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Research Article

KHEJRI (*PROSOPIS CINERARIA* L. DRUCE) BASED AGROFORESTRY SYSTEMS IN ARID AND SEMI-ARID PARTS OF NORTH-WESTERN INDIA

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Abstract: *Prosopis cineraria* commonly known as Khejri, a tree legume plays an important role in the socio-economic development of rural community. The traditional Khejri based agroforestry systems were assessed for phyto-sociology and crop production. Phyto-sociology of Khejri based agroforstry systems in terms the frequency, density, basal area and importance value index (IVI) of tree species of woody vegetation and production of wheat (*Triticum aestivum*), Indian mustard (*Brassica juncea*) and chick pea (*Cicer arietinum*) was studied in arid (Rajasthan) and semi-arid (Haryana) regions of northwest India. The frequency of Khejri was the highest (100%) and its IVI ranged between 183 to 223 showing that Khejri was highly dominant tree species in agricultural fields in this region. The other woody species were *Dalbergia sissoo, Tecomella undulata, Acacia tortilis, Capparis aphylla* and *Prosopis juliflora*. The growth and yield of all crop's underneath Khejri were significantly (P<0.05) higher as compared to fields devoid of trees.

Keywords: *Prosopis cineraria, Khejri, Agroforestry, Arid and Semi-Arid Region*

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Introduction

The Indian hot arid zone occupies an area of 0.32 million km^2 comprising of the northwestern states of Rajasthan, Gujarat, Punjab, Haryana and scattered landmasses of Maharashtra, Karnataka and Andhra Pradesh states. Low and erratic rainfall, extreme temperatures, hot wind with high velocity and high evapotranspiration are the characteristics of the region. Moreover, the soils are poor in nutrients and scarcity of water and recurring droughts are perennial constraints. These factors cause several problems like agricultural, ecological, social and economic. Despite this situation in this area Khejri based agroforestry systems offers food, fodder, fuel; and conserve ecology without degradation of natural resources.

Khejri a tree legume plays a vital role in the socio-economic development of rural community. It is extremely useful at the time of droughts and famines. It is called as 'KalpTaru' of arid regions because it provides fuel wood, fodder and timber apart from providing shade to wildlife and cattle during the scorching heat of extreme summer. It is very effective for soil improvement and sand dunes stabilization [1, 2, 3]. Different studies on Khejri based agroforestry systems in association with pearl millet (*Pennisetum typhoides*), cluster bean (*Cyamopsis tetragonolobus*), cowpea (*Vigna sinensis*), Indian mustard (*Brassica juncea*) and mung bean (*Vigna radiata*) showed increased returns, organic matter, total N, P & K and dry matter yield [4,5]. Productivity of Khejri based agroforestry systems was more beneficial as compared to *Tecomella undulata* based agroforestry systems [6] and increase in crop yield was 11.1% due to improved soil conditions. Keeping in view the most important agroforestry systems, in dry areas, Khejri based agroforestry systems were assessed for phyto-sociology and effect on Rabi crops in north-west India.

Materials and Methods

An extensive survey of Khejri based agroforestry systems were carried out in districts of Bhiwani, Haryana (semi-arid region) and Sikar, Rajasthan (arid region). In total, six fields (one acre each) were selected (3 each in Haryana and Rajasthan). In Haryana at Jhumpa (Bhiwani) three fields were selected for two crops namely, Indian mustard (*Brassica juncea*) as these two crops are mainly grown at the farmers in this area. Similarly, in Rajasthan three fields of two farmers in Fatehpur Sekhawati and Laxmangarh were selected for wheat as grown in the interspaces of Khejri and other associated trees. Detailed phyto-sociological analysis of three fields was carried out following quadrat method. Ten quadrates, each 10 m x10 m were laid out in each field; and frequency, density and basal area of tree species existing in agricultural fields were measured. The calculations were done as suggested by Misra [7]. The growth and yield attributes of wheat at Fatehpur Sekhawati and Lakshmangarh, and Indian mustard & black gram at Jhumpa in sandy and loam soils underneath Khejri and associated woody vegetation was studied through standard methods. For each crop, 9 quadrates (each of 1 m x1 m) were laid out in the entire field to estimate yield. The placing of quadrates was further divided into 0-2, 2-4 and 4-6 m away from the tree. For each crop, the yield attributes were also estimated in the area devoid of trees as control. For wheat, Indian mustard or black gram, crop the parameter like number of plants per m^2; plant height; number of seeds per pod/ silique/spike; 100-seed weight; weight of seed per pod/ silique/spike; root and shoot weight per plant (dry), and grain weight per plant (dry) were recorded from randomly selected fifty plants in each replication. The data were analyzed statistically by using the methods described by Panse and Sukhatme [8] in factorial Randomized Block Design with three replications.

