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Effect of organically grown cropping systems on uptake, yield and shedded biomass

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Abstract
Organic agriculture is getting vital significance and considering the benefits of intercropping in crop diversity, sustainability and its role in the enhancement of organic carbon in soil, Effect of organically grown cropping systems on soil physical and chemical properties in vertisols was investigated during Kharif 2021-22 at Research Farm, Centre for Organic Agriculture Research and Training, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in Randomized Block Design (RBD) with seven treatments consisting cropping systems *viz.* cotton (sole), cotton + sunhemp (2:1), cotton + blackgram (2:1), soybean + pigeonpea (3:1), blackgram - chickpea (rabi), greengram + sorghum (2:1) and sunhemp (sole), replicated three times. The nutrients were supplied through FYM and vermicompost based on nitrogen - 50% N through FYM + 50% N through vermicompost. The compensation of phosphorus was made available through PROM (Phosphate rich organic manure). The lowest bulk density of soil (1.42 Mg m^{-3}), maximum hydraulic conductivity (0.76 cm hr^{-1}) and mean weight diameter (0.73 mm) were recorded with Cotton + Sunhemp intercropping system. Soil pH (8.04 to 8.11) and electrical conductivity (0.13 to 0.15 dS m^{-1}) were reduced over the initial value (8.12 & 0.16 dS m^{-1}). The significant improvement in soil organic carbon was noted in Cotton + Sunhemp (6.09 g kg^{-1}). The highest available nitrogen (209.27 kg ha^{-1}), available phosphorus (22.28 kg ha^{-1}) and available potassium (354.26 kg ha^{-1}) was recorded in Soybean + Pigeonpea intercropping system.

Keywords: Organically grown cropping systems, uptake, yield, shedded biomass, carbon pools

Introduction
Organic agriculture is a holistic production management system that promotes and enhances agro ecosystem biodiversity, biological cycles and soil biological activities. Organic farming is one of the ways to promote self-sufficiency and food security. The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals and people (Scialabba and Hattam, FAO, 2002) [15]. Cotton (*Gossypium spp*) is one of the most important fibres and cash crops in India. It plays a key role in the Indian economy. It is globally known as the 'king of fibres' and is popularly known as "White Gold". India is the largest producer of organic cotton and accounts for a 50 per cent share of global organic cotton production. Two per cent of India's cotton is organically grown. Pigeon pea (*Cajanus cajan* L.) commonly known as red gram or Tur or Arhar is popular and widely used as an intercrop under rainfed areas of Maharashtra. The initial slow growth rate and wide spacing with a deep root system of pigeon pea offer good scope for intercropping with fast-growing, early maturing and shallow-rooted crops. Green gram (*Vigna radiata*) also called mungbean Being a short duration crop, green gram fits well in various multiple and intercropping systems. Soybean (*Glycine max* L.) is known as the miracle "Golden bean", is mainly grown as an oilseed crop. It enriches the soil by fixing atmospheric nitrogen through nodules and thus improves soil fertility. Black gram (*Vigna mungo* L.) also known as Urdbean, is drought tolerant and its ability to use residual moisture during the dry season make it an important rainfed crop. Sorghum [*Sorghum bicolor* (L.) *Monech*] is a cereal plant having wide agroecological adaption, drought tolerance, high production, low input crop and more resistance to pests and diseases than other food crops. Sunhemp (*Crotalaria juncea* L.) is a quick growing warm-season legume crop cultivated for green manure as well as a fibre crop.

It is grown for its ability to produce large biomass and fix atmospheric nitrogen. The leguminous green manure crops *viz.*, sunhemp, green gram and black gram are highly valued for their fast-growing habit, producing a large quantity of plant biomass as excellent cover crops with root nodules and the capability to fix atmospheric nitrogen. Green manures are fertility-building crops and may be broadly defined as crops grown for the benefit of the soil. Green manure being legumes provides N to soils through biological N fixation and increases the soil N supply to subsequent crops. In order to make organic farming more viable under the intercropping system, the judicious use of farm yard manure (FYM), vermicompost and crop residues is found to be useful. However, biomass production through legume cropping and its incorporation in the soil can be another strategy to overcome the limitation of organic matter availability.

