Growth and Yield Performance of Different Varieties of Fennel (*Foeniculum vulgare* Mill.) under Shisham (*Dalbergia sissoo* Roxb.) based agroforestry system in South-Eastern Rajasthan

ABSTRACT

Thepresentinvestigation waslaidoutinRBDwith three replications during the September, 2022 to April, 2023 at Herbal Garden, under the Department of Silviculture and Agroforestry, College of Horticulture and Forestry, Jhalawar (Agriculture University, Kota). FouryearsoldPlantationsofShisham(*Dalbergiasissoo*Roxb.)at5 m × 5 mspacingwereusedfor intercroppingoffive varietiesofFennel(*Foeniculum vulgare*Mill.)viz.'AF-1,AF-2,RF-125, RF-205andRF-290'plantedat50 cm×20cmwereselectedforthepresent study. The analysis of variance showed significant differences among intercropping fennel under Shisham based Agroforestry system as well asSole cropping system. The analysis of variance showed non-significant differences for the plant height (m), number of primary branches, collar diameter (cm), crown spread East-West (m) and crown spread North-South (m). Significant maximum plantheightofFennelat harvest (182.14 cm), no. of branch per plant (8.12), no. of umbels per plant (20.30), no.of seeds per umbel (683.40), diameter of umbel (115.93mm), seed yield per plant (25.64 g), seed yield per plot (3.08 kg) and minimum Days taken to 50% flowering (86.78) wasrecordedintheT$_1$(Shisham+*Foeniculum vulgare*Mill.var.AF-1).However,maximumeconomicalyield(25.64 q/ha)andbiological yield (68.92 q/ha) was foundinT$_6$(*Foeniculum vulgare*Mill.var.AF-1 sole).

Keywords: Agroforestry, Fennel, Intercropping, Seed yield, Shisham.

1. INTRODUCTION

Agroforestry is defined as the direct mixing of trees and crops on the same piece of land in aspatial and temporal sequence, known as agroforestry. Agroforestry, a loosely defined term, involvesthe deliberate growing of trees and shrubs with crops and/or animals in interacting combinations for avariety of objectives. Such farming practices have been used throughout the world for a long time; butscientific attention was focused on them and thus they attained prominence as a land-use practice, onlysince the late 1970s.

Fennel (*Foeniculum vulgare* Mill.) is a perennial herb. The fruit is a dry schizocarp from 4-10millimeters($^3/_{16}$-$^3/_8$inch)long,halfaswideorlessandgrooved.Sincetheseedinthefruitisattachedto the pericarp,

the whole fruit is often mistakenly called "seed". The variety and quantity of vitamins contained is variable: folates, 270 mg/ kg; vitamin B3, 6.4 mg/kg; vitamin C, 8.7–340 mg/kg. Fennel contains potassium (4.24–5.85 g/kg), the most abundant mineral by far, with low amounts of phosphorus (500 mg/kg), calcium (5.6–363 mg/kg), magnesium (8.2–389 mg/k) and sodium (7.7– 512 mg/kg) [1]. As per ministry of agriculture and farmers welfare (2021-22) 3rdadvance estimate, the total area in India under Fennel cultivation is 0.79 lakh hectares andproduction is 1.28 lakh metric tonnes [2]. The major Fennel growing statesareGujarat,Rajasthan,MadhyaPradesh, WestBengal,UttarPradesh, PunjabandBihar.

Shisham(*Dalbergiasissoo*Roxb.)isanimportanttreespeciesbelongingtothefamilyPapilionaceae.Itisamediumtolargetreeofabout25metershighwithgrey-yellowtrunk,longitudinal crack, and downcast twig. Leaves are leathery, pinnately compound, with about fivealternate leaflets. Leaf stalk (petiole) measures about 15 cm long, each leaflet widest at the base, to 6cm long with a fine pointed tip [3]. TheShisham tree is a characteristic species of Khair–Sissoo (*Acacia catechu–Dalbergia sissoo* Roxb.)primaryseraltypeforest.

