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ALLELOPATHY AND VEGETATION IN ACACIA TORTILIS PLANTATIONS IN INDIAN DESERT

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ABSTRACT

The properties of soil beneath *Acacia tortilis* and *Prosopis cineraria* at Jodhpur did not differ significantly. The common understorey plants of *A. tortilis* showed lower phytomass and higher phosphorus, potassium, and also nitrogen in *Boerhavia diffusa* and *Gisekia pharnacioides* than *P. cineraria* indicating that no apparent competition exists. In A. tortilis, soil extracts exhibited inhibitory effect on germination and seedling growth on pearlmillet, sesame and clusterbean. Leaves + stem leachate showed maximum inhibitory effect. Extracts exhibited higher inhibitory effect than the respective leachate. Concentrations of extracts and leachates were negatively correlated with germination and seedling growth. Sesame was most affected.

INTRODUCTION

Available lIterature indicates that the allelopathic interactions in a tree crop association have more bearing on crop production under integrated land use system (agroforestry); rather than agriculture alone (Al-Naib and Al-Mousawi 1976; Chou and Waller 1980 Chou and Kuo 1986; Rice 1987). Therefore, comprehensive studies on effect of tree allelochemicals on germination, growth and metabolism of crop plants should be considered before recommending any tree species for large scale plantations under agroforestry programme.

Acacia tortilis, localley known as Israeli Babool planted during 1962 showed 100% survival. Its understorey was very poor at many sites especially at shelter belts andsand dunes, which suggests that an allelopathic mechanism may be in operation in addition to some demographic interference. Despite this, the exotic tree was recommended for introduction to different habitats, viz. shallow sandy loam soils, sand stones, road side plantations, rock refractory sites, shifting sand dunes, wind breaks and shelter belts (Mann and Muthana 1984). Therefore, the present study was conducted primarily to determine whether *A. tortilis* is allelopathic to seed germination and seedling growth of some arid zone crops.

MATERIAL AND METHODS

Phytosociological studies : In order to understand species composition under neath *A. tortilis* and nearby *Prosopis cineraria* stands, frequency, density and abundance for each species were computed using predetermined quadrats (Misra 1968).

Analysis of plant and soil samples : Major mineral composition (nitrogen, phosphous, potassium) of plants of *A. tortilis* and *P. cineraria* stands and physico chemical properties, pH, EC, total nitrogen, available phosphorus, exchangeable potassium of soils of both the stands were analysed to determine whether *A. tortilis* causes any change in plants composition or in soil properties which could account for the allelopathic effects.

For chemical analysis, species, common at both stands were separately dried (48 h at 80'C) and digested in H_2SO_4+ H_2O_2 mixture (Allen et al. 1976). Nitrogen was estimated using microkjeldahl method (Peach and Tracey 1985), phosphorus based on the development of blue colour (Allen et al. 1976) and potassium by using flame photometer.

For soil analysis, the samples were air dried, passed through 0.5 mm sieve, and analysed for pH, EC, total nitrogen (Piper 1942), available phosphorus and exchangeable potassium (Allen et al 1976).

Effect of aqueous leachates : For leachate preparation, air dried materials of leaves+stem, litter, soil of *A. tortilis* and *P. cineraria* stands were separately immersed in distilled water (1:4 ratio) for 72 h in cold conditions (4°C). The filtrate, thus obtained, was made upto 100 ml and the same considered as stock solution. From this various concentrations (0, 25, 50, 75, 100%) of test solutions were prepared for bioassay.

For bioassay, twenty seeds each of pearlmillet (BJ-104), sesame (T-25) and clusterbean (Durgapura safed) were germinated separately in petridishes (diameter 10 cm), lined with single layer of filter paper. The filter paper and petridishes were sterilized before bioassay. Each petridish was moistened separately with different concentrations of test solution, and a total of 6 ml in three split was used per petridish. After 72 h of incubation of seeds in controlled growth room conditions (temperature $28 \pm 2^{\circ}C$), the number of seeds germinated and seedling growth (length of radicle and plumule) were measured. The bioassay for each concentration was tetraplicated, the results were statistically analysed, and the germination percentage was transformed to arc sine value for analysis.

