition pattern was observed for all the four species, initially, a slower phase which followed by a rapid phase. Decomposition rate was recorded to be highest in *Celtis australis* and minimum *in Ficus roxburghii*. Decomposition studies indicate that in one year leaf litter decayed to 89.75 % in *Celtis australis* wheresas, leaf litter of *Ficus roxburghii* decomposed to 65.35 % of its original mass in the same period

Evaluation of rooting media and rootstocks of major subtropical fruit spp. for raising quality planting materials on degraded lands (AC Rathore, H Mehta, Deepak Singh, J. Jayprakash, DM Kadam-D.Dun)

This externally funded HMNEH project was started during 2015-16 for evaluating rooting media and rootstocks for mass multiplication of grafts of mango, litchi, guava, aonla, pomegranate, bael, etc. Rootstocks of mango, guava and aonla have been raised using different combinations of soil, microbes and organic manures in pots comprising eight treatments. Higher growth has been recorded in T_4 treatment (10 g AZB + 10 g PSB + Soil +FYM) for all rootstocks of mango, guava and aonla after 6-8 months (Fig.17). Seedlings of mango and aonla collected from different blocks of Dehradun have also raised in pots to compare performance. Rootstocks collected from Kalsi block shown maximum root and shoot ratio. Rootstocks of mango, guava, aonla and bael have also been raised in pots with different moisture regime for assessing water requirement. Mango sapling has attained graftable diameter irrigated at 80% ET (Fig.18a) whereas guava sapling attained graftable diameter irrigated at 60-70% ET (Fig.18b).

Fig.-17: Performance of mango sapling in with various rooting media

Fig-18 Performance of sapling under different level of irrigation based on ET in mango (a) and guava (b)

Up-scaling research on assessment of productivity, hydrological behavior, resource conservation and intangible benefits of selected commercial bamboo species in Uttarakhand (R. Kaushal, Ambrish Kumar, D. Mandal, Pradeep Dogra, J.M.S. Tomar, D.V. Singh, Harsh Mehta, N.M. Alam, Anand Kumar Gupta-D.Dun)

The collaborative project funded by International Network for Bamboo and Rattan (INBAR) State Forest Department, Uttarakhand aims at generating scientific information on allometrics and environmental metrics of different bamboo species.

The project also envisages capacity building of African partners under South-South institutional strengthening programme of INBAR. The data on different bamboo species is being generated from different locations in Uttarakhand. At Dhulkot research farm, seven different species of bamboos *viz*., *Bambusa bambos, B. balcooa, B. nutans, B. vulgaris, Dendrocalamus hamiltonii, D. strictus, D. stocksii* were planted in randomized block design in the year 2012. At Selaqui, experimental site is gravelly and bouldery marginal land (class VI based on land capability classification) where eight species viz., *Bambusa bambos, B. balcooa, B. tulda, B. vulgaris, Dendrocalamus asper, D. hamiltonii, D. longispathus, D. strictus were planted in the year 2015* in randomized block design. To quantify runoff and soil loss, seven different bamboo species viz., *B. balcooa, B. vulgaris, Dendrocalamus giganteus, D. hamiltonii, D. stocksii, D. strictus Thyrosatchyus oliverii* were planted in the year 2016 on 9% slope. At GBPUAT, Pantnagar, *Bambusa bambos, B. balcooa, B. nutans, Dendrocalamus hamiltonii and D. strictus were planted in the year 2005 in* randomized block design, Data at all the locations is being recorded for growth, biomass, root distribution, rainfall portioning, runoff and soil loss and soil properties viz., bulk density, infiltration, organic carbon, NPK, soil microbial properties. At Dhulkot, after 5 year of study period, maximum bulk density was observed in *D hamiltonii* which was followed by *B. balcooa* and *D. strictus*. Lowest bulk density was observed in *D. stocksii.* Average number of number of coarse roots (CR) and fine roots (Fr) roots irrespective of soil depth (0-60 cm) were studied by trench method. Maximum CR and FR were observed in *Bambusa bambos* which was followed by *B. vulgaris*. Lowest coarse roots were recdorded in *D. stocksii* and fine rootys in *B. balcooa* (Fig. 19).

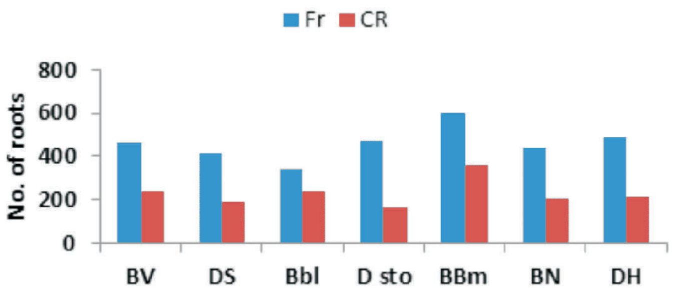


Fig-19. Number of coarse and fine roots in different bamboo species

Results on rainfall partitioning in different bamboo species (Fig 6a) revealed that maximum stemflow was recorded in *D. hamiltonii* while minimum was recorded in *B. nutans.* Maximum throughfall was recorded in *B. vulgaris* while lowest was in case of *D. hamiltonii.* Interception of rainfall was highest in case of *D. hamiltonii.* At GBPUAT, Pantnagar, hydraulic conductivity was maximum in D. *hamiltonii* and minimum in open plot. Bulk density also showed similar pattern (Fig. 20)