Intercroppingfennel (*Foeniculumvulgare*Mill.)underShisham(*Dalbergiasissoo*Roxb.)based agroforestry system couldbean interesting research topic with potential benefits for bothagricultural productivity and sustainable land use. Many potential aspects such as agroforestry systemdesign, crop performance and interaction, soil health and nutrient cycling, microclimate modifications,economic viability and sustainability and environmental impact (climate change) could be considered for exploring theresearch.

2. MATERIALS AND METHODS

The present investigation entitled **"**Intercropping Fennel (*Foeniculum vulgare* Mill.) under Shisham (*Dalbergia sissoo* Roxb.) based Agroforestry system in South-Eastern Rajasthan**"**was conducted at the Herbal Garden, College of Horticulture and Forestry, Jhalawar. Geographically, District Jhalawar falls in Zone-V i.e., Humid south eastern plains, which extends over 6.32 Lac hectare land area among 23°4' to 24°52' N (latitude) and 75°29' to 76°56' E (longitude).The average rainfall in the region is 954.7 mm and the district receives maximum rainfall with heavy rainstorms in the months of July-August upto the first week of September. Maximum temperature range in the summer is 43 - 48°C and minimum 1.0 - 2.6°C during winter. The experiment was laid outin RBD withthree replications during summer season (September, 2022 to April, 2023). The present experiment was conducted at Herbal Garden, under the Department of

Silviculture and Agroforestry, College of Horticulture and Forestry, Jhalawar (Agriculture University, Kota).In order to assess the physico-chemical properties of the soil at the experimental site, the soil samples were drawn randomly from different spots in the experimental site at a depth of 0-30 cm before the commencement of the experiment. The soil of the experimental site was clayey with a pH of 7.95 [4], having 0.45 Organic Carbon [5] and 289.50, 38.14 and 256.3 kg per ha available N [6], P_20_5 [7]and K_2O[8]respectively.Four years old plantations of Shisham (*Dalbergia sissoo* Roxb.) grown at 5 m ×5m spacing wasused forintercroppingstudy. Five varieties of fennel (*Foeniculum vulgare* Mill.)crop viz.AF-1, AF-2, RF-125, RF-205 and RF-290were selected for the present study. The Shisham plants of uniform size and growth were selected at Herbal Garden in Department of Silviculture and Agroforestry, College of Horticulture and Forestry, Jhalawar for experimentation. The gross plot area and net plot area of fennel was 5 m × 5 m and 4 m× 3 m respectively.

2.1 Experimental details

Theexperimentwasconductedinwinterseason,2022-23 withfollowingdetails.

A)	Treatmentdetails
T_0	Shisham(*Dalbergiasissoo*Roxb.)Sole
T_1	Shisham (*Dalbergia sissoo*Roxb.) + *Foeniculum vulgare* Mill. var. Ajmer fennel-1 (AF-1)
T_2	Shisham(*Dalbergiasissoo*Roxb.)+*Foeniculum vulgare* Mill. var. Ajmer fennel-2(AF-2)
T_3	Shisham(*Dalbergiasissoo*Roxb.)+*Foeniculum vulgare* Mill. var. Rajasthan fennel-125(RF-125)
T_4	Shisham(*Dalbergiasissoo*Roxb.)+*Foeniculum vulgare* Mill. var. Rajasthan fennel- 205(RF-205)
T_5	Shisham(*Dalbergiasissoo*Roxb.)+*Foeniculum vulgare* Mill. var. Rajasthan fennel- 290(RF-290)
T_6	*Foeniculum vulgare* Mill. var. Ajmer fennel-1 (AF-1)
T_7	*Foeniculum vulgare* Mill. var. Ajmer fennel- 2 (AF-2)
T_8	*Foeniculum vulgare* Mill. var. Rajasthan fennel- 125 (RF-125)
T_9	*Foeniculum vulgare* Mill. var. Rajasthan fennel-205 (RF-205)
T_{10}	*Foeniculum vulgare* Mill. var. Rajasthan fennel- 290 (RF-290)

2.2 Statistical Analysis

The data obtained from were subjected to statistical analysis (ANOVA) in MS Excel programme on computer system through the procedure of randomized block design (RBD) for various characters studied in present investigation. The treatment differences were tested by "F" test for significance based on null hypothesis. The appropriate standard error (S.Em.±) was calculated in each case and critical difference (CD) at 5 per cent level of probability was worked out to compare the treatment means, where the treatment effects were significant [9].

