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Traditional *Vrikshayurveda* practices yielded equally to modern scientific agricultural practices in Proso millet (*Panicum miliaceum* L.)

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Ancient India adopted many traditional practices to maintain soil health and therefore crop yields and, one such facet is "*Vrikshayurveda"*; meantime, post green revolution era followed scientific conventional practices, which enhanced crop yields, at loss of soil health. It is the time to evaluate ancient organic practices for chemical free food production. Millets are rich in nutrients and sustaining more than 30% of world's population. Proso millet, a versatile crop capable of adapting to varied environments from tropics to temperate, is rich in nutrients. As there is little information available on evaluation of such practices in crops like millets, we conducted this study to evaluate field performance of proso millet under *Vrikshayurveda* practices in comparison with modern crop production practices and do-nothing practice. Laboratory and field research were carried out at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai during 2020-21. Treatments include; Biomass Transfer (BMT) from five trees *viz*., *Albizia lebbek* (L.) Benth*, Delonix regia* Boj.ex Hook*., Gliricidia sepium* (Jacq.) Steud*, Peltophorum ferrugineum* (Decne.) Benth and *Pongamia pinnata* (L.) Pierre and Leaf Tea spray of extracts from five tree species *viz., Morinda tinctoria* Roxb*., Moringa oleifera* Lam., *Mangifera indica* (L.), *Annona squamosa* (L.) and *Aegle marmellos* (L.) Correa. Study revealed that agrochemical-free, high-quality foodgrains in proso millet is achievable by adopting *Vrikshayurveda* practice of soil enrichment with BMT of *Albizia lebbek* and *Gliricidia sepium* on nitrogen equivalent basis and leaf tea spray (LTS) *viz., Mangifera indica* and *Moringa oleifera* at 5% resulted in <10% in yield reduction, when compared to conventional CPG practice.

Keywords: Ancient texts, Conventional practice, Do-nothing practice, GC-MS, Grain yield, Proso millet, *Vrikshayurveda*

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Ancient India has provided us a treasure house of knowledge, and one such is '*Vrikshayurveda*' and utilising them wisely would certainly be a boon to agriculture. Looking at unscientific use of agrochemicals in conventional/modern agriculture, it is right time to look back and bring forth, good and safe agricultural practices. Hence, the need for sustainable and chemical-free food grains production, indisputably boosts demand for millets by adopting traditional methods. Proso millet (common millet, white millet)[1] is one of the oldest C_4 crops among 20 millet species with a low transpiration ratio that can do well under semi-arid conditions besides being suitable for sustaining agriculture and food security.

Ancient texts

Rig-Veda and Atharvaveda have documents referencing to this science, apart from them, other treasured information on *Vrikshayurveda*, is available in Kautilya Arthashastra[2]. *Vrikshayurveda* means "Ayurveda for plants" and refers to knowledge of plant life[3] and was founded around 400 B.C. Information about soil analysis, genetic variability, seed testing, green manure, liquid biofertilizers, and other plant science topics are included in that. Amarsimha's *Amarkosha*, Patanjali's *Mahabhasya, Krishi-Parashara, Varahamihira* and *Brihat Samhita* are a few other ancient documents. However, among all, three chief ancient texts *viz.,* 1) Varahamihira, 505 A.D., Birhat Samhita, *Vrikshayurveda* Part I, Chapter 55 (edited by M. Ramakrishna Bhat, 1950), 2) Lokopakara, *Vrikshayurveda*, chapter 6 (edited by H. Sesha Iyengar, 1950), and 3) Sarangadhara Samhita, 1363 A.D., *Vrikshayurveda* (edited by S.K. Ramachandra Rao, 1993). The most detailed of all these three appears to be that of Chaundarya II dated 1025 A.D.[4], discuss more about this science.

Asian Agri-History Foundation in 1996[5] printed the English translation of *Vrikshayurveda*. It stated a

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holistic crop management system that highlights glorification of trees, arrangement of planting and cultivation of food crops, field management aspects and animal production[6,7]. These practices were in practice from Kautilya's period (296- 321BC) till thirteenth century A.D. This document was assembled, composed, and written by different authors[8,9]. Surapala (1000 A.D.), Sharangadhara (1283-1301 A.D.) and Chakrapanimishra (1577A.D.) also documented herbal *Kunapajala* preparations, which is a substitute for modern synthetic fertilizers[10].