Materials and Methods

The experiment was conducted on organically certified field at Centre for Organic Agriculture Research & Training (COART), Department of Agronomy, Dr. PDKV, Akola during *kharif* season of 2021-22 and analytical work was carried out at Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola, with the objective to assess the impact of various organically grown cropping system on soil physical, chemical properties and yield of crops. The soil of the experimental field comprised clayey montmorillonite, hyperthermic, vertisols.

The nutrients were supplied through FYM and vermicompost based on nitrogen - 50% N through FYM + 50% N through vermicompost. The compensation of phosphorus was made available through PROM (Phosphate rich organic manure). Application of *Trichoderma, Rhizobium and PSB* was done in all crops as seed treatment. Plant protection schedule was followed organically. Similarly, sunhemp was buried in soil after 35 to 40 days of sowing, while other intercrops were harvested and the residues of the same were incorporated in the soil after harvest. Soil and plant samples were analysed after harvest of crops.

The representative soil samples were taken from 0-20 cm depth. The soil samples were air-dried in shade and pulverized using a mortar and pestle and then homogenized through a 2 mm sieve. For mean weight diameter analysis, 8 mm size aggregates were retained on the sieve and used. For analysis of organic carbon, the soil was passed through a 0.5 mm sieve. The sieved soil was preserved in plastic bags and labelled properly for subsequent analysis.

The experiment was laid out in Randomized Block Design (RBD) with seven treatments shown below in treatment details which replicated three times.

Cropping Systems			
T_1	Cotton	Sole	Arboreum (HDPS)
T_2	Cotton + Sunhemp	2:1	Hirsutum and Sunhemp green manuring at 35-40 DAS
T_3	Cotton + Blackgram	2:1	Hirsutum and in situ mulching of Black gram (After harvest)
T_4	Soybean + Pigeon pea	3:1	In situ mulching of Soybean (After harvest)
T_5	Blackgram – Chickpea (*Rabi*)		In situ mulching of Black gram (After harvest)
T_6	Greengram + Sorghum	2:1	In situ mulching of Greengram (After harvest)
T_7	Sole Sunhemp		Sunhemp was buried at 35-40 DAS.

Results and Discussion

Effect of organically grown intercropping systems on total nutrient uptake

Total Nitrogen

Nitrogen is the primary essential element and major component of the plant. Because of the occurrence of widespread deficiencies, it is referred to as a universally deficient nutrient element in crop production. Nitrogen is mostly deficient in the soil and which creates a major problem for the plant. It is evident from the data concerning the total nitrogen uptake as influenced by organically grown intercropping systems as presented in Table 1 and depicted in Fig. 1, that higher total uptake of nitrogen was recorded in the treatment of Soybean + Pigeon pea intercropping system (134.95 kg ha^{-1}) followed by Greengram + Sorghum (58.17 kg ha^{-1}). The lowest total uptake of nitrogen was found in sole cotton (35.16 kg ha^{-1}). The higher uptake of nitrogen by Soybean + Pigeon pea intercropping system might be due to the higher input of shedded biomass to soil from soybean and pigeon pea crops compared to that of other treatments. Similar results were reported by Kundu *et al.* (2008) [7]. The results are in conformity with the findings reported by Mitra *et al.* (2010), Zaki and Habshy (2011) [20], Thimmareddy *et al.* (2013) [17] and Nasar *et al.* (2024) [8].

Table 1: Effect of organically grown intercropping systems on total nitrogen uptake

Treatments		**N uptake (kg ha^{-1})**		**Total N uptake (kg ha^{-1})**
		Seed	**Straw**	
T_1	Cotton Arb.	24.51	10.65	35.16
T_2	Cotton Hir.	27.52	13.56	49.19
	Sunhemp	0.00	8.11	
T_3	Cotton Hir.	25.08	11.54	47.52
	Blackgram	7.64	3.26	
T_4	Soybean	74.96	12.44	134.95
	Pigeon pea	25.95	21.59	
T_5	Blackgram	27.19	9.08	36.28
T_6	Greengram	23.26	8.33	58.17
	Sorghum	19.27	7.31	
T_7	Sunhemp	0.00	24.10	24.10
SE± (m)		-	1.071	2.606
CD at 5%		-	3.299	8.029