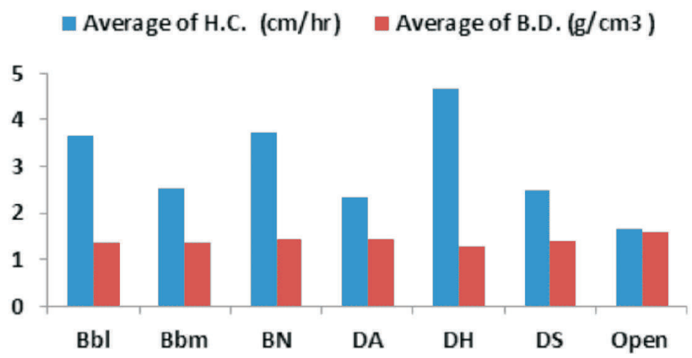


Fig-20: Hydraulic conductivity and bulk density in different bamboo species.

Under capacity building programme, short Term Training Course on Bamboo Allometrics and Environmental Metrics was conducted in Ethiopia, Tanzania and Madagascar from August 1-18, 2017 in which 62 trainees from different academic, research and development institutions participated.

Assessment and Improvement of Nutritional Quality of Horticultural Crops on Sloping Lands in North Western Himalayas (D.M.Kadam, M.Sankar, D.V.Singh-D. Dun)

Mango field of about 2 ha was selected in Badwala village for the study having 225 trees of Dashehari variety at 9 m X 9 m spacing. It lies between latitudes of 30°29'49.5" and 30°29'56.7" N and longitudes of 77°50'8.6" and 77°50'15.3" E. mango plantation was established 20 years ago on mildly sloping land which is truly representative of foot hills of North Western Himalayas. Initial soil sampling was done before tomato transplanting to assess the soil quality; total 27 samples were collected from 0-15 cm depth, 9 samples from each slope. The soil parameters are presented in Table -11

Table -11: Initial soil chemical parameter (average)

	pH	EC(dSm^{-1})	P(ppm)	K(ppm)	Cu(ppm)	Zn(ppm)	Fe(ppm)	Mn(ppm)
Up slope	5.18	0.088	8.14	119.68	0.99	3.59	25.26	52.45
Mid slope	4.71	0.080	8.51	99.84	0.85	2.01	34.97	109.68
Down slope	4.66	0.112	6.11	81.08	0.84	1.79	36.97	128.10

Phyto-rehabilitation of saline – sodic vertisols through *Prosopis juliflora* based silvipastoral system (H. Biswas and A.S. Morade-Ballary)

The long-term project at the Research Farm, Ballari, was initiated to evaluate the phyto-rehabilitation of saline-sodic Vertisols through *Prosopis juliflora* based silvi-pastoral systems. The experiment was laid out in a spilt plot design with time replication of five years during 2015-16. The study comprises of two tree species, viz., *P. juliflora* and *P. pallida* and two grass species viz., *Leptochloa fusca* and *Cenchrus ciliaris*. The soil of the experimental field is alkaline, with pH ranging from 7.5 to 8.5 and saline, with EC ranging from 0.78 to 11.0 dS m^{-1}. The soil is low in organic carbon.*P. pallida* were planted at two spacing's – 3 × 3 and 6 × 6 m. Seedlings were established and maintained with life-saving irrigation during the dry season. Pruning was carried out during September, 2017 in order to avoid excessive overlap of *P. juliflora* and *P. pallida* and shading to grass species. The growth parameters of *P. pallida* after two years of the study revealed that trees planted at 3 × 3 m attained more height compared to those planted at 6 × 6 m. This could be attributed to the lesser space available for lateral spread. Higher collar diameter and DBH were also recorded under trees planted at 3 × 3 m spacing (Table.12).

Table -12: *P. pallida* growth parameters at two spacings

Spacing levels / Growth Parameters	Main plots: spacing (m)	
	3×3	6×6
Height (cm)	511 ± 30	422 ± 49
Collar diameter (mm)	91 ± 23	71 ± 23
DBH (mm)	64 ± 17	51 ± 20
Canopy spread (N-S)	3.12 ± 0.30	3.08 ± 0.50
Canopy spread (E-W)	3.09 ± 0.20	3.06 ± 0.60

Regulated deficit irrigation and canopy architecture management for fig (*Ficus carica* L.) in semi-arid vertisols (A.S. Morade and M. Prabhavathi-Ballary)

Fig plants of cultivar 'Bellary' planted in July, 2016 at Research Farm, Ballari. Fig plants recorded 78% of survival. Canopy architecture treatments were imposed by training and pruning. Three tier plant canopies were developed by regulating the growth of primary and secondary branches. Nearly 50% of plants started fruiting in November, 2017. Variation in plant growth is observed due to intrinsic plant vigor and extrinsic environmental factors. Preliminary fruit quality analysis (n=49) revealed that, average fruit diameter ranged from 35 to 40 mm and fruit weight at harvesting varied from 20 to 25 g per fruit. The TSS of fully ripen fruits was varied from 19 to 23 degree brix at room temperature. Specific gravity of fig fruits at edible maturity was 1.03 (Plates 1 to 5).