Contemporary texts

Recent books *viz.,* '*Vrikshayurveda*'[11] and, '*Vrikshayurvedic farming*-Traditional Indian Agriculture'[12] have documented scientific validation of such practices.

Production systems

To maintain soil health in cultivated fields, ancient India used traditional and environmentally friendly practices, while in the post-Green Revolution period fertilizers and other scientific inputs have been used. But now it has been demonstrated that through *Vrikshayurvedic* farming[13] and later rechristened as Low Budget Natural way Farming- LBNF[14], higher yields could be realised from *Vrikshayurvedic* practices besides maintaining soil health through a principle of "*Feed the soil; not the Crop*". As little scientific reports are available on validation of such practices and hence, this research was made to evaluate cultivation of proso millet under *Vrikshayurveda* practices in comparison with conventional scientific as well as do-nothing practice.

Methodology

Laboratory study and field studies were conducted at Agricultural College and Research Institute, TNAU, Madurai-625104 in 2020-21. Lab study was conducted during December, 2020 at department of Agronomy to evaluate the influence of seed fortification with leaf extracts of five tree species; *Morinda tinctoria* Roxb*., Moringa oleifera* Lam., *Mangifera indica* (L.), *Annona squamosa* (L.) and *Aegle marmellos* (L.) Correa. on germination characteristics in proso millet. Two consecutive field experiments were conducted in February-June and July-October, 2021 at college experimental farm (situated at 9^0 54' N latitude, 78^0 5' E longitude and at an altitude of 147 m above sea level) to compare the effect of *Vrikshayurvedic* farming practices with scientific conventional and do-nothing practices in proso millet. Field topography was medium, soil was sandy clay loam. The experimental site was kept fallow for previous two seasons and the study was set up in a Split-plot design with two replications.

Materials and Methods

Lab study

From the campus premises, fresh, clean leaves of various tree species were gathered. In order to make leaf extracts, fresh leaves were ground in a 1:1 ratio with distilled water; the resulting extract was then filtered and used as a stock solution. Five % solution was made from stock solution for seed infusion for 6 h[12] and seeds were subjected to a germination test with eight replications using between paper technique (BP) in which seeds were kept and rolled between two layers of germination paper. Fifty seeds per replication were kept in BP roll and positioned separately upright in sterilized conical flasks whose bottoms were filled with aqueous leaf extracts. Distilled water was used as control. In each treatment, 400 seeds were tested[15]. Control and treated seeds were scrutinised for germination and seed quality characteristics for 10 days. To measure root and shoot length, 10 normal seedlings were randomly selected in each replicate after germination period and were used for the observations. Root length and shoot length were measured and mean value was expressed in centimetres. The vitality indices were calculated[16].

Gas chromatography–mass spectrometry (GCMS) analysis

Mandatory quantity of air-dried plant samples were taken in a 500 mL conical flask, added 100 mL of milli Q water and placed in a mechanical shaker for 72 h. It was then evaporated, filtered and clear extract utilised for analysis. One microlitre of clear extract was injected into GCMS in an oven maintained at a temperature of 80ºC at 5ºC/min to 250ºC (10 min). Injector temperature was maintained at 220ºC and detector temperature at 250ºC. Carrier gas was Helium, which had a flow rate of 1 mL/min. A 30-meter long HP5 Polar capillary column was used. GCMS/MS analysis was carried out at Centre of Innovation, Agricultural College and Research Institute, Madurai. GCMS was interpreted using National Institute Standard and Technology (NIST) database of 62,000 samples, wherein spectrum of unknown components was compared with known

spectrum of components from NIST library. Peak compounds were identified based on retention time and area spread.