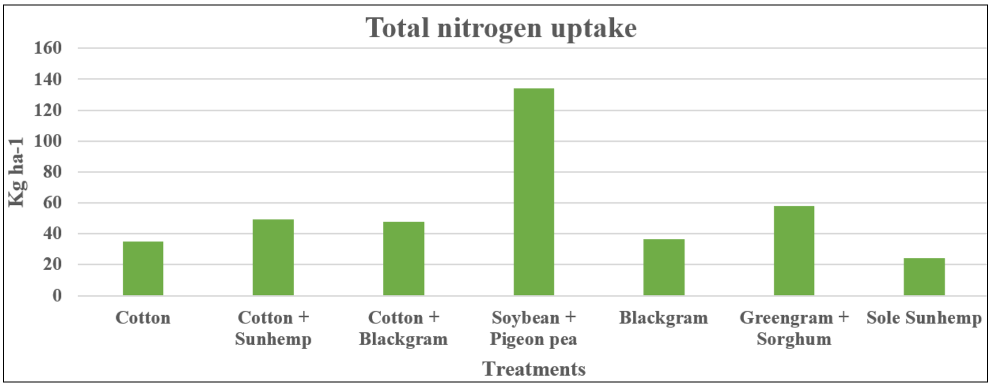

Fig 1: Effect of organically grown intercropping systems on total nitrogen uptake

Total Phosphorus

Phosphorus is the second most important primary essential element in the plant life cycle. It does not occur as abundantly in the soil as nitrogen and potassium. The data pertaining to total phosphorus uptake as influenced by organic intercropping systems were found to be significant as presented in Table 2 and depicted in Fig. 2. It ranged from 3.64 to 13.17 kg ha^{-1}. Significantly higher total phosphorus uptake was observed in the treatment Soybean + Pigeon pea intercropping system (13.17 kg ha^{-1}) followed by Cotton + Sunhemp (7.75 kg ha^{-1}). The lowest total uptake of phosphorus was found in sole Cotton (5.50 kg ha^{-1}). The higher nutrient uptake with organic manure might be attributed to the solubilization of native nutrients, chelation of complex intermediate organic molecules produced during the decomposition of added organic manures, their mobilization and accumulation of different nutrients in different plant parts. The findings are in close agreement with the results reported by Zaki and Habshy (2011) [20], Thirunavukkarasu *et al.* (2013) [18], Carvalho *et al.* (2015) [3] and Nasar *et al.* (2024) [8].

Table 2: Effect of organically grown intercropping systems on total phosphorus uptake

Treatments		P uptake (kg ha^{-1}) Seed	Straw	Total P uptake (kg ha^{-1})
T_1	Cotton Arb.	2.03	3.47	5.50
T_2	Cotton Hir.	2.36	3.94	7.75
	Sunhemp	0.00	1.44	
T_3	Cotton Hir.	2.40	3.77	7.48
	Blackgram	0.55	0.76	
T_4	Soybean	3.15	2.76	13.17
	Pigeon pea	1.92	5.32	
T_5	Blackgram	1.82	2.05	3.87
T_6	Greengram	1.76	2.08	6.90
	Sorghum	1.78	1.28	
T_7	Sunhemp	0.00	3.64	3.64
SE± (m)		-	0.229	0.362
CD at 5%		-	0.706	1.114

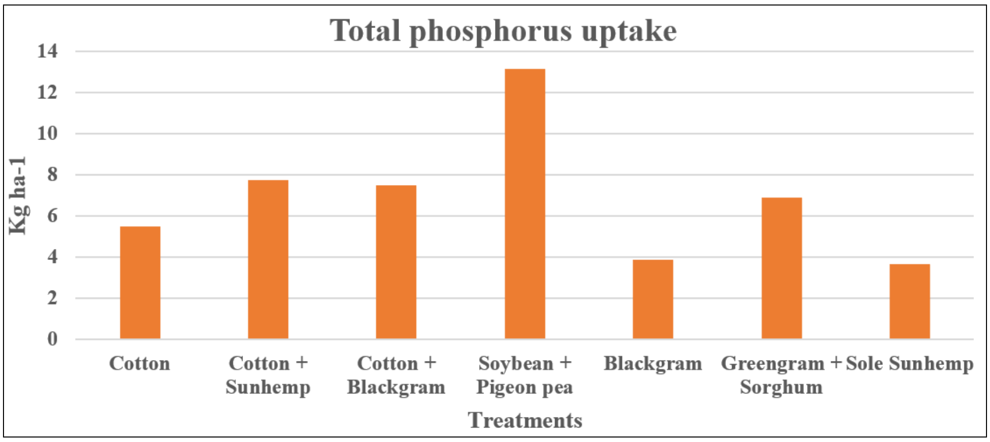

Fig 2: Effect of organically grown intercropping systems on total phosphorus uptake