Plate 1. Fig Plant orchard (18 months old) at Research farm, Ballary

Plate 2: Early vegetative growth

Plate 3: Three tier canopy and fruiting

Plate 4: Fig fruits at harvesting maturity

Plate 5: Vertical and transverse sections of fig fruits

Peach based agri-horticulture land use system for degraded Shivaliks (R. Prasad, S. Pal, and S.L. Arya-Chandigarh**)**

Peach based agri-horticulture land use system was established in 2008 in degraded lands in Shivalik foot hills near Chandigarh (UT) with the following objectives as (i) To study the growth performance of peach plants with fodder (inter) crops and vice-versa, (ii) To monitor soil health and moisture conservation, (iii) To estimate soil loss and runoff from different systems, and (iv) To study economic viability of the system. Grafted saplings of peach cultivar Shan-i-Punjab were procured from PAU, Ludhiana and planted in 3rd week of January,2008 in a pit size of 1 m^3 at a spacing of 6mx6m, consisting 278 plants/ha. The plantation was done in a square system and the study consisted of 12 treatments in all and replicated three times having 9 plants per treatment. Ramser samplers were installed in one replication for the estimation of soil loss and run off. The plot size was maintained as 18m x 18m. Recommended package of practices were followed for peach cultivation. The intercrops /fodder crops viz sorghum, pearl millet and cluster bean are sown during kharif season in the vacant space between peach plantation. Control plots for sole crops were also made (6m x6m). In this study, the following moisture conservation measures are made: -

i) Control (flat basins),
ii) Rectangular trench,
iii) Circular trench

Rectangular trenches are made on one side of the plant having a dimension of 1mx0.5x0.3m and the circular trenches made around plant trunk to conserve moisture. Soil loss and runoff was measured/ recorded from one replication. The study consisted of following 12 treatments as:

T-1: Pure Peach
T-2: Pure peach + Trench
T-3: Pure peach + Circular trench
T-4: Peach + Sorghum
T-5: Peach + Pearl millet
T-6: Peach + Cluster bean
T-7: Peach + Sorghum + Trench
T-8: Peach + Pearl millet + Trench
T-9: Peach + Cluster Bean + Guar + Trench
T-10: Peach + Sorghum + Circular Trench
T-11: Peach + Pearl millet + Circular Trench
T-12: Peach + Cluster bean + Circular Trench

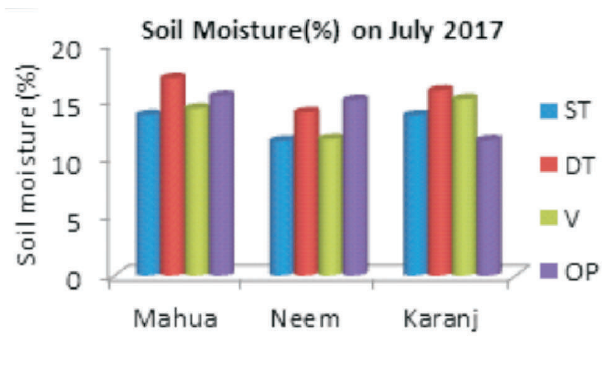
Data showed that height (5.74m), spread (7.92m) and yield (137.0 kg) was found maximum in treatment Peach + Guar + Circular Trench (T_{12}) as compared to other treatments. Height ranged from 4.4m to 5.74m, spread from 5.9m to 7.92m, and yield from 103.25 kg to 137.0 kg per plant among various treatments. The fruit weight ranged from 76.28 to 88.63g, fruit length ranged from 5.75cm to 6.29cm, pulp weight ranged from 63.20g to 76.98g, stone weight ranged from 6.50g to 12.43g, and TSS from 10^0 to 12.75^o Brix. Mean fruit weight was 80.55g, mean fruit length was 6.10cm, mean stone weight was 9.99g, and mean TSS^0 was 11.39^o Brix respectively.

Evaluation of Moisture Conservation Techniques for sustainable production of Tree Borne Oil seeds (TBOs) in Bundelkhand (MonalishaPramanik and RS Yadav-Datia)

The experiment was laid down in the year 2010 in red upland soils of Bundelkhand, in split plot design.Three trees borne oil seed plantation was done namely Neem, Karanj and Mahua with four treatments, viz. T-1: Double Trench, T-2: Single Trench T-3: V-shape catchment and T-4 Farmers practice (Ordinary Pit) as control. The growth of Karanj has been found better than other two species. Maximum average collar diameter was recorded in case of Karanj (11.36 cm) under Double trench treatment. There was 100% survival of all the species during the current year, thus no replacement of any species was done under any moisture conservation treatment imposed (Table 13). The average soil moisture content was higher irrespective of species in double trench treatment during the monsoon (Fig.21). It was also observed that there is not much difference in soil moisture content in double trench and V shape during the post monsoon season. Mean soil moisture content recorded under “double trench treatment” was 15.7 per cent and 6.92 per cent during months of July and December respectively against 14.1 per cent and 5.26 per cent under control. Growth of Karanj has been found better than other two species. Maximum average collar diameter was recorded in case of Karanj (11.1 cm) followed by Mahua (6.00 cm). The highest growth with respect to height (427 cm) was found in Karanj and followed by Neem (343 cm).