Table-1 *Phyto-sociology of Khejri based agroforestry systems*

Field No.	Location	Tree Species	Frequency (%)	Density (10x10m)	Basal area (cm^2)(10x10 m)	Relative frequency(%)	Relative density(%)	Relative basal area(%)	Importance Value Index(IVI)
I	Lakshmangarh	*Prosopis cineraria*	100	1.7	1226	63	68	66	197
		Dalbergia sissoo	20	0.3	409	13	12	22	47
		Zizyphus mauritiana	20	0.2	32	12	8	2	22
		Tecomella undulata	10	0.1	71	6	4	4	14
		Acacia tortilis	10	0.2	118	6	8	6	20
II	Lakshmangarh	*Prosopis cineraria*	100	4.1	3240	53	81	89	223
		Tecomella undulata	40	0.5	229	21	8	6	35
		Dalbergia sissoo	23	0.3	77	16	6	2	24
		Capparis aphylla	20	0.2	108	10	5	3	18
III	Fatehpur Sekhawati	*Prosopis cineraria*	100	3.8	3018	40	68	75	183
		Tecomella undulata	60	0.8	565	24	14	14	52
		Zizyphus mauritiana	30	0.4	131	12	7	3	23
		Capparis aphylla	40	0.4	160	16	7	4	27
		Acacia tortilis	20	0.2	126	8	4	3	15
IV	Jhumpa (Bhiwani) Loam soil	*Prosopis cineraria*	100	2.4	1907	59	70	71	200
		Dalbergia sissoo	20	0.4	463	12	12	17	41
		Zizyphus mauritiana	20	0.2	72	12	6	3	21
		Acacia tortilis	20	0.4	223	18	12	8	38
V	Jhumpa (Bhiwani) Sandy soil	*Prosopis cineraria*	100	3.6	1979	56	77	81	214
		Acacia tortilis	30	0.5	240	17	11	10	37
		Zizyphus mauritiana	30	0.3	121	17	6	5	28
		Tecomella undulata	10	0.1	47	6	2	2	9
		Prosopis juliflora	10	0.2	44	6	4	2	12
VI	Jhumpa (Bhiwani) Sandy soil	*Prosopis cineraria*	100	2.5	1648	42	61	80	183
		Prosopis juliflora	40	0.5	102	17	12	5	34
		Zizyphu smauritiana	50	0.6	154	21	15	7	43
		Tecomella undulata	10	0.1	37	4	2	2	8
		Acacia tortilis	40	0.4	112	12	10	5	32

Table-2 *Growth and yield of chick pea in Khejri based agroforestry systems*

Distance from tree (m)	Plant height (cm)	Number of pods $plant^{-1}$	100-seed weight (g)	Weight pod^{-1} (g)	Root weight $plant^{-1}$ (g)	Shoot weight $plant^{-1}$ (g)	Grain weight $plant^{-1}$ (g)	No. of plants m^2
0-2	58.80	73.40	14.10	0.14	1.17	12.57	11.37	9
2-4	58.70	69.29	13.53	0.13	1.19	12.47	11.23	10
4-6	55.40	59.00	11.70	0.11	1.25	11.83	8.60	12
Open	53.20	56.20	10.68	0.09	1.35	10.70	8.13	13
CD (P≥ 0.05)	1.89	5.77	1.15	0.01	0.05	0.84	0.68	2.54