Field trials

Main plot treatments included incorporation of tree leaves on N equivalent basis (referred as biomass transfer - BMT) of five trees *viz.,* M1-*Albizia lebbek* (L.) Benth*,* M2-*Delonix regia* Boj.ex Hook*, M3-Gliricidia sepium* (Jacq.) Steud*,* M4-*Peltophorum ferrugineum* (Decne.) Benth and M5-*Pongamia pinnata* (L.) Pierre was done. Subplots included foliar spraying of leaf extracts (referred as leaf tea spray-LTS) of five tree species *viz.,* S1-*Aegle marmellos*, S2-*Annona squamosa ,* S3-*Mangifera indica, S4-Moringa oleifera* and *S5-Morinda tinctoria.* For comparison, two separate plots in the same field were maintained at a buffer distance of 3.0 m from the treatment areas and one plot was maintained using conventional practices (RDF 40:30:0 NPK kg/ha) and another plot followed Do-nothing farming practice (just preparing the field and seeds were sown). Proso millet cv. ATL-1 was sown at a seed rate of 10 kg/ha and sowing took place on same day in all three systems. For *Vrikshayurvedic* farming practices, before sowing of seeds, biomass transfer of green leaves (N-equivalent air-dry basis) was done and incorporated at field preparation and the following six weeks the field was left undisturbed to enable decomposition of applied leaf litter. In addition, seeds were pretreated with 5% leaf extracts (leaf tea spray treatments) for at least 6 h before sowing. During growth phases, foliar nutrition was administered three times with 5% leaf extracts at critical periods. Observations were made on growth and yield parameters at harvest and Leaf Area Index (LAI) was recorded at 45 DAS. Thus observed growth and yield data were statistically evaluated and exposed to ANOVA (Analysis of Variance) with a probability of 5%[17].

Results

Lab study

Among different leaf extracts, seed fortification with 5% leaf extracts of *Mangifera indica* and *Moringa oleifera* showed comparable performances with respect to germination and seedling parameters. Highest germination (78.67%), root length (10.93 cm), shoot length (11.07 cm) and Vigour Index I (1717.8) and Vigour Index II (3091.68) were noticed in *Moringa oleifera* leaf extract treated proso millet seeds, and *Mangifera indica* leaf extract treated seeds showed maximum germination (76.00%), root (11.30 cm) and shoot (10.70 cm) lengths, and Vigour Index I (1638.80) and Vigour Index II (3068.12) values (Table 1). Nevertheless, the recorded values for all the five leaf extracts showed a better performance than control in proso millet.

Influence of different farming practices on growth parameters

Vrikshayurvedic farming practices influenced growth parameters of proso millet at tillering (Table 2) and at harvest stage (Table 3) significantly. Among BMT, *Albizia lebbek* significantly produced taller plants in both seasons and also at both growth stages of observations with a pooled mean of 98.7 cm at tillering stage and 105.01 cm at harvest. This was followed by *Gliricidia sepium* with a pooled mean of 92.9 and 98.87 cm, respectively. Among foliar spraying (LTS), *Mangifera indica* leaf extract produced taller plants at tillering (95.0 cm) and (101 cm) at harvest stage and it was closely followed by *Moringa oleifera* leaf extract spray. Interaction was significant and tallest plants were produced in *Vrikshayurvedic* farming practice of *Albizia lebbek* followed by *Mangifera indica* leaf extract spray. The least performance of plant height was noted in *Vrikshayurvedic* farming practice *Pongamia pinnata* followed by *Aegle marmellos* and *Morinda tinctoria*. This mixed trend was seen in tiller no./plant also. There was no uniform trend between seasons and pooled mean reflected altogether a different trend.

Table 1 — Effect of different leaf extracts on germination parameters in proso millet at 10 DAS in lab study

Treatments	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index I	Vigour index II
T_1 – *Aegle marmellos*	66.67	10.80	10.87	1441.60	2574.72
T_2 – *Annona squamosa*	73.33	10.00	9.07	1497.20	2940.44
T_3 – *Mangifera indica*	76.00	11.30	10.70	1638.80	3068.12
T_4 – *Moringa oleifera*	78.67	10.93	11.07	1717.87	3091.68
T_5 - *Morinda tinctoria*	68.00	9.80	9.73	1327.20	2624.40
Control	50.33	9.40	9.43	1076.40	2066.56
S. Ed	5.86	0.57	0.45	-	-
C.D ($p<0.05$)	17.91	1.72	1.36	-	-

Table 2 — Effect of Vrikshayurvedic farming practices on plant height at tillering stage

Plant height (cm)