Total Potassium

Potassium is the third important element in crop production. Potassium is absorbed by plants in a large amount than any other nutrient except nitrogen. Although the total K content in soil is usually many times greater than the amount taken up by a crop during the growing season.

The data in respect of total potassium uptake as influenced by organically grown intercropping systems were found to be significant as presented in Table 3 and depicted in Fig. 3. It was found to be varied from 19.78 to 46.81 kg ha^{-1}. The higher total potassium uptake was recorded in the treatment of Soybean + Pigeon pea intercropping system (46.81 kg ha^{-1}) followed by Cotton + Sunhemp (39.20 kg ha^{-1}). The higher nutrient uptake with organic manure might be attributed to the solubilization of native nutrients and higher input of shedded biomass due to soybean, pigeon pea and sunhemp as compared to other treatments. The findings are in close agreement with the results reported by Mitra *et al.* (2010), Zaki and Habshy (2011) [20], Thimmareddy *et al.* (2013) [17], Carvalho *et al.* (2015) [3] and Nasar *et al.* (2024) [8].

Table 3: Effect of organically grown intercropping systems on total potassium uptake

Treatments		K uptake (kg ha^{-1})		Total K uptake (kg ha^{-1})
		Seed	Straw	
T_1	Cotton Arb.	4.73	25.01	29.74
T_2	Cotton Hir.	5.55	27.36	39.20
	Sunhemp	0.00	6.29	
T_3	Cotton Hir.	4.90	25.07	36.47
	Blackgram	1.59	4.91	
T_4	Soybean	7.28	18.84	46.81
	Pigeon pea	5.61	15.09	
T_5	Blackgram	5.46	16.85	22.30
T_6	Greengram	4.97	10.67	27.44
	Sorghum	4.02	7.78	
T_7	Sunhemp	0.00	19.78	19.78
SE± (m)		-	1.332	1.663
CD at 5%		-	4.105	5.125

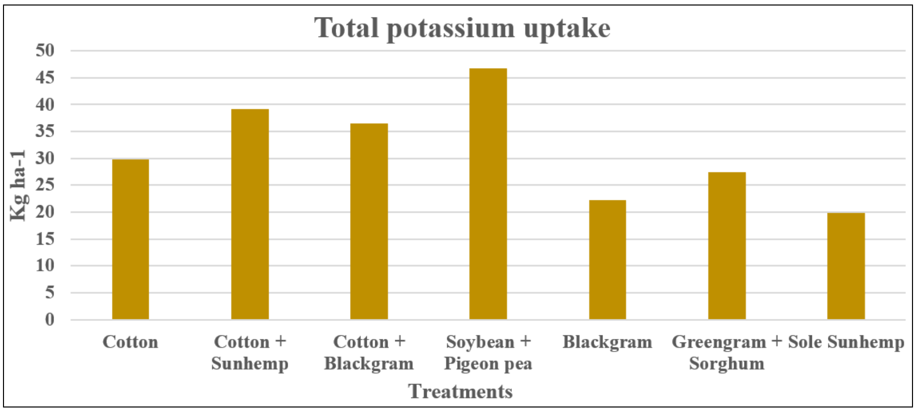

Fig 3: Effect of organically grown intercropping systems on total potassium uptake

Effect of organically grown intercropping systems on yield

The data pertaining to seed yield and stalk yield of cotton, similarly, grain yield and stover yield of other crops and system equivalent yield (SEY) is presented in tables 4 & 5 and graphically depicted in Fig. 4.