Table-3 *Growth of Indian mustard in Khejri based agroforestry system*

Growth parameter	Distance from tree (m)				CD (P ≥ 0.05)
	0-2	2-4	4-6	Open	
Plant height (cm)	148.13	151.60	156.13	121.50	6.30
Root length (cm)	114.05	119.47	125.23	124.74	3.65
Collar diameter (mm)	11.62	11.80	13.12	13.15	0.84
No. of leaves $plant^{-1}$	23.33	26.67	23.67	24.50	1.77
Root weight $plant^{-1}$ (g)	26.73	28.33	30.73	31.81	1.73
Stem weight $plan^{-1}t$ (g)	23.13	24.80	23.78	23.75	0.88
No. of plants m^2	9.5	7.0	8.25	10.25	1.51
No. of siliquae $plant^{-1}$	301.83	282.77	253.60	227.10	15.32
1000 seed weight (g)	5.90	6.00	5.63	5.55	0.21
Seed weight $siliqua^{-1}$ (g)	0.08	0.07	0.07	0.08	0.003
Husk weight $siliqua^{-1}$ (g)	0.08	0.08	0.07	0.07	0.004
Grain weight $plant^{-1}$ (g)	26.55	23.71	19.91	18.45	0.82

Results and Discussion

Phyto-sociology of tree species

The frequency of Khejri was the highest (100%) in all the fields of study irrespective of state. *Dalbergia sissoo* (20%), *Tecomella undulata* (60%), *A. totilis* (30%) and *Zizyphus mauritiana* (50%) ranked number 2 in terms of frequency in field no. I, III, V and VI, respectively. Similarly, density (1.7 - 4.1), basal area (1226 - 3240), relative frequency (40-63), relative density (61-81), relative basal area (66 - 89) and IVI (183-223) of Khejri was also the highest in all the fields [Table-1].

Growth and yield of chick pea

Growth and yield of chick pea showed a boosting effect in association of Khejri [Table-2]. Plant height, number of pods per plants, 100 seed weight, weight per pod, shoot weight per plant and grain weight per plant decreased significantly beyond 4 m distance from the tree trunk of Khejri. The beneficial results underneath Khejri might be due to its nitrogen fixing ability and high efficiency of recharging the soil with organic matter [9]. Puri *et al*. [10] also reported that the crop growth and yield of chickpea was higher in area of 3.5 m radius from Khejri tree and then decreased. Hooda *et al*. [11] also reported the higher number of plants per square meter, pods per plant, seed per pod, 100 seed weight and seed yield of chickpea under the canopy of Khejri as compared with chickpea in area devoid of trees. Deep root system of Khejri [12] which absorbs nutrients from deeper layers and recharges the soil of the upper layer, could be another reason for better growth underneath of Khejri [13]. Jaimini and Tikka [14] also reported that Khejri improves soil fertility by fixing nitrogen and adding organic matter. Singh *et al*. [15] and Singh and Rathod [16] have recorded an increase in crop yields beneath the Khejri canopy.

Root length, stem diameter, root weight and number of plants per m^2 of Indian mustard increased significantly at 4 meters away from the tree [Table-3]. The difference in the values of growth parameters at a distance of 4-6 m as compared to the area without any tree, were at par with each other.

Table-4 *Growth and yield of wheat in association of different tree species in Khejri based agroforestry systems*