Effect of extracts : For extract preparation air dried materials of leaves+stem, litter, soil of *A. tortilis and P. cineraria* stands were separately extracted using 10% aqueous methanol (1:4 ratio) for 72 h in soxhlet apparatus. The extract, thus obtained, was made upto 100 ml and considered as stock solution. Different concentration were prepared and bioassyed as in the case of leachates.

RESULTS AND DISCUSSION

Phytosociological studies : Phytosociologically the communities associated with *Prosopis cineraria* and *Acacia tortilis* have low similarity index of 25 and 35% based on density and frequency, respectively. *Cenchrus ciliaris, Cyperus rotundus, Gisekia Pharnacioides, Indigofera cordifolia, Portulaca oleracea* and *Amaranthus* ssp. were common in both stands and their density was higher in A. tortilis stand than *P. cineraria* stand (Table 1).

Soil physico-chemical properties : The pH, EC, total nitrogen, exchangeable potassium were found to be lower in *A. tortilis* stand as compared *P. cineraria* stand, but the available phosphorus was higher in the former than in the latter. However, the nutrient status of soils of *A. tortilis* stand is mostly higher than the cultivated fields, where the weeds dominate, especially in poorly managed fields (Table 2).

Table 1. Phytosociological observations in stands of *Acacia tortilis* and *Prosopis cineraria*

Plant species	*A. tortilis*			*P. cineraria*		
	F	D	A	F	D	A
Cenchrus ciliaris	50	7.7	15.4	80	5.2	8.5
Cyperus rotundus	40	1.3	3.25	10	0.1	1.0
Gisekia pharnacioides	40	1.3	3.25	50	1.6	3.2
Indigofera cordifolia	80	5.5	6.87	10	0.1	1.0
Portulaca oleracea	30	0.5	1.66	90	3.9	4.3
Amaranthus sp.	20	0.2	1.00	10	0.1	1.0
Acacia tortilis	30	2.8	9.33	—	—	—
Trianthema portulacastrum	40	1.3	3.25	—	—	—
Cleome viscosa	20	0.2	1.00	—	—	—
Unknown sp*	10	0.1	1.00	—	—	—
Cucumis sp.	10	0.1	1.00	—	—	—
Boerhavia diffusa	—	—	—	10	0.4	4.0
Tribulus terrestris	—	—	—	100	8.4	8.4
Eragrostis tremula	—	—	—	30	0.8	2.6
Corchorus tridens	—	—	—	50	16.0	32.0
Indigofera hochstetteri	—	—	—	10	0.1	1.0
Digera alternifolia	—	—	—	10	0.2	2.0

* The specimen was at seeing stage, later not found in marked places at *A. tortilis* stand.
F = Frequency, D = Density, A = Abundance

Table 2. Characteristics of soil beneath *A. tortilis*, *P. cineraria* and cultivated fields

Soil parameter	*A. tortilis*	*P. cineraria*	Cultivated fields*
pH	6.3	6.7	7.4—7.8
EC (dSm^{-1})	1.091	1.49	1.5—2.1
Total N (%)	0.029	0.03	0.025—0.058
Available P (mg 100 g^{-1} dry soil)	9.25	7.6	1.97—3.56
Exchangeable K ,,	3.59	7.88	4.25—12.00

* Sundaramoorthy, 1987

Nutrient status : In contrast to higher density in *A. tortilis* stand, the phytomass per plant was less as compared to *P. cineraria* stand, except for *Cyperus rotundus* which showed 0.72 g plant^{-1} in the former, while 0.50 g plant^{-1} in the latter. Interestingly, all the common plants showed higher phosphorus and potassium percentage, except *Cenchrus ciliaris*, and also nitrogen in *Boerhavia diffusa* and *Gisekia pharnacioides* of *A. tortilis* stand than *P, cineraria*, indicating that no apparent competition exists in the understorey. And thus, the interference may be accounted for allelopathy (Table 3).