Table 4: Effect of organically grown intercropping systems on seed yield, stalk yield and biological yield

Treatments		Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})
T_1	Cotton Arb.	965	2316	3281
T_2	Cotton Hir.	1027	2465	4250
	Sunhemp	-	758	
T_3	Cotton Hir.	961	2219	3180
	Blackgram	248	446	694
T_4	Soybean	1213	1721	2934
	Pigeon pea	801	2958	3759
T_5	Blackgram	866	1465	2331
T_6	Greengram	765	1301	2066
	Sorghum	774	1161	1935
T_7	Sunhemp	-	2274	2274
GM		693	1735	2670

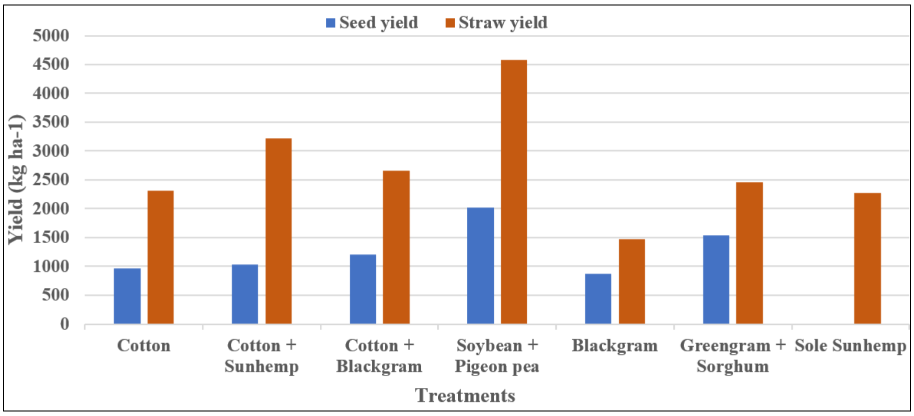

Fig 4: Seed and stalk yield as influenced by organically grown intercropping systems

Seed Yield

Data related to seed yield of was significantly influenced by organically grown intercropping systems as presented in Table 4 and graphically depicted in fig. 4. It ranged from 765 to 1213 kg ha^{-1}. The highest seed yield was reported with Soybean + Pigeon pea intercropping system (1213 kg ha^{-1}) followed by Cotton + Sunhemp (1027 kg ha^{-1}). This may be ascribed to the improvement in the soil's physical, chemical and biological properties and due to *in situ* incorporation of leguminous crops, shedded biomass and application of FYM and vermicompost which might have hastened the nutrient availability as well as better soil condition for root penetration. The results are in close conformity with the results reported by Sangakkara *et al.* (2008) [12], Sonawane *et al.* (2009) [16], Gabhane *et al.* (2013) [6], Nasar *et al.* (2024) [8] and Sanjay and Suganya (2024) [13].

Analysis of the results revealed that, among the treatments of cotton, the highest seed cotton yield was recorded in Cotton+ Sunhemp (1027 kg ha^{-1}) followed by Cotton (965 kg ha^{-1}) and Cotton + Black gram (961 kg ha^{-1}), intercropping system. This could be attributed to the green manuring effect of sunhemp in cotton. It could also be noted that seed cotton yield in Cotton + Blackgram treatment recorded a lower yield than sole Cotton. This could be attributed to the competitive effect of Cotton + Blackgram (2:1) for nutrition, moisture and sunlight. As per note given in material and methodology on page no. 45, in T_7 the Sunhemp was buried after 35-40 DAS. Therefore, the final yield cannot be generated and considered. Hence, the general mean is mentioned instead of statistical value.

Similar results were reported by Praharaj *et al.* (2009) [11], Vekariya *et al.* (2015) [19], Jayakumar and Surendran (2017) [6], Schulz and Janssens (2020) [14] and Sanjay and Suganya (2024) [13].

Stalk Yield

The data pertaining to stalk yield as influenced by organically grown intercropping systems was found to be significant as presented in Table 4 and depicted in Fig. 4. The stalk yield ranged from 1301 to 2465 kg ha^{-1} and the significantly highest stalk yield was registered by the Cotton + Sunhemp (2465 kg ha^{-1}) treatment followed by Sole Cotton (2316 kg ha^{-1}). This might be due to the addition of FYM, vermicompost and *in situ* decomposition of sunhemp and other leguminous crops. The results are in close agreement with the findings reported by Sangakkara *et al.* (2008) [12], Nawlakhe and Mankar (2011) [9], Thimmareddy *et al.* (2013) [17], Thirunavukkarasu (2013) [18] and Sanjay and Suganya (2024) [13].