Field no. and Location	Growth parameter	Treatments (tree species)					CD	Distance from tree (m)			CD	Interaction
		P. cineraria	*D. sissoo*	*T. undulata*	*Z. mauritiana*	*C. aphylla*	(P≥ 0.05)	0-2	2-4	4-6	(P≥ .05)	
Field no. I Lakshmangarh	Plant height (cm)	80.57	*60.61*	68.11	72.90	-	3.28	66.75	68.53	76.36	2.84	5.7
	Grains spike^{-1}	58.13	*47.33*	49.40	48.13	-	2.62	50.45	50.85	50.95	NS	NS
	100-seed weight (g)	4.78	*4.16*	4.16	4.00	-	0.32	4.17	4.31	4.34	NS	NS
	Weight spike^{-1} (g)	1.63	*1.50*	1.54	1.50	-	NS	1.47	1.58	1.59	NS	NS
	Root weight plant $^{-1}$(g)	1.59	*1.69*	1.73	1.71	-	NS	1.61	1.68	1.73	NS	NS
	Shoot weight plant^{-1} (g)	2.17	*1.62*	1.69	1.70	-	0.12	1.78	1.79	1.87	NS	NS
	Grain weight plant^{-1} (g)	2.78	*1.73*	1.79	1.80	-	0.13	1.91	1.98	2.18	NS	0.22
	No. of plants m^2	139	*80*	104	111	-	2.25	94.75	111.25	119.50	1.95	3.9
Field no. II Lakshmangarh	Plant height (cm)	80.40	-	68.61	72.69	-	2.6	71.34	72.34	78.05	2.1	4.48
	Grains spike^{-1}	58.13	-	49.07	48.40	-	3.1	51.53	52.20	51.87	NS	NS
	100-seed weight (g)	5.03	-	4.16	4.19	-	0.3	4.48	4.45	4.45	NS	NS
	Weight spike $^{-1}$ (g)	1.65	-	1.55	1.49	-	NS	1.50	1.59	1.60	NS	NS
	Root weight./plant (g)	1.56	-	1.75	1.77	-	NS	1.65	1.67	1.76	NS	NS
	Shoot weight plant^{-1} (g)	2.21	-	1.77	1.72	-	0.16	1.90	1.90	1.91	NS	NS
	Grain weight plant^{-1} (g)	2.81	-	1.81	1.84	-	0.16	2.07	2.13	2.26	NS	0.27
	No. of plants m^2	123.67	-	97.66	81.00	-	3.00	93.00	103.30	105.00	3.00	5.19
Field no. III Fatehpur Sekhawati	Plant height (cm)	80.94	-	69.09	72.77	70.58	3.0	70.45	71.94	77.64	2.6	5.2
	Grains spike^{-1}	58.67	-	48.87	49.60	47.47	2.34	50.80	51.60	51.05	NS	NS
	100-seed weight (g)	4.92	-	4.19	4.02	3.96	0.28	4.25	4.30	4.27	NS	NS
	Weight spike^{-1} (g)	1.65	-	1.56	1.52	1.53	NS	1.48	1.61	1.60	NS	NS
	Root weight plant $^{-1}$ (g)	1.63	-	1.66	1.74	1.72	NS	1.63	1.70	1.73	NS	NS
	Shoot weight plant^{-1} (g)	2.29	-	1.69	1.73	1.66	0.14	1.81	1.85	1.86	NS	NS
	Grain weight plant^{-1} (g)	2.85	-	1.80	1.85	1.74	0.13	1.98	2.01	2.19	NS	0.22
	No. of plants m^2	127.67	-	91.33	76.67	76.00	1.83	86.75	94.24	97.75	1.59	3.17

The growth of crop was significantly greater in loam soil as compared to the sandy soil irrespective of distance from the tree, whereas, the root length was significantly longer in sandy soil as compared to loamy soil. The values of number of leaves of per plant were, however, remained more or less the same in both types of soil.

Growth and yield of Indian mustard

The yield parameters in Indian mustard such as number of siliquae per plant and grain weight per plant decreased significantly as the distance from the trunk increased up to 6 m [Table-3]. The values of these parameters were the greatest underneath trees (0-2 m). Total weight per plant, 1000-seed weight and husk weight per siliqua were significantly higher at a distance of 0-2 m or 2-4 m from the tree as compared to the distance of 4-6 m, and in area without trees. The value of 1000 seed weight and husk weight were higher up to a distance of 4 m from the trees but decreased significantly as the distance from the tree increased. The values of seed weight per siliqua at 0-2 m distance from the tree and in area having no tree were higher as compared to plant 2-6 m distance from the tree. However, the reverse was true for seed weight per siliqua. Root length, stem diameter, root weight and number of plants per square meter of Indian mustard increased significantly at 4 m distance from the tree but height of the plants increased significantly up to 6 m away from the tree whereas stem weight increased at 2-4 m distance from the tree. This trend could be due to positive effects of Khejri which enhance the growth of adjacent crop [17]. During the period of Indian mustard growth (November to February), the competition for light is reduced because the major litter fall of Khejri starts in November and continues up to April of next growing season with peak in March [18].