BMT/LTS	First season						Second season						Pooled					
	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN
M_1	105.80	110.06	95.10	100.66	104.96	103.32	93.8	97.6	84.4	89.3	93.1	91.6	94.3	98.7	103.6	99.5	97.4	98.7
M_2	71.83	94.50	76.80	107.53	112.06	92.54	63.7	83.8	68.1	95.4	99.4	82.1	81.6	82.9	85.4	92.2	90.3	86.5
M_3	98.80	86.73	103.46	83.60	81.40	90.80	87.6	76.9	91.8	74.2	72.2	80.5	95.2	89.7	98.0	97.0	84.8	92.9
M_4	76.43	87.20	70.30	105.13	87.80	85.37	67.8	77.3	62.4	93.3	77.9	75.7	87.9	90.0	93.4	89.2	90.8	90.3
M_5	91.93	102.40	93.43	90.76	87.26	93.16	81.5	90.8	82.9	80.5	77.4	82.6	78.6	89.8	94.7	89.9	82.1	87.0
MEAN	88.96	96.18	87.82	97.54	94.70		78.9	85.3	77.9	86.5	84.0		87.5	90.2	95.0	93.6	89.1	
		S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)		
M		3.14		6.31				1.8		3.8				1.89		5.24		
S		2.95		6.13				1.7		3.6				2.52		6.99		
M x S		4.65		9.68				4.0		8.2				21.42		NS		
CPG				102.5						94.8						98.6		
Zero Input				59.4						74.1						70.5		

Main plot: Biomass Transfer Technique (BMT):
M1 – Albizia lebbek
M2 –Delonix regia
M3 – Gliricidia sepium
M4 – Peltophorum ferrugineum
M5 – Pongamia pinnata

Sub Plot: Leaf Tea Spray (LTS):
S1 – Aegle marmellos
S2 – Annona squamosa
S3 – Mangifera indica
S4 – Moringa oleifera
S5 - Morinda tinctoria

Table 3 — Effect of *Vrikshayurvedic* farming practices on plant height at harvest stage

Plant height (cm)

BMT/LTS	First season						Second season						Pooled					
	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN
M_1	112.5	120.83	124.67	117.8	115.06	118.17	88.13	89.18	95.85	93.83	92.21	91.84	100.31	105.00	110.26	105.82	103.64	105.01
M_2	98.16	98.53	99.56	110.65	112.35	103.85	75.36	77.80	82.16	85.54	79.69	80.11	86.76	88.16	90.86	98.09	96.02	91.98
M_3	106.13	106.43	115.46	113.45	102.6	108.81	96.41	84.33	93.05	92.99	77.83	88.92	101.27	95.38	104.25	103.22	90.22	98.87
M_4	106.78	107.6	113.67	105.40	112.23	109.14	80.23	83.88	85.04	84.38	80.96	82.90	93.50	95.74	99.35	94.89	96.60	96.02
M_5	89.60	114.56	111.2	104.83	99.78	103.99	77.68	76.46	90.35	86.51	74.80	81.16	83.64	95.51	100.775	95.67	87.29	92.58
MEAN	102.634	109.59	112.12	110.426	108.404		83.56	82.33	89.29	88.65	81.10		93.1	95.96	101.10	99.54	94.75	
		S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)		
M		2.17		5.01				2.07		4.78				1.89		5.24		
S		2.05		4.15				1.97		3.99				2.52		6.99		
M x S		4.65		9.68				4.46		9.29				21.42		NS		
CPG				122.45						104.83						113.64		
Zero Input				79.45						76.45						77.95		

Main plot: Biomass Transfer Technique (BMT):
M1 – Albizia lebbek
M2 –Delonix regia
M3 – Gliricidia sepium
M4 – Peltophorum ferrugineum
M5 – Pongamia pinnata

Sub Plot: Leaf Tea Spray (LTS):
S1 – Aegle marmellos
S2 – Annona squamosa
S3 – Mangifera indica
S4 – Moringa oleifera
S5 - Morinda tinctoria

Influence of different farming practices on physiological parameters

Understanding of crop growth physiology provides scientific base on various aspects of metabolism, photosynthetic activity, stomatal mechanism, growth and development. Data on physiological parameters are given in Table 4, 5 & 6. Treatment combinations of BMT and LTS showed their superiority in physiological attributes like leaf area index (LAI) and dry matter production (DMP). Among BMT,

Table 4 — Effect of *Vrikshayurvedic* farming practices on tiller no/plant at harvest stage