3. RESULTS AND DISCUSSION

3.1 Plant height

Both agroforestry systems and sole cropping influenced the plant height significantly at all the growth stages. After 30 DAS, 60 DAS, 90 DAS and at harvest of intercrop, plant height was found to be higher in T_1(Shisham + *Foeniculum vulgare* Mill. var. AF–1) under Shisham based agroforestry system viz. (16.15 cm, 106.42 cm, 157.50 cm and 182.14 cm respectively). However, minimum plant height was recorded in T_8(Shisham+ *Foeniculum vulgare* Mill. var. RF-125) (11.50 cm, 75.13 cm, 114.94 cm and 132.21 cm respectively) at different interval as 30 DAS, 60 DAS, 90 DAS and at harvest respectively. The reason behind the maximum plant height of Fennel under Shisham based agroforestry might be due to the importance of nitrogen for the proper growth of the plant because N is necessary for most of the physiological growth processes and its absence or deficiency causes stunted growth also sowing in September affect the plant height. Somehow the canopy shading which is considered as the major factor responsible for the general trend of increased plant height also high moisture content in soil affect the height [10, 11].

3.2 Number of branches per plant, umbels per plant, seeds per umbel and diameter of umbel

The maximum total number of branches per plant (8.12), number of umbels per plant (20.30), number of seeds per umbel (683.40) and diameter of umbel (115.93 mm) was recorded in treatment T_1(Shisham + *Foeniculum vulgare* Mill. var. AF-1) and minimum total number of branches per plant (5.45) , number of umbels per plant (17.70), number of seeds per umbel (560.11) and diameter of umbel (94.09 mm) was recorded in T_8(*Foeniculum vulgare* Mill var. RF-125) (5.45). The greater number of umbels per plant, seeds per umbel, diameter of umbel and primary branches were attributed to favourable

microclimatic conditions including higher moisture availability throughout trail period under tree as compared outside tree canopy and also Shisham is a nitrogen fixing tree which provide proper amount of nitrogen over RDF which helps to improve all these characteristics in the treatments. The number of umbels per plant, seeds per umbel, diameter of umbel and primary branches in five varieties under study showed significant difference [12,13].

3.3 Days to 50% flowering

Minimum days to 50% flowering was found in the treatment T_1(Shisham + *Foeniculum vulgare* Mill. var. AF-1) (86.78) whereas maximum days to the flowering was found in T_8(*Foeniculum vulgare* Mill. var. RF -125 sole) (95.67).Among the climatic factors, temperature plays a prominent role in determining the duration of various phenophases. This might be due to its genetics potential of performing better within short duration under adequate supply of nutrients and moisture [14].

3.4 Seed yield per plant, seed yield per plot

The maximum seed yield per plant (25.64 g) and seed yield per plot (3.08 kg) was found in T_1(Shisham + *Foeniculum vulgare* Mill. var. AF-1) and the minimum seed yield per plant (17.53 g) and seed yield per plot (1.05 kg) was found in T_8(*Foeniculum vulgare* Mill. var. RF-125 sole). This results obtained so might be also due to as crop distance from tree increased, yield also increased. Somehow, tree interaction causes improvement in soil physical condition in agroforestry system as compared to sole cropping system, which is responsible for better metabolic activity and seed formation [15].

