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Effect of Different Tree Spacings of *Grewia optiva* and Combined Doses of Poultry Manure and Vermicompost on Growth and Yield of Bell Pepper under Agrisilviculture System

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A B S T R A C T

A field trial was established to study the effect of four spacing (8m×1m, 8m×2m, 8m×3m and open *i.e.* tree less area) of *Grewia optiva* trees, and eight manure doses treatment (T_1 to T_6 - 160 %, 140 %, 120 %, 100 %, 80 %, 60 % of recommended doses of nitrogen through vermicompost and poultry manure in 50-50 ratio respectively, T_7- 100 % of recommended doses of NPK (chemical fertiliser) and T_8- Control *i.e.* no manures and fertilisers) on growth and yield of bell pepper under agrisilviculture system. The benefit cost ratio increased upto T_3, and then after decreased depicting that 120 % of the recommended doses of nitrogen through vermicompost and poultry manure was the best treatment for the optimum yield of bell pepper, both under different spacings of agrisilviculture system and open condition. Agrisilviculture system integrating bell pepper with widely spaced *Grewia optiva i.e*. 8m×3m was found to be economically superior to sole cropping of bell pepper in open condition.

Introduction

Agroforestry is a collective name for land use systems and technologies where woody perennials (tree, shrubs, palms, bamboos, etc.) are deliberately used on the same land management units as agriculture crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry system there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982). It is a land use system which is capable of yielding both wood and food, while conserving and rehabilitating the ecosystems. It has the capability to increase the productivity and at the same time maintain the nutrient balance as well as protect the nature.

According to the State of Indian Agriculture report, India shares only 2.4 per cent of the world's land and only 4.0 per cent of the world's freshwater resources, but the agricultural sector has to cater 17.5 per cent of the world's population. The net sown area has been stagnant at about 140 million hectares and, in view of the competing demands for land, it is not likely to increase. Thus, for resolving the twin issues of food security and environmental quality that the country faces, natural resource management needs to be accorded the highest priority (Anonymous 2016). The increasing population is also imposing higher demands on the forest products and the fact is that, even today the production in forestry sector is not enough to meet out the existing demands, which is also bringing down the reserve forest under increased pressure. As per IPCC, agroforestry systems can provide significant opportunities of creating synergies linking both adaptation and mitigation actions with a technical mitigation potential of 1.1-2.2 Pg C in terrestrial ecosystems in coming 50 years (IPCC, 2007). Under such circumstances, agroforestry can be advantageous over traditional agricultural and forest production methods, in which the same unit of land can be exploited for production of diverse products in a sustainable basis, and at the same time secures livelihood of the farmers, checks soil degradation and maintains ecological balance.

According to Brandis (1972) *Grewia optiva* belonging to family Tiliaceae is distributed throughout the sub-Himalayan tract up to an altitude of 1800 m and is one of the most important multipurpose trees of north-western Himalayas. It provides nutritive and palatable fodder during the lean winter season, bast fibre and fuelwood. In addition, it also adds large quantities of organic matter to the soil through litter fall. Organic vegetable cultivation offers one of the most sustainable farming systems with recurring benefits not only to long term soil health but also provides a lasting stability in production by making it resistance to all kind of stress. Growing of bell pepper using organic manures under widely spaced *Grewia optiva* can offer economically more benefits than sole cropping of bell pepper in open condition when the tree component is properly managed. The information on these aspects of Grewia based agrisilviculture system involving vegetable crops and the use of organic manures is meager. There are still many unanswered questions, which require great deal of research.

Materials and Methods

Site description

The experiment was conducted in the existing agroforestry model of *Grewia optiva* in the department of Silviculture and Agroforestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the period of March, 2018 to August, 2018. The area is located at 30º 51’ N latitude and 76º 11’ E longitude, with an elevation of 1200 m above MSL and slope of 7-8 percent, which falls in sub-tropical, sub-humid agro-climatic zone of Himachal Pradesh, India. The area receives an annual rainfall which varies from 1000-1400 mm and about 75 percent of it is received during the monsoon period (June-September). The average annual temperature is 17.4^{o}C. The soil of the area belongs to Typic Eutrochrept subgroup as per the soil taxonomy of USDA. The soil is gravelly sandy loam in texture and the pH of the top layer of the soil (15 cm) is neutral and containing high organic matter.