Table-13: Survival, height, collar girth, DBH, number of branches, crown diameter of TBOs seedlings and *in situ* soil moisture content during December 2017

Main plot Treatment	Mahua					Neem					Karanj				
Sub plot Treatment	ST	DT	V	OP	Mean	ST	DT	V	OP	Mean	ST	DT	V	OP	Mean
Survival per cent	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Avg. ht (cm)	288	244	253	246	258	383	336	353	339	353	474	433	443	406	439
Collar Dia. (cm)	6.5	5.7	6.0	5.7	6.0	6.7	5.6	5.8	5.5	5.9	11.0	11.3	11.0	10.6	11.1
DBH (cm)	4.1	3.1	3.0	3.0	3.3	5.0	3.6	3.9	3.6	4.0	7.1	7.4	6.2	6.2	6.7
Crown dia (cm)	102	79.7	78.3	77.7	84.4	171	115	123	147	139	481	455	395	392	4317



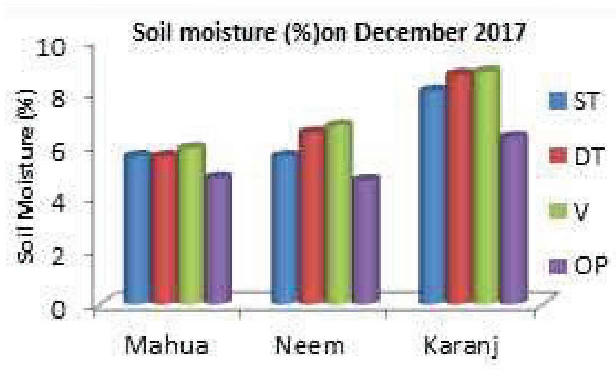


Fig-21: Effect of moisture conservation techniques on *in situ* soil moisture content (%) during 2017

After seven years of experimentation, the soil study revealed that the effect of trees species and soil moisture techniques on soil properties was not found distinctive. However, maximum mean soil organic C and available K (0 – 15 cm depth) was 0.439 per cent and 286 kg ha^{-1} under *A. indica* with control and V-shape basin, respectively. Further, minimum soil pH (7.38) was found under *A. indica* with double trenching and EC (0.074 dSm^{-1}) under *P. pinnata* with single trench.

Evaluation of promising fruit species with different moisture conservation practices in red soils of Bundelkhand region (Rajeev Ranjan, MonalishaPramanik and SP Tiwari-Datia**)**

The experiment was started in 2015-16 with three fruit species *viz.* custard apple, pomegranate and lemon and four moisture conservation treatments *viz.* sun hemp, plastic, stone and no mulch as control replicated thrice in factorial randomized block design to identify the most promising fruit species for sustainable production in semi-arid region of Bundelkhand. After two years of plantation, pomegranate and lemon were survived almost 100 per cent irrespective of mulch treatments, whereas survival of custard apple was mere 71.0 per cent. Growth parameters of fruit plants such as plant height, collar diameter, no. of branches and canopy spread were recorded in different mulch treatment and data revealed that the mean maximum plant height 106 cm, 154 cm and 154 cm were observed in custard apple, pomegranate and lemon under plastic mulch treatment respectively, whereas the mean minimum plant height 72.4 cm, 140 and 137 cm were recorded in custard apple, pomegranate and lemon under control respectively (Table.14).

Table -14: Effect of different mulch treatments on survival (%) and growth parameters of fruit plants during 2017

Species/ Treatment	Custard apple				Pomegranate				Lemon			
	Sun hemp	Plastic	Stone	Control	Sun hemp	Plastic	Stone	Control	Sun hemp	Plastic	Stone	Control
Survival (%)	78	56	74	78	100	100	100	100	100	100	100	100
Plant ht (cm)	91	106	83	72	147	154	149	140	151	154	148	137
Collar dia (mm)	18	21	14	10	25	25	27	26	37	38	36	34
No. of branches	5	4	3	2	10	10	10	9	12	13	12	11
Canopy dia. (cm)	42	50	23	13	97	110	104	91	143	151	126	120

The soil moisture data was recorded on daily basis after irrigation. The soil moisture content was higher in the sunhemp treatment plantation of pomegranate and lemon, whereas the soil moisture was lowest in stone mulch treatment. The study showed that water availability to the plant was higher in case of sunhemp mulch treatment for longer duration. (Fig. 22)