Inhibitory effect of soils of *A. tortilis* stand : The soil extracts of *A. tortilis* inhibited germination and seedling growth of all test crops, with maximum inhibition in sesame. Increase in the concentration of soil extract increases the inhibitory effect, and negatively correlated with germination and seedling growth. The computed correlation coefficients are -0.92, -0.99, -0.94 (pearlmillet), -0.92, -0.96, -0.94 (sesame), -0.81, -0.95, -0.98 (clusterbean) for germination, hypocotyl and readicle growth, respectively. The increase in concentration of extract also showed maximum inhibitory effect in seedling growth of sesame and the affect rate per unit increase was -0.02 ± 0.01, -0.02 ± 0.01 for radicle and hypocotyl growth, respectively (Table 4).

Table 3. Phytomass and mineral composition of plants sharing both stands

Plant	*Acacia tortilis*					*Prosopis cineraria*				
	Phy.*	N%	P%	K%	Na%	Phy.	N%	P%	K%	Na%
C. ciliaris	0.17	2.46	0.23	0.29	2.30	0.77	3.11	0.02	0.32	0.43
C. rotundus	0.72	2.05	0.25	1.37	2.28	0.50	2.04	0.02	0.04	0.60
B. diffusa	0.54	3.66	0.29	1.34	0.67	0.69	2.40	0.02	0.35	0.34
G. pharnacioides	0.05	.25	0.16	1.32	0.67	0.21	0.53	0 02	0.11	0.54
I. cordifolia	0.01	—	—	0.05	4.92	0.27	3.15	0.02	0.03	1.02
P. oleracea	0.01	—	—	—	—	0.30	3.42	0.02	0.35	0.61

*Phy. = Phytomass g plant^{-1}

To compare the inhibitory effect of soils of *A. tortilis* the soil extracts of *P. cineraria* stand was also bioassayed. Increas in the concentration of soil extracts increased the inhibition in all the test crops. However, the rate of inhibition of the extract of *P. cineraria* is very low as compared to *A. tortilis* (Table 5).

Effect of *A. tortilis* leachates : The leaves+stem leachate of *A. tortilis* inhibited germination and seedling growth of all test crops. Sesame showed complete inhibition of seedling growth at 75% and 100% concentrations of leachates, and the rate of inhibition per unit increase in concentration was -0.60 ± 0.34 in case of seed germination. The rate of inhibition of pearlmillet and clusterbean was -0.39 ± 0.11, -0.01 ± 0.01, 0.03 ± 0.03, -0.15 ± 0.04, -0.01 ± 0.02 ± 0.01 for germination, hypocotyl and radicle growth, respectively (Table 6).

Table 4. Effect of different concentrations (%) of aqueous methanolic extracts (1 : 4 ratio) of *A. tortilis* stand soil on test crops

Conc-[a]	Pearlmillet			Sesame			Clusterbean		
	Ger.[c]	Rad.	Hyp.	Ger.	Rad.	Hyp.	Ger.	Rad.	Hyp.
0[b]	100	5.84	4.74	100	2.32	2.22	98	2.77	2.11
25	100	4.50	2.40	100	2.00	1.11	93	2.82	1.49
50	80	2.69	1.43	95	0.92	0.57	93	2.10	1.37
75	83	2.01	1.40	88	0.48	0.28	95	1.96	0.92
100	88	0.38	0.14	38	0.40	0.13	83	1.23	0.74
r	−0.92	−0 99	−0.94	−0.92	−0.96	−0.94	−0.81	−0.95	−0.98
	±0.72	±0.21	±0.63	±0.73	±0.53	0.65	±1.09	±0.67	±0.41
a.f.	−0.37	−0.05	−0.04	−0.50	−0.02	−0.02	−0.12	−0.02	−0.01
	±0.29	±0.01	±0.03	±0.39	±0.01	±0.01	±0.16	±0.01	±0.01

Table 5. Effect of different concentration (%) of aqueous methanolic extracts (1 : 4 ratio) of *P. cineraria* stand on test crops