Details of structural components

Woody component of the agroforestry system *i.e. Grewia optiva* tree rows runs in East-West orientation. It was established in three different spacings (8m×1m, 8m×2m and 8m×3m), since July, 2004. The details of the growth attributes of the trees, and some physiological parameters like Leaf Area Index, Photosynthetically Active Radiations and Light Intensity under different spacings of the *Grewia optiva* tree rows are presented in the Table 1.

Bell pepper (*Capsicum annuum* L.), variety Solan Bharpur was grown with spacing of 60cm×45cm, solely and also with Grewia trees, in plots of size 3m×1m accommodating 12 plants per plot. Nursery raised 60-65 days old seedlings were transplanted on 25th of March, 2018. In addition, the effect of percentage increasing doses (60-160%) of vermicompost and poultry manure on performance of bell pepper was also analysed.

Design of the experiment and treatment details

The experiment was established as per split-plot design, in which the main plot treatment (4) was tree spacing and sub plot treatment (8) was the manure doses, details of which are given in the Table 2. The total number of treatment combination was 32 and it was replicated thrice. In the treatment plots of T_1 - T_6, respective quantities of vermicompost and poultry manure were applied during soil preparation. For T_7, full dose of SSP, MOP and half dose of urea was applied as basal application, and rest ½ dose of urea was applied in 2 equal splits *i.e.* after 1 month of transplanting and during flowering.

Parameters recorded

Certain yield attributing parameters of the bell pepper like- days to first flowering, plant height, total number of fruits per plant, 1000 seed weight and fruit yield per hectare were assessed both under system and open condition. Data were collected from 5 randomly selected bell pepper plants (physiological maturity stage) in each plot. Under agroforestry system, parameters like Leaf Area Index (LAI) and Photosynthetically Active Radiation (PAR) were measured using the instrument CI-110 Digital Plant Canopy Analyser, whereas, the light intensity was measured using Lux Meter. Economic parameters like net return and benefit cost ratio were analysed for estimating the economic viability of the treatment combinations. While estimating the cost of cultivation, due considerations were made to incorporate the initial establishment cost, and the annual lopping and fibre extraction cost by using the annuity method. And during return calculations, returns from leaf fodder, fibre and fuel wood was also considered. The data obtained from various characters under study were analyzed by the method of analysis of variance as described by (Gomez and Gomez, 1984).

Results and Discussion

Parameters of bell pepper such as days to first flowering, plant height, total number of fruits per plant, 1000 seed weight and fruit yield per hectare were recorded under three spacings of Grewia based agroforestry system as well as in open condition (Fig. 1).

Days to first flowering

Data presented in Table 3 reveals that, tree spacing and the manure doses had a significant influence on the number of days to first flowering of bell pepper under *Grewia optiva*. Days to first flowering decreased with increase in light intensity and PAR, longest span (35.85 days) being recorded under S_1 (8m×1m) spacing and shortest (31.80 days) under open condition (S_0). The prolonged duration of flowering under agroforestry system may be due to late initiation of bud formation under relatively more prolonged shade conditions. These results are in line with the findings of Hadi *et al.,* (2006), Nasrullahzadeh *et al.,* (2007). Further, under different manure doses, the longest span to first flowering (38.15 days) was recorded in T_8 (no manures), while the shortest (30.84

days) was recorded in T_1 (160 % OM), which was statistically at par with T_2 (140 % OM) *i.e.* 31.63 days to first flowering. The earliness in flowering in the plots treated with higher doses of organic manure (vermicompost and poultry manure), could be attributed due to the faster enhancement of vegetative growth and storing sufficient reserved food materials for differentiation of buds into flowers (Wolff and Coltman, 1990).