System Equivalent Yield (SEY)

The data concern to system equivalent yield as influenced by organic intercropping systems were found to be significant as presented in Table 5. It ranged from 953 to 1718 kg ha^{-1}. The highest SEY was observed in Soybean + Pigeon pea intercropping system (1718 kg ha^{-1}) and it followed the order $T_4 > T_6 > T_3 > T_2 > T_1 > T_5$. The results are in close conformity with the findings reported by Vekariya *et al.* (2015) [19], Jayakumar and Surendran (2017) [6], Sanjay and Suganya (2024) [13].

Table 5: Effect of organically grown intercropping systems on System Equivalent Yield

	Treatments	System Equivalent Yield (kg ha^{-1})
T_1	Cotton	965
T_2	Cotton + Sunhemp	1027
T_3	Cotton + Blackgram	1234
T_4	Soybean + Pigeon pea	1718
T_5	Blackgram- Chickpea (Rabi)	953
T_6	Greengram + Sorghum	1342
T_7	Sole Sunhemp	-
	GM	1034

Effect of organically grown intercropping systems on shedded biomass

The potential crops which add considerable quantity of biomass to the soil improves fertility of the soil by recycling the nutrients. The nutrient content and nurients supplied through shedded biomass are presented in table 6. Data related to biomass as influenced by organically grown intercropping systems is presented in Table 6. The maximum shedded biomass was supplied by Sunhemp (22.74 q ha^{-1}) followed by Pigeon pea (20.38 q ha^{-1}). This contributed to the accumulation of organic matter in soil which enhanced the efficient utilization of native as well as applied nutrients, also, it hastened the rate of decomposition of organic residues improving the soil's physical, chemical and biological properties and seed and stalk yield of crops in the organically grown intercropping systems. Similar results were reported by Abril *et al.* (2013), Alam *et al.* (2014) [2], Jayakumar and Surendran (2017) [6], Hadke *et al.* (2020) [5] and Neely *et al.* (2024) [10].

Table 6: Effect of organically grown intercropping systems on shedded biomass

Sr. No.	Crop	Shedded Biomass (Oven dry) (q ha^{-1})	Total NPK content (%)			Total NPK supplied (kg ha^{-1})		
			N	P	K	N	P	K
1	Sunhemp	22.74	1.06	0.16	0.87	24.11	3.63	19.78
2	Black gram	7.27	0.62	0.14	1.15	4.51	1.02	8.360
3	Green gram	7.36	0.64	0.16	0.82	4.71	1.18	6.035
4	Soybean	12.64	0.72	0.16	1.09	9.10	2.02	13.77
5	Pigeonpea	20.38	0.73	0.18	0.51	14.87	3.67	10.39

Conclusion

Organically grown intercropping systems significantly influence nutrient uptake, yield, and biomass shedded.

Significantly higher total uptake of nitrogen was recorded in the treatment Soybean + Pigeon pea intercropping system (134.95 kg ha^{-1}) followed by Greengram + Sorghum (58.17 kg ha^{-1}). The lowest total uptake of nitrogen was found in sole Cotton (35.16 kg ha^{-1}).

Significantly higher total phosphorus uptake was observed in the treatment Soybean + Pigeon pea intercropping system (13.17 kg ha^{-1}) followed by Cotton + Sunhemp (7.75 kg ha^{-1}).

The highest total potassium uptake was recorded in the treatment of Soybean + Pigeon pea intercropping system (46.81 kg ha^{-1}) followed by Cotton + Sunhemp (39.20 kg ha^{-1}).

Significantly higher seed yield (1213 kg ha^{-1}) was reported with Soybean + Pigeon pea intercropping system. However, in respect of cotton, the highest seed yield (1027 kg ha^{-1}) and stalk yield (2465 kg ha^{-1}) was recorded with the Cotton + Sunhemp treatment. The highest system equivalent yield was recorded with Soybean + Pigeon pea intercropping system (1718 kg ha^{-1}).

The maximum shedded biomass was supplied by Sunhemp (22.74 q ha^{-1}) followed by Pigeon pea (20.38 q ha^{-1}).
A consistent increase in the organic carbon of soils could be attributed due to the incorporation of organic material and shedded biomass of the intercrops into the soil. Cotton + Sunhemp intercropping system recorded higher soil organic carbon as compared to other treatments.

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