Conc-[a]	Pearlmillet			Sesame			Clusterbean		
	Ger.[c]	Rad.	Hyp.	Ger.	Rad.	Hyp.	Ger.	Rad.	Hyp.
0[b]	100	5.83	4.73	100	2.31	2.22	98	2.77	2.11
25	98	4.82	2.44	98	1.36	1.36	93	2.49	1.06
50	95	5.09	2.76	100	1.61	1.11	90	2.78	1.40
75	93	5.56	3.14	100	1.98	1.43	90	2.66	1.21
100	93	3.90	2.64	100	0.44	0 84	88	1.31	1.38
r	−0.92	−0.66	−0.60	−0.35	−0.69	−0.60	−0.90	−0.70	−0.51
	±0.71	±1.38	±1.48	±1.72	±1.33	±1.47	±0.79	±1.31	±1.58
a.f.	−0.15	−0.01	−0.010	−0.03	−0.01	−0.01	−0.11	−0.01	−0.01
	±0 13	−0.03	±0.04	±0.16	±0.02	±0.02	±0.10	±0.02	±0.02

Ger. = Germination (%) Rad. = Radicle length (cm)
Hyp. = Hypocotyl length (cm)
r = Correlation coefficient
a.f. = Affect rate (confidence interval for 'b' 95% of the time)
a = Each value is average of tetraplicates
b = Comparison among tables invalid. Sets kept in different dates. Growth room condition very different.
c = For data analysis angular transformation employed.

Table 6. Effect of different concentrations (%) of aqeous leachates (1 : 4 ratio) of stem+leaves of *A. tortilis* on test crops

Conc-a	Pearlmillet			Sesame			Clusterbean		
	Ger.c	Rad.	Hyp.	Ger.	Rad.	Hyp.	Ger.	Rad.	Hyp.
0b	100	3.84	4.02	95	2.00	2.01	98	2.68	2.12
25	98	2.81	4.10	75	0.74	1.03	95	2.08	2.02
50	85	0.91	3.88	30	0.91	0.88	93	1.22	1.11
75	80	0.98	3.02	15	—	—	90	1.30	1.62
100	60	0.68	2.43	13	—	—	83	0.43	0.66
r	−0.99	−0.92	−0.92	−0.96	—	—	−0.99	−0.96	−0.85
	±0.27	±0.73	±0.72	±0.54	—	—	±0.28	±0.54	±0.97
a. f.	−0.39	−0.03	−0.02	−0.60	—	—	−0.15	−0.02	−0.01
	±0.11	±0.03	±0.01	±0.34	—	—	±0.04	±0.01	±0.05

Table 7. Effect of different concentrations (%) of aqueous leachates (1 : 4 ratio) of litter of *A, tortilis* on test crops

Conc-a	Pearlmillet			Sesame			Clusterbean		
	Ger.c	Rad.	Hyp.	Ger.	Rad.	Hyp.	Ger.	Rad.	Hyp.
0b	100	6.43	4.51	100	3.88	2.17	97	3.80	2.88
25	98	7.81	4.06	98	4.34	2.31	97	2.84	2.62
50	85	7.06	4.20	100	2.79	2 549	92	3.47	2.92
75	95	6.18	4.00	100	2.20	2.50	93	3.60	2.66
100	88	7.98	4.24	97	2.56	1.90	83	3.20	2.33
r	−9.78	0.29	−0.47	−0.43	−0 83	−0.21	−0.88	−0.19	−0.73
	±1.16	±1.76	±1.63	±1.66	±1.02	±1.10	±0.88	±1.80	−1.27
a.f.	−0.18	−0.01	−0.002	−0.06	−0.02	−0.001	−0.12	−0.002	−0.01
	±0.27	−0.04	±0.008	±0.23	±0.02	±0.012	±0.12	±0.017	±0.01

Ger., Hyp., r, a.f., a, b, and c are same as Table 4 and 5

The litter leachates also expressed inhibitory effect on all test crops. Concentration and the effect are negatively correlated, but the rate of inhibition is low as compared to leaves+stem in all crops (Table 7).