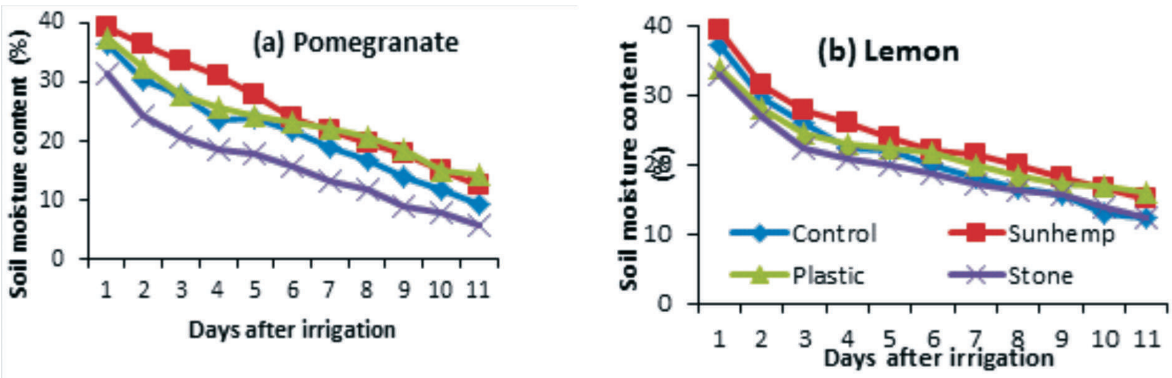


Fig-.22: Soil moisture depletion in (a) Pomegranate and (b) Lemon under different mulch treatments

***Evaluation* of cover crops under cashew and mango plantation for improving soil health and productivity in Eastern Ghats High Land Region of Odisha** (M. Madhu , D. C.Sahoo ,P.P. Adhikary and H.Gowda- Koraput)

Cover crops plays vital role in improving soil properties and enhancing the productivity of crops. Soil cover management is one of the important aspects in preventing soil erosion particularly in high rainfall areas. But tree crops may require several years to close their canopy, whereas most annual crops provide adequate cover within six weeks after planting. At initial stage of plantation establishment, soil and nutrient loss is enormous without vegetation cover. Farmers in this region hardly apply external source of nutrients to plantation crops like cashew and mango leads to poor growth and development and yield at later stage. Due to poor socio-economic conditions application of costly external source of nutrients is very difficult apart from low fertility status of the soil. In view of this, growing of cover crops will be the better options since it improves the soil properties and provides nutrients to plantation crops without much additional cost. With the above background, field experimentation was initiated with the following objectives.

- To study the resource conservation efficiency of cover crops under cashew and mango plantation.
- To study the impact of cover crops on soil properties, carbon sequestration and global warming potential of the system.

Mango and cashew grafts were planted in 8 mX 8 m spacing on sloping field of 8-10%. Eight treatments comprising seven cover crops and one plot without cover crops laid out in RBD design.

T_1 : Mimosa invisa
T_2 : *Calopogonium mucunoides*
T_3 :*Pueraria javanica*
T_4 : *Centrosema pubescens*
T_5 : *Cowpea*
T_6 : *Stylosanthus*
T_7 : *Mucuna bracteata*
T_8 : *Control*

Cover crops seeds were sown during July, 2016 as per the treatment details both in mango and cashew plantation. During this period runoff, soil loss, initial soil properties, canopy cover of cover crops and growth performance of mango and cashew were recorded.Growth parameters of mango and cashew plants were collected 20 months after planting in the field. The average plant height and collar diameter of mango plants varied between 60.4 to 112.6 cm and 1.7 to 2.2 cm, respectively. Similarly average plant height and collar diameter of cashew plants varied between 71.3 to 120.0 cm and 2.2 to 2.4 cm, respectively. Canopy of different cover crops measured at 20 months after planting showed that the maximum canopy cover of 95% in *Mucuna bracteata* followed by *Mimosa invisa* (90%) and *Pueraria javanica* under mango plantation (Fig. 23). Similarly, maximum canopy cover was found in *Mucuna bracteata* (95%) followed by *Mimosa invisa* (90%) and *Pueraria javanica (89%) under cashew plantation.* The lowest canopy cover was found in cow pea and control treatments for both mango and cashew plantations (Fig. 24). *The total rainfall during the year 2017 is 1535.9 mm (89 days). Runoff was measured during the year 2017.* About 640.7 mm of runoff producing rainfall was received in 18 rainfall events. Runoff under mango with different cover crops was varied between 32.2 and 82.4 mm which account about 6.7 to 12.86% of the seasonal rainfall of 894 mm. Runoff under cashew with different cover crops was varied between 29.3 and 76.8 mm which account about 4.58 to 11.99% of the seasonal rainfall of 894 mm (Fig. 25). Soil losses varied between 39.07 kg/ha in Mucuna bracteata and 317.72 kg/ha plot without cover crops in mango and cashew plantation. However, soil loss was the lowest in all the cover crops compared to control plots. Soil conservation efficiency of cover crops varied between 19.1 and 87.2% over control plot (Fig. 26).Maximum volumetric soil moisture content (%) was in control followed by *Mucuna bracteata both in Mango and Cashew plantation.* Above ground dry biomass production of cover crops varied between 2.6 and 11.0 t/ha/yr which contributed total NPK nutrients of 129 to 650 kg/ha to soil. Highest biomasses were obtained in *Mimosa invasia* plot of about 9.6 and 11 t/ha at mango and cashew plantation respectively. Whereas, the lowest biomass were obtained in *Calopogonium mucunoides* of about 2.9 and 2.8 t/ha in mango and cashew plantation, respectively (Fig. 27&28).