Plant height (cm)

Table 4 reveals that, under different spacings, bell pepper plant height was recorded maximum under open condition (S_0), *i.e.* 55.58 cm and then decreased with decrease in light intensity and PAR under agroforestry system from S_3- S_1. This may be attributed due to the decrease in competition for light, moisture and nutrients between the roots of trees and vegetable crop, with increase in distance from trees (Manurung *et al.*, 2007). On the other hand, among the different manure doses, maximum plant height (55.59 cm) was registered in T_1 (160 % OM), which was statistically at par with T_2 (140 % OM) and T_7 (100 % NPK), however minimum plant height (47.47 cm) was recorded in T_8 (no manures) treatment. The differential response of plants to differed doses of organic manures is due to production of lesser quantity of growth-promoting substances by lower doses of organic manures than in higher doses (Arancon *et al*., 2004 b). In addition to these, vermicompost also contains micro nutrients such as Calcium, Magnesium, Zinc and Manganese, resulting in better plant height of capsicum.

Total number of fruits per plant and fruit yield (q ha^{-1})

Perusal of the data presented in table 5 and 6 reveals that, tree spacing, organic manures and their interaction significantly influenced the total number of fruits per plant and the fruit yield per hectare. Among the four spacings, highest number of fruits per plant (14.18) and maximum fruit yield per hectare (216.12 q) were recorded in S_0 (open) spacing, which were statistically at par with that of S_3 (8m×3m) spacing; however, lowest number of fruits per plant (9.72) and minimum fruit yield per hectare (137.57 q) were recorded in S_1 (8m×1m) spacing. There was an increasing trend of fruits per plant and fruit yield per hectare, with increase in spacing and increase in light intensity, this could be due to poor photosynthetic capacity and resource pool competition under the tree. These findings are in line with Manurung *et al.,* (2007) and Islam *et al.,* (2008) who reported higher yield per plant of *Capsicum annuum* and Chilli in plot without shade as compared with plots under full shade. Among the manure doses, the highest number of fruits per plant (14.87) and maximum fruit yield per hectare (227.19 q) were recorded in T_1 (160 % OM), which were statistically at par with T_2 (140 % OM). However, lowest number of fruits per plant (5.64) and minimum fruit yield per hectare (73.94 q) were registered in T_8 (no manures). Number of fruits per plant and fruit yield per hectare in T_7 (100 % NPK) were found to be significantly at par with that of T_4 (100 % OM). The incremental advantages in terms of yield observed with the increasing dosage of organic manure may be due to the optimum nutrient supply to the capsicum plant, enhancing the growth and development by increasing the rate of plant metabolic processes like photosynthesis, respiration and their better acclimatization that encouraged greater green leaf area, helping in higher carbohydrate synthesis and leading to increase formation of plant metabolites that helped to build the plant tissue and yield attributes (Lego *et al*.) Besides, vermicompost also contains significant quantities of nutrients, a large amount of beneficial microbial populations and biologically active metabolites particularly, gibberellins, cytokinins, auxins and group B vitamins (Bhavalkar, 1991) all of which have a beneficial effect on photosynthesis and translocation, resulting in higher yield attributing factors. Similar results were obtained by Jamir *et al.,* (2017), Gopinath *et al.,* (2011) and Adhikari *et al.,* (2016).A combined effect of treatment and spacing (S×T) revealed that, highest number of fruits per plant (17.19) and maximum fruit yield per hectare (271.51 q) were recorded in treatment combination S_0T_1, which were significantly at par with S_0T_2 and S_0T_3. On the other hand, lowest number of fruits per plant (4.93) and minimum fruit yield per hectare (63.36 q) were recorded in S_1T_8, which were found to be statistically at par with S_2T_8 and S_3T_8.