Effect of *A. tortilis* extracts : To estimate the total inhibitory effects, cxtracts were made from leaves+stem and litter and the same were bioassayed using all the test crops. The extracts, like leachates showed inhibitory effect and the rate of inhibition was higher than respective leachates. Sesame showed no seedling growth at any selected dilution of the extracts (25, 50, 75, 100%) of leaves+stem and the rate of inhibition for germination was -0.62 ± 0.43, the higher of all the cases. The higher inhibition of extracts than leachates suggests that some compounds are not leachable and/or the compounds in the test solutions are higher in extracts than leachates (Table 8 & 9).

Table 8. Effect of different concentrations (%) of aqueous methanolic extracts (1 : 4 ratio) of stem + leaves *A. tortilis* on test crops

Conc-[a]	Pearlmillet			Sesame			Clusterbean		
	Ger.[c]	Rad.	Hyp.	Ger.	Rad.	Hyp.	Ger.	Rad.	Hyp.
0[b]	100	3.84	4.02	95	4.35	2.01	98	2.68	2.11
25	98	0.74	3.91	42	—	—	93	0.92	1.57
50	75	0.70	2.12	35	—	—	80	0.50	0.31
75	33	0.33	1.39	7	—	—	60	0.50	0.20
100	27	0.30	0.75	5	—	—	45	0.43	—
rr	—0.98	0.79	—0.97	—0.65	—	—	—1.00	—0.81	—
	±0.39	±1.13	±0.44	±0.94	—	—	±0.16	±1.07	—
a.f.	—0.66	—0.03	—0.04	—0.62	—	—	—0.41	—0.02	—
	±0.26	±0.04	±0.02	±0.43	—	—	±0.07	±0 03	—

Table 9. Effect of different concentrations (%) of aqueous methanolic extracts (1:4 ratio) of litter of *A. tortilis* on test crops

Conc-[a]	Pearlmillet			Sesame			Clusterbean		
	Ger.[c]	Rad.	Hyp.	Ger.	Rad.	Hyp.	Ger.	Rad.	Hyp.
0[b]	100	6.43	4.51	100	3.89	2.17	97	3.80	2.88
25	100	8.14	4.40	98	3.20	1.96	95	3.26	2.47
50	100	7.80	4.96	95	2.29	2.09	87	3.67	2.67
75	85	6.88	4.01	70	1.57	1.57	87	2.79	1.97
100	83	5.86	2.88	60	1.49	1.33	88	2.52	1.84
r	—0.88	—0.40	—0.73	—0.99	—0.97	—0.91	—0.85	—0.87	—0.91
	±0.90	±1.68	±1.25	±0.25	±0.42	±0.77	±0 96	±0.91	±0.76
a.f.	—0.25	—0.01	- 0.02	—0.41	—0.03	—0 01	—0.10	—0.01	—0.01
	±0.26	±0.04	±0.03	±0.10	±0.11	±1.01	±0.12	∓0.01	±0.01

Ger., Ayp., r, a.f., a, b, and c are same as Table 4

The common plants analyses of *P. cineraria* and *A. tortilis* showed less phytomass beneath *A. tortilis* but no drastic reduction in nutrient composition. This indicates that the inhibition of growth of understorey plants is apparently not due to changes in mineral status of the substratum but probably due to some chemical inhibition.

The chemical inhibition was proved when the leachates or extracts were bioassayed using the crops of semiarid zone. The soils of *A. tortilis* also showed the presence of inhibitory principle. *P. cineraria* is known to enhance the growth of understorey plants and the associated plants also exhibit higher nitrogen content. In the present study also, most of the plants growing in *P. cineraria* stand showed higher nitrogen content. The inhibitory effect of *P. cineraria* soils was probably due to some chemicals added by the associated herbaceous plants.

The allelopathic potential of *A. tortilis* was evident in bioassays with aqueous methanolic extracts from either leaves+stem or litter. The leaves + stem contained larger amount of allelopathic principles, which showed strong biological activity over sesame, pearlmillet and clusterbean, as compared to litter. *A. tortilis* seedlings were recorded in its understorey, but it is premature to state about autointoxication, as no detailed experiment was carried out on this line. On the contrary, it is amply clear that *A. tortilis* is allelopathic to seed germination and seedling growth of semiarid zone crops.

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