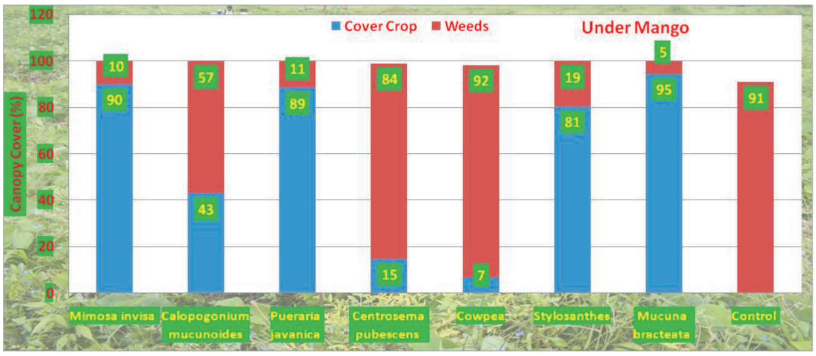


Fig.- 23: Canopy cover of different cover crops under mango plantation

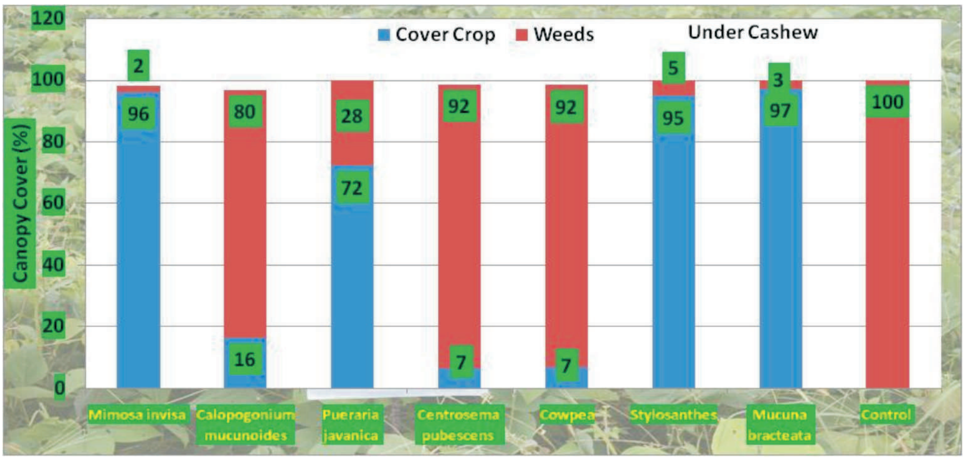


Fig. -24: Canopy cover of different cover crops under mango plantation

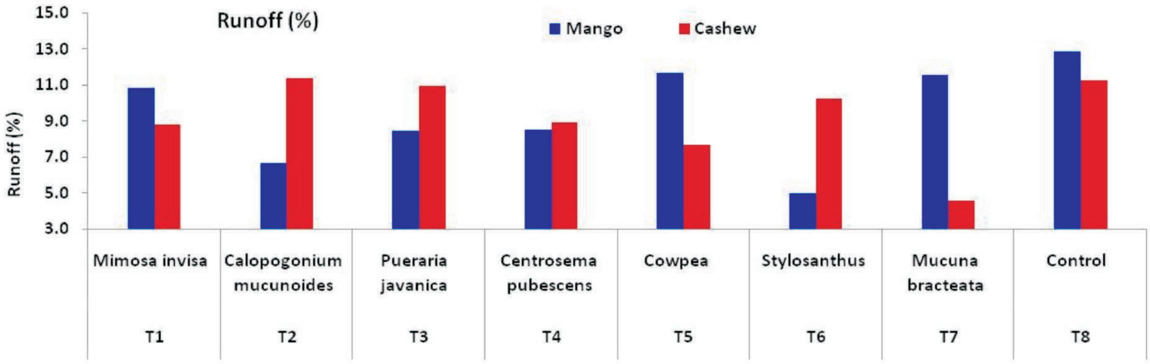


Fig.-25: Runoff under different cover crops in mango and cashew during 2017