3.5 Biological yield of Fennel

Highest total biological yield (68.92 q/ha)was found in the treatment T_6 (*Foeniculum vulgare* Mill. var. Ajmer Fennel- 1 sole). However, lowest total biomass (36.32 q/ha) was recorded in the treatment T_3(Shisham + *Foeniculum vulgare* Mill. var. RF -125).This might due to higher seed yield and straw yield which is directly correlated with sowing time, more availability of nitrogen over RDF, better microclimate, reduction in EC, pH and adding more organic carbon and moisture content during the experimental period

under Shisham tree as compare to sole. These results are in confirmation with the findings of [16] in Fennel and [17] in Wheat and Cowpea under Shisham

3.6 Seed yield of Fennel

Highest total seed yield (25.64 q/ha) was found in the treatment T_6 (*Foeniculum vulgare* Mill. var. Ajmer Fennel- 1 sole) whereas lowest total seed yield (17.53 q/ha) was recorded in the treatment T_3(Shisham + *Foeniculum vulgare* Mill. var. RF -125).The economical yield (q/ha) showed minimum yield in intercropping and maximum in sole cropping system which is only because the per ha. yield is calculated as per the gross plot area size and not as per the net plot area size. Further, overall if the yield is calculated as per the net plot area size, then the intercropping yield will be superior in both the system [10].

Table 1. Growth parameters of Shisham plants

S.No.	Treatments	Plantheight Initial (m)	Plantheight after (m)	percent increase	Collar diameter perplant (cm)initial	Collar diameter perplant (cm)after	percent increase	Number of primary branches initial and after	Crown spread (m) (E-W) initial	Crown spread (m) (E-W) after	Percent increase	Crown spread (m) (N-S) initial	Crown spread (m) (N-S) after	percent increase
1.	T_0Shisham Sole	4.86	5.68	16.87	98.47	100.50	2.06	2.83	2.71	3.17	16.97	2.67	3.19	19.48
2.	T_1Shisham+Fennel var. AF – 1	4.38	5.66	29.22	93.62	95.56	2.07	3.67	2.80	3.15	12.50	2.76	3.24	17.39
3.	T_2Shisham+Fennel var. AF – 2	4.51	5.66	25.5	95.43	97.60	2.27	3.58	2.68	3.05	13.81	2.57	3.00	16.73
4.	T_3Shisham+Fennel. var. RF - 125	4.88	5.61	14.96	98.95	100.64	1.71	3.33	2.66	3.14	18.05	2.88	3.33	15.63
5.	T_4Shisham+ Fennel. var. RF – 205	4.64	5.60	20.69	96.44	98.61	2.25	3.50	2.63	3.23	22.81	2.98	3.43	15.10
6.	T_5Shisham+Fennel var. RF- 290	4.78	5.53	15.69	97.20	99.29	2.15	3.25	2.77	3.26	17.69	2.81	3.29	17.08
	C.D.at5%	NS	NS		NS	NS		NS	NS	NS		NS	NS	
	SE(m)	0.26	0.21		2.28	3.77		0.17	0.13	0.11		0.15	0.14	

Table 2. Mean performance of growth and yield attributes of Fennel sole and under Shisham based intercropping

S.No.	Treatments	Plant height (cm)				Number of branch per plant	Daystaken to 50% flowering	Number of umbels per plant	Number of seed per umbel	Diameterofumbel(mm)	Seedyield(g)perplant	Seedyield(kg)per plot	Biological yield (q/ha)	Economic yield (q/ha)
		30 DAS	60 DAS	90 DAS	at harvest									
1.	T_1Shisham+Fennel var. AF – 1	16.15	106.42	157.50	182.14	8.12	86.78	20.30	683.40	115.93	25.64	3.08	43.47	18.65
2.	T_2Shisham+Fennel var. AF – 2	15.47	98.20	155.29	176.81	7.43	87.8	19.26	671.15	111.58	25.42	3.05	40.49	18.52
3.	T_3Shisham+Fennel. var. RF125	11.80	75.53	115.44	141.62	6.15	94.61	18.25	561.11	94.82	23.87	2.86	36.32	17.53
4.	T_4Shisham+ Fennel. var. RF – 205	14.60	95.38	148.52	169.79	7.22	88.92	18.60	621.36	113.92	24.46	2.94	39.99	17.90
5.	T_5Shisham+Fennel	13.88	83.80	121.49	153.37	6.42	94.29	18.30	581.74	110.15	24.14	2.90	38.85	17.71