1000 seed weight (g)

Data presented in Table 7 reflects that only manure doses had significant influence on the 1000 seed weight of capsicum. Maximum weight of 1000 seeds (4.78 g) was recorded in T_1 (160 % OM) and minimum (4.10 g) was recorded in T_8 (no manures), which was statistically at par with T_6 (60 % OM) treatment. 1000 seed weight in T_7 (100 % NPK) i.e. 4.57 g, was found to be statistically at par with T_3 (120 % OM) *i.e.* 4.54 g. Heavier seeds might have resulted from greater accumulation of food reserves with application of higher quantity vermicompost and poultry manure. In addition Vermicompost contains several micro nutrients, among which boron helps in better seed quality. The results are in conformity with that of Sharma (1999) and Kumar and Sharma (2006).

Economic analysis

Economic analysis revealed that growing of bell pepper under wider spacing (8m×3m) of *Grewia optiva* proved to be more profitable than sole cropping of bell pepper in open condition. The cost of cultivation was more under agroforestry system as compared to the sole cropping of bell pepper; this is due to the additional cost incurred in the agroforestry system on the tree component for initial establishment, yearly lopping and fibre extraction. With the increase in manure doses rate, the cost of cultivation also increased. The cost of cultivation of bell pepper with inorganic fertilisers were less as compared all the organic manure treatments, this is due to the cheaper market prices of the inorganic fertilisers (Table 8). The net return (Rs. 4.08 lakh ha^{-1}) and B:C (3.20) of bell pepper under S_3 (8m×3m) spacing was higher than the net return (Rs. 3.63 lakh ha^{-1}) and B:C (3.17) of sole cropping of bell pepper under open condition (Table 9 and 10). Net return increased with increase in organic manure rates upto treatment T_1 (application of 160 % of recommended dose of nitrogen through VC and PM) in all spacings, however the marginal increment in the return reduced drastically after T_3 (application of 120 % of recommended dose of nitrogen through VC and PM).

Table.1 Details of the growth attributes of the trees

Tree Spacing	Tree height (m)	D.B.H (cm)	Crown spread (m)	LAI	PAR (µmol m^2s^{-1})*	Light Intensity (Lux)**
S_1 (8m×1m)	5.45	10.15	1.50	1.26	266.13	11044
S_2 (8m×2m)	5.39	11.58	1.96	1.13	321.70	14498
S_3 (8m×3m)	5.17	12.52	2.31	0.92	407.67	17725

* PAR in open condition (460.19 µmol m^2s^{-1}); ** Light Intensity in open condition (19845 Lux)

Table.2 Details of main plot and sub plot treatments

Main plot treatment	Spacing (S)
S_1	8m × 1m
S_2	8m × 2m
S_3	8m × 3m
S_0	open condition
Sub plot treatment	**Manure doses (T)**
T_1	160 % RD N through VC & PM on 50:50 N-equivalence basis
T_2	140 % RD N through VC & PM on 50:50 N-equivalence basis
T_3	120 % RD N through VC & PM on 50:50 N-equivalence basis
T_4	100 % RD N through VC & PM on 50:50 N-equivalence basis
T_5	80 % RD N through VC & PM on 50:50 N-equivalence basis
T_6	60 % RD N through VC & PM on 50:50 N-equivalence basis
T_7	100 % RD NPK (chemical fertilizers- urea, SSP, MOP)
T_8	Control (no fertilizer & no manure)

Table.3 Effect of tree spacing and organic manures on days to first flowering of bell pepper after transplanting under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	32.32	31.52	30.89	28.62	**30.84**
T_2 (140% VC+PM)	33.74	32.61	31.08	29.08	**31.63**
T_3 (120% VC+PM)	35.08	33.43	32.03	29.88	**32.61**
T_4 (100% VC+PM)	35.89	34.40	33.54	31.34	**33.79**
T_5 (80% VC+PM)	36.43	35.91	34.58	32.84	**34.94**
T_6 (60% VC+PM)	37.66	36.79	35.84	34.24	**36.13**
T_7 (100% NPK)	35.99	34.92	33.72	31.74	**34.09**
T_8 (no manures)	39.71	38.93	37.31	36.65	**38.15**
MEAN	**35.85**	**34.82**	**33.62**	**31.80**	
			$CD_{0.05}$	**S**	1.11
				T	0.84
				S×T	NS