Growth and yield of wheat

The values of plant height and number of plants per square meter of wheat underneath, *P. cineraria* were significantly higher as compared to *D. sissoo, T. undulate,* and *Z. mauritiana.* The values regarding grain per spike, 100 seed weight, shoot weight per plant and grain weight per plant were also recorded significantly higher underneath *P. cineraria* as compared to other plant species. The values of weight per spike and root weight per plant were found to be non-significant under different tree species. The yield of wheat under *P. cineraria* increased by 179 percent compared to *D. sissoo* [Table-4]. The yield of wheat increased by 44 percent in 4-6 m distance from the tree as compared to 2-4 m distance from the tree [Table-4]. The values of the plant height and number of plants per square meter of wheat at Lakshmangarh were significantly higher under Khejri followed by *T. undulata* and *Z. mauritiana*. The values of grain per ear head, 100 seed weight, shoot weight per plant and grain weight per plant were also recorded significantly higher in Khejri, whereas, under *T. undulata* and *Z.mauritiana* these values were found at par. The values of weight per spike and root weight per plant were recorded non-significant under all the tree species such as Khejri, *T. undulata* and *Z. mauritiana*. The yield of wheat under Khejri increased by 133 percent compared to *Z. mauritiana*. The values of plant height increased significantly beyond 4 m distance from the tree, whereas, the number of plans per square meter increased significantly up to 4 m distance from the tree trunk. The values of other parameters such as grain per ear head, 100 seed weight, weight per spike, root weight per plant, shoot weight per plant and grain weight per plant were recorded non-significant in all the distance from the tree trunk. The yield of wheat increased by 23.27 percent in 4-6 m distance from the tree as compared to 2-4 m distance from the trees [Table-4]. The increase in growth and yield parameters under *Prosopis cineraria* may be attributed to its nitrogen fixing ability and higher efficiency of reaching the soil with organic matter [9] and also due to lesser light interception in mono-layered canopy of Khejri [19]. As explained earlier due to its deep tap root system, it absorbs water and nutrients from deeper soil layers while the crop absorbs them from the top 50-60 cm soil [13]. Lateral roots are initiated below 50 cm soil depth in Khejri as compared to just below the soil surface in *Z. mauritiana*. Further, Khejri has fewer roots and most of them Khejri does not appear to have any toxic are of 2 mm diameter and distributed uniformly in soil [13]. The short life span of leaves (65 days) of Khejri as compared to longer leaf span in other species [18, 9, 19] might decrease the shedding effect on crop underneath Khejri. *Prosopis cineraria* trees do not appear to have any toxic effect on plants below its canopy [20]. *D. sissoo, T. undulata, Z. mauritiana* and *C. aphylla* having the shallow root system increase the moisture competition for the crop which directly reduces the growth of wheat. Further, exhaustive crops such as wheat can't perform optimum underneath shallow rooted tree species. Kulkarni *et al*. [21] also reported that wheat growing under *Prosopis cineraria* compared with the values for those growing away from the trees, were ascribed to higher levels of fertility and soil moisture contents in soils underneath the trees. This is not true with other trees such as *D. sissoo, T. undulata, Z. mauritiana* and *C. aphylla*.

Conclusion

The frequency of Khejri was the highest (100%) and its IVI ranged between 183 to 223 showing that Khejri was highly dominant tree species in agricultural fields in this region.

The other woody species were *Dalbergia sissoo, Tecomella undulata, Acacia tortilis, Capparis aphylla* and *Prosopis juliflora*. The growth and yield of all crop's underneath Khejri were significantly ($P<0.05$) higher as compared to fields devoid of trees.

Application of research: The Khejri based agroforestry systems conserve ecology without degradation of natural resources in arid and semi-arid regions.

Research Category: Agroforestry

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