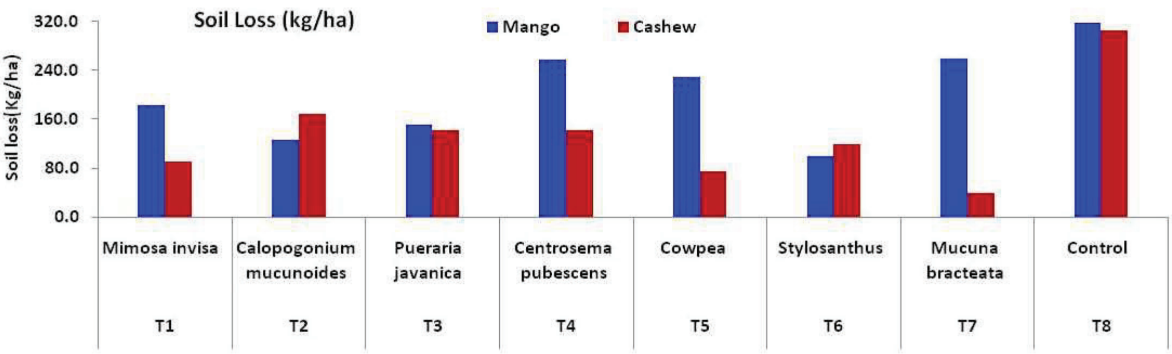


Fig. -26: Runoff under different cover crops in mango and cashew during 2017

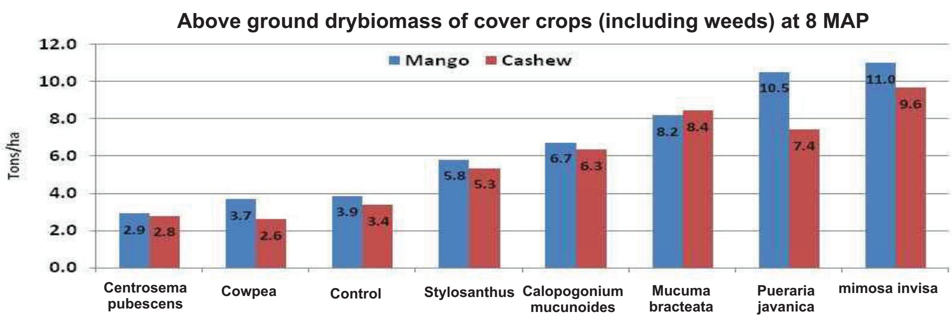


Fig. -27: Above ground dry biomass of different treatments in mango and cashew plantation

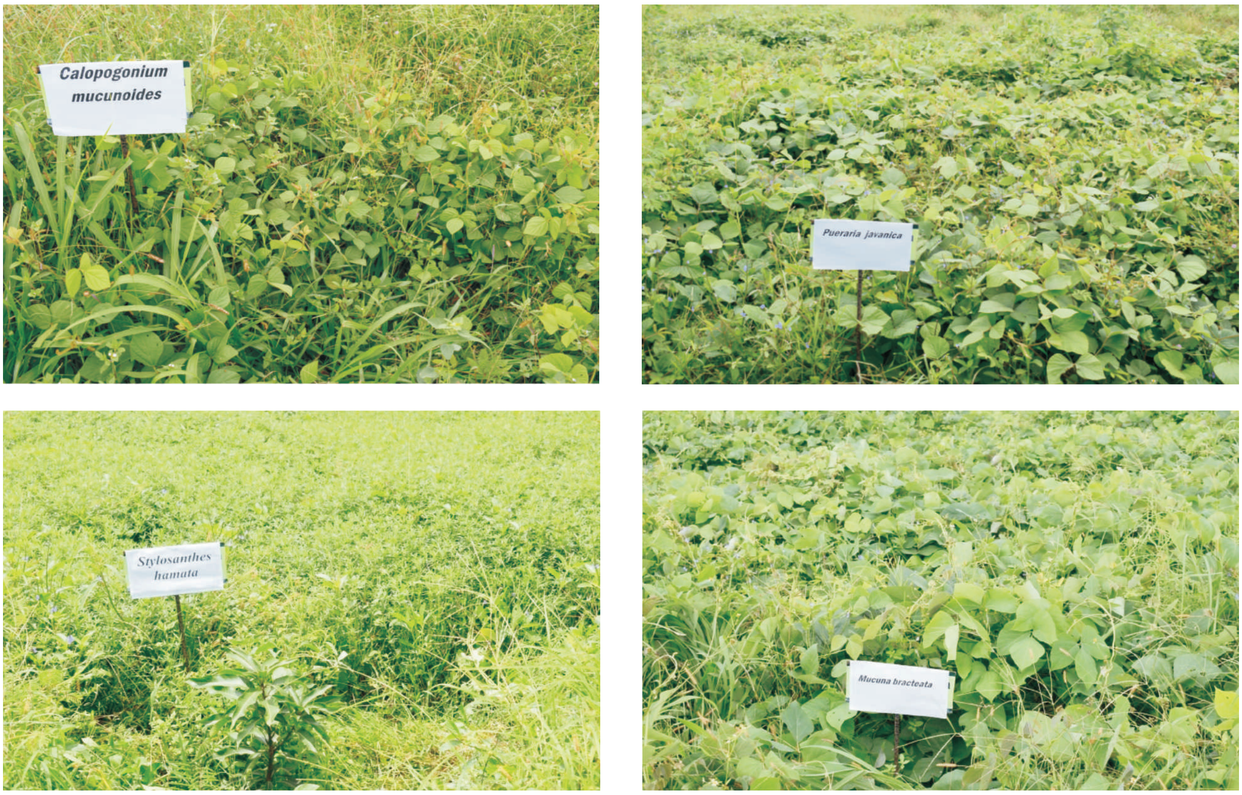


Fig.-28: Growth of different cover crops in mango and cashew field.