Table.4 Effect of tree spacing and organic manures on plant height at harvest (cm) of Bell Pepper under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	52.97	53.66	56.96	58.77	**55.59**
T_2 (140% VC+PM)	51.82	53.20	56.73	58.20	**54.99**
T_3 (120% VC+PM)	50.33	52.52	55.27	56.74	**53.72**
T_4 (100% VC+PM)	50.12	52.64	54.42	55.76	**53.23**
T_5 (80% VC+PM)	49.61	50.78	52.41	53.15	**51.49**
T_6 (60% VC+PM)	48.16	49.40	51.28	52.50	**50.33**
T_7 (100% NPK)	51.96	53.85	56.04	58.65	**55.13**
T_8 (no manures)	46.05	46.92	46.00	50.90	**47.47**
MEAN	**50.13**	**51.62**	**53.64**	**55.58**	
			$CD_{0.05}$	**S**	0.87
				T	1.07
				S×T	NS

Table.5 Effect of tree spacing and organic manures on total number of fruits per plant of bell pepper under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	11.91	14.30	16.09	17.19	**14.87**
T_2 (140% VC+PM)	11.73	14.07	15.91	17.03	**14.69**
T_3 (120% VC+PM)	11.55	13.71	15.61	16.82	**14.42**
T_4 (100% VC+PM)	10.32	12.54	14.45	15.64	**13.24**
T_5 (80% VC+PM)	8.84	11.02	12.76	13.32	**11.48**
T_6 (60% VC+PM)	8.20	9.25	11.32	11.59	**10.09**
T_7 (100% NPK)	10.26	12.46	14.37	15.07	**13.04**
T_8 (no manures)	4.93	5.14	5.73	6.75	**5.64**
MEAN	**9.72**	**11.56**	**13.28**	**14.18**	
			$CD_{0.05}$	**S**	1.34
				T	0.42
				S×T	0.97

Table.6 Effect of tree spacing and organic manures on fruit yield (q ha^{-1}) of bell pepper under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	173.01	213.49	250.77	271.51	**227.19**
T_2 (140% VC+PM)	170.06	209.19	246.51	267.78	**223.38**
T_3 (120% VC+PM)	165.46	204.98	241.89	263.27	**218.90**
T_4 (100% VC+PM)	146.58	185.91	220.71	236.92	**197.53**
T_5 (80% VC+PM)	122.84	160.33	189.24	197.62	**167.51**
T_6 (60% VC+PM)	113.91	131.73	165.92	168.87	**145.11**
T_7 (100% NPK)	145.32	185.87	217.83	233.13	**195.54**
T_8 (no manures)	63.36	66.85	75.70	89.83	**73.94**
MEAN	**137.57**	**169.79**	**201.07**	**216.12**	
			$CD_{0.05}$	**S**	18.42
				T	6.22
				S×T	14.31

Table.7 Effect of tree spacing and organic manures on 1000 seed weight (g) of Bell Pepper under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	4.75	4.77	4.79	4.81	**4.78**
T_2 (140% VC+PM)	4.75	4.73	4.76	4.72	**4.74**
T_3 (120% VC+PM)	4.56	4.58	4.52	4.51	**4.54**
T_4 (100% VC+PM)	4.38	4.45	4.41	4.37	**4.40**
T_5 (80% VC+PM)	4.28	4.30	4.31	4.34	**4.31**
T_6 (60% VC+PM)	4.08	4.07	4.14	4.14	**4.11**
T_7 (100% NPK)	4.55	4.55	4.58	4.60	**4.57**
T_8 (no manures)	4.04	4.09	4.11	4.15	**4.10**
MEAN	**4.43**	**4.44**	**4.45**	**4.46**	
			$CD_{0.05}$	**S**	NS
				T	0.03
				S×T	NS