var. RF- 290													
6. T_6Fennel var. AF - 1 Sole	15.98	106.02	156.99	179.81	6.41	88.29	19.70	682.40	115.71	18.65	1.12	68.92	25.64
7. T_7Fennel var. AF - 2 Sole	15.20	97.85	154.70	170.26	6.15	89.01	18.45	670.15	111.94	18.52	1.11	65.86	25.42
8. T_8Fennel. var. RF -125 Sole	11.50	75.13	114.94	132.21	5.45	95.67	17.70	560.11	94.09	17.53	1.05	60.78	23.87
9. T_9Fennel. var. RF 205 Sole	14.39	94.98	148.01	163.23	6.09	90.83	18.25	620.36	113.7	17.90	1.07	64.85	24.46
10. T_{10}Fennel var. RF- 290 Sole	13.50	83.29	120.99	149.91	5.98	95.33	17.90	580.74	109.87	17.71	1.06	62.32	24.14
C.D.at5%	1.03	3.57	5.20	8.35	0.29	3.98	0.68	32.89	3.86	0.86	0.09	2.36	1.10
SE(m)	0.34	1.20	1.75	2.81	0.10	1.34	0.23	11.07	1.30	0.28	0.03	0.79	0.37

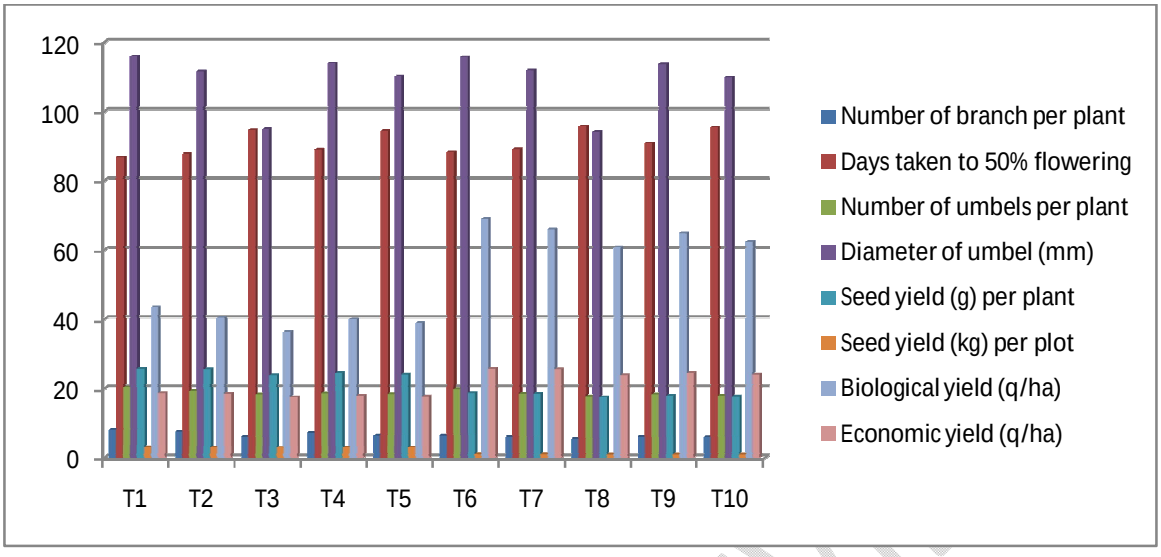

Fig. 1 Graphical representation of different growth and yield attributes of fennel

4. CONCLUSION

From the present investigation, it can be concluded that the growth and yield of Fennel underShishambasedAgroforestrysystemishigherascomparedtosolecropping, with respect to all the varieties except for the biological yield and economic yield as net area was considered for its calculation. UnderShishamthe performance was higherthan solecropping system becauseShishamprovidesomeextraN to the plants which helps to its metabolic activities. AF-1 variety of Fennel performed better amongall the Five varietiesoftheFennelintercropped underShishambasedAgroforestrysystem (as pernetplotsizearea)as wellassolecropping.

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