Plant growth - MAS

Plant growth - 6 MAS

Early flowering observed in CA-3

Field Progeny Evaluation Trial

Fig.- 29. Establishment of field progeny evaluation trail with 30 genotypes of cassia auriculata

Evaluation, characterization and development of elite genotypes of cassia auriculata for cultivation under arid and semi-regions (S. Kala, H. R. Meena, and I. Rashmi –Kota)

C.auriculata is one among the multipurpose medicinal shrub species has not been utilized effectively. The objective of the project was to identify potential *C.auriculata* genotypes for cultivation and resource conservation in non-arable lands. The main objective of the current year is to evaluate and identify the superior genotypes/ seed source of *Cassia auriculata* under nursery and field condition using plant traits. Basic parameters of average plant height, collar diameter and number of stem /plant, fresh weight of flower yield/plant, pod yield /plant, seed yield /plant were recorded. The assembled genotypes biometric traits viz., plant height (avg. mean range varies from 1.16 m to 2.15 m), collar diameter (avg. mean range varies from 18.15 mm to 28.25 mm), no. of stems /plant (avg. mean range varies from 5 to 12) and seed weight (range varies from 3.14 g to 4.34 g). Plant morphometric and biochemical observations were also recorded for further analysis on phenotypic and genotypic characterization (Fig.29).

Effect of shade trees on productivity and soil health in rejuvenated tea plantations in Nilgiris (R. Ragupathy and K. Rajan-Udhagamandalam)

An experiment on effect of shade trees on the yield of tea and soil health involving *Grevillearobusta*and the *Morusalba* was initiated during 2012 in the research farm. From 2016 onwards observational tea yield under different shade trees were carried out in the farmersfields.Orahalli in Kotagiri Taluk in Nilgiri district was selected for the study in the farmers field. The treatments are Tea + Silveroak, Tea +Morus and Tea only, The collected data at Orahalli near Kotagiri on growth parameters and on soil fertility are presented in table 15&16.

Table -15: Growth rate of tea and shade trees and the yield

Treatment	**Month**	**Tea**	**Shade tree**	**Yield of tea (t ha^{-1}one plucking)**
		Pruned height (m)	**Total height (m)**	
Tea only	Feb.	0.74	-	2.20
	Dec.	0.74	-	0.75
Tea+Silver oak	Feb.	0.70	9.70	2.00
	Dec.	1.03	15.00	0.75
Tea+Morus	Feb.	0.83	6.00	2.10
	Dec.	0.86	7.50	2.30

Table.-16: Effect of shade trees and tea on soil health

Treatment	**Month**	**pH**	**EC (dSm^{-1})**	**OC (%)**	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**
Tea only	Feb	5.17	0.59	3.01	426	12	92
	Dec	4.30	0.03	3.75	75.6	74	740
Tea+ Silveroak	Feb	4.35	0.66	5.03	430	18	96
	Dec	4.30	0.01	5.9	147	87	870
Tea+Morus	Feb	4.89	0.49	3.19	396	10	87
	Dec	4.18	0.01	1.6	77.7	65.5	655

Resource utilization and productivity of Dragon fruit based horti-silviculture system under rainfed agro eco-systems of Central Gujarat (V. Kakade, P.R. Bhatnagar, Raj Kumar (till 15.7.2017) and D. Dinesh-Vasad)

An experiment was initiated in 2016 to analyse the resource utilization and productivity of Dragon fruit and *Melia dubia*, to evolve the suitable cropping system under rainfed agro ecosystems of central Gujarat. The initial growth parameters were taken after planting of *Melia dubia*. But, in the month of September, 2016 but the plants of *Melia dubia* were damaged by wild animals. Therefore, replanting of *Melia dubia* was done in the month of June, 2017 and then initial growth parameters including plant height and stem diameter was recorded. The planting of Dragon fruit was done in the month of February, 2017 under different treatments. The four plants of Dragon fruit were planted around one cement pole. After planting, plants were covered with branches of thorny plants and old sari to protect the plants from wild life damage. The plant survival percentage of Dragon fruit and *Melia dubia* was recorded during December, 2017 and ranged between 56.95 to 90.3 % in case of Dragon fruit and 66.66 to 100% in case of *Melia dubia* (Table 17). In experiment 2, the planting of Dragon fruit was done at the spacing of 3 x 3m and four plants were planted per pole in the month of January, 2018(Fig.30&31).

Table -17: Plant survival (%) of Dragon fruit and *Melia dubia* under different treatments

Treatment	Treatment details	Dragon fruit	*Melia dubia*
T1	Natural vegetation	-	-
T2	Dragon fruit + *Melia dubia* + *in-situ* moisture conservation measure (Half-moon) (3x3m)	90.3	100
T3	Dragon fruit + *Melia dubia* (3x3m)	90.3	96.4
T4	*Melia dubia* (3x3m)	-	88.89
T5	Dragon fruit (3x3m)	86.12	-
T6	*Melia dubia* + *in-situ* moisture conservation measure (Half-moon) (3x3m)	-	94.5
T7	Dragon fruit + *in-situ* moisture conservation measure (Half-moon) (3x3m)	80.56	-
T8	Dragon fruit + *Melia dubia* (4x4m)	80.56	83.34
T9	Dragon fruit + *Melia dubia* + *in-situ* moisture conservation measure (Half-moon)	56.95	66.66

Fig. 30 : Measurement of growth parameters in *Melia dubia*

Fig. 31: A view of Dragon fruit project