Table.8 Cost of cultivation (Rs. lakh ha^{-1}) of bell pepper under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	2.27	2.24	2.22	2.04	**2.19**
T_2 (140% VC+PM)	2.18	2.16	2.14	1.95	**2.11**
T_3 (120% VC+PM)	2.10	2.07	2.06	1.87	**2.03**
T_4 (100% VC+PM)	2.02	1.99	1.98	1.79	**1.95**
T_5 (80% VC+PM)	1.94	1.91	1.90	1.71	**1.86**
T_6 (60% VC+PM)	1.86	1.83	1.81	1.63	**1.78**
T_7 (100% NPK)	1.67	1.64	1.63	1.44	**1.60**
T_8 (no manures)	1.06	1.03	1.02	0.83	**0.99**
MEAN	**1.89**	**1.86**	**1.84**	**1.66**	

Table.9 Net return (Rs. lakh ha^{-1}) from bell pepper under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	3.78	4.32	5.04	4.75	**4.47**
T_2 (140% VC+PM)	3.79	4.29	5.02	4.74	**4.46**
T_3 (120% VC+PM)	3.76	4.27	4.99	4.71	**4.43**
T_4 (100% VC+PM)	3.37	3.87	4.54	4.13	**3.98**
T_5 (80% VC+PM)	2.86	3.31	3.83	3.23	**3.31**
T_6 (60% VC+PM)	2.72	2.68	3.33	2.59	**2.83**
T_7 (100% NPK)	2.96	3.29	3.73	3.22	**3.30**
T_8 (no manures)	2.25	1.86	1.87	1.41	**1.85**
MEAN	**3.19**	**3.49**	**4.04**	**3.60**	

Table.10 B C of growing Bell Pepper under Grewia based agrisilviculture system

MANURE DOSES	TREE SPACING				MEAN
	S_1 (8m×1m)	S_2 (8m×2m)	S_3 (8m×3m)	S_0 (Open)	
T_1 (160% VC+PM)	2.67	2.93	3.27	3.33	**3.05**
T_2 (140% VC+PM)	2.74	2.99	3.34	3.43	**3.12**
T_3 (120% VC+PM)	2.79	3.06	3.42	3.52	**3.20**
T_4 (100% VC+PM)	2.67	2.94	3.30	3.31	**3.05**
T_5 (80% VC+PM)	2.47	2.73	3.02	2.89	**2.78**
T_6 (60% VC+PM)	2.46	2.47	2.84	2.59	**2.59**
T_7 (100% NPK)	2.77	3.00	3.29	3.24	**3.08**
T_8 (no manures)	3.12	2.79	2.84	2.70	**2.86**
MEAN	**2.71**	**2.87**	**3.16**	**3.13**	

*NS- Non Significant at $P > 0.05$

Fig.1 Bell pepper under Grewia based agrisilviculture system

The Benefit Cost Ratio increased upto T_3 (120 % OM) and thereafter with the increase in organic manure rates, it decreased. So it is clearly evident that, T_3 (120 % of recommended dose of nitrogen through VC and PM) is the most economically profitable treatment dose and treatment combination of S_3T_3 was the best treatment combination.

In conclusion the growth and yield parameters of bell pepper increased with the increase in tree spacing of *Grewia optiva* and rate of organic manure application. Among the different manure doses the treatment T_3 (application of 120 % of recommended dose of nitrogen through VC and PM) was proved to be the best dose, on the other hand, among different treatment combinations S_3T_3 was the best as compared to others. The yield reduction in bell pepper under agroforestry system ranged between 6.96 % - 36.35 % as compared to sole cropping of bell pepper. The income generated from the fodder, fibre and fuel wood of Grewia not only compensated the yield reduction of bell pepper under tree, but also increased the overall income of the farmers, apart from providing certain other indirect benefits like carbon sequestration, prevention of soil erosion, crop diversification and maintenance of micro-climate.

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