Tiller no/plant

BMT/LTS	First season						Second season						Pooled					
	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN
M_1	11.00	12.70	15.00	9.33	14.00	12.41	11.00	12.50	17.00	8.00	11.60	12.02	11.00	12.60	16.00	8.66	12.80	12.21
M_2	12.30	11.00	10.30	8.78	10.67	10.61	15.70	8.20	7.80	12.50	11.80	11.20	14.00	9.60	9.05	10.64	11.23	10.90
M_3	13.70	9.00	8.67	15.00	14.00	12.07	14.30	11.40	11.80	10.30	13.40	12.24	14.00	10.20	10.23	12.65	13.70	12.15
M_4	8.67	9.80	9.00	8.00	8.67	8.83	9.00	6.80	9.00	14.20	7.00	9.20	8.83	8.30	9.00	6.10	7.83	8.01
M_5	8.33	14.60	10.45	9.33	7.00	9.94	15.50	10.30	10.20	9.50	8.50	10.80	11.91	12.45	10.32	9.41	7.75	10.36
MEAN	10.80	11.42	10.68	10.09	10.87		13.10	9.84	11.16	8.90	10.46		11.94	10.63	10.90	9.49	10.66	
		S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)		
M		0.24		0.55				0.21		0.49				0.70		1.93		
S		0.29		0.59				0.25		0.50				1.09		NS		
M x S		0.63		1.30				0.54		1.11				2.06		4.31		
CPG			18.20						17.77						17.98			
Zero Input			4.50						5.33						4.92			

Main plot: Biomass Transfer Technique (BMT):
M1 – Albizia lebbek
M2 –Delonix regia
M3 – Gliricidia sepium
M4 – Peltophorum ferrugineum
M5 – Pongamia pinnata

Sub Plot: Leaf Tea Spray (LTS):
S1 – Aegle marmellos
S2 – Annona squamosa
S3 – Mangifera indica
S4 – Moringa oleifera
S5 - Morinda tinctoria

Table 5 — Effect of *Vrikshayurvedic* farming practices on Leaf Area Index (LAI) at flowering stage

LAI

BMT/LTS	First season						Second season						Pooled					
	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN
M_1	3.23	3.26	4.23	4.14	3.42	3.66	3.14	3.24	4.14	4.05	3.33	3.58	3.19	3.25	4.19	4.10	3.38	3.62
M_2	2.61	3.56	3.45	3.27	3.44	3.27	2.46	3.51	3.31	3.21	3.15	3.13	2.54	3.54	3.38	3.24	3.30	3.20
M_3	3.65	3.52	3.96	3.76	3.33	3.64	3.42	3.49	3.90	3.72	3.24	3.55	3.54	3.51	3.93	3.74	3.29	3.60
M_4	2.97	3.40	3.02	3.14	3.31	3.17	2.97	3.20	2.91	2.97	3.04	3.02	2.97	3.30	2.97	3.06	3.18	3.10
M_5	2.47	2.98	3.68	3.72	2.45	3.06	2.39	2.98	3.43	3.13	2.32	2.85	2.43	2.98	3.56	3.43	2.39	2.96
MEAN	2.99	3.34	3.67	3.61	3.19		2.88	3.28	3.54	3.42	3.02		2.93	3.32	3.61	3.51	3.11	
		S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)		
M		0.061		0.141				0.082		0.189				0.037		0.104		
S		0.069		0.139				0.084		0.171				0.036		0.102		
M x S		0.151		0.313				0.188		0.390				0.143		0.307		
CPG			4.44						4.23						4.33			
Zero Input			1.78						2.05						1.92			

Main plot: Biomass Transfer Technique (BMT):
M1 – Albizia lebbek
M2 –Delonix regia
M3 – Gliricidia sepium
M4 – Peltophorum ferrugineum
M5 – Pongamia pinnata

Sub Plot: Leaf Tea Spray (LTS):
S1 – Aegle marmellos
S2 – Annona squamosa
S3 – Mangifera indica
S4 – Moringa oleifera
S5 - Morinda tinctoria

Albizia lebbek had higher LAI during both seasons (3.66 and 3.58) with a pooled mean of 3.62. This was closely followed by *Gliricidia sepium*. Same trend was noticed in DMP also. As regards LTS, *Mangifera indica* ruled its superiority with maximum values for both LAI and DMP during both seasons. Pooled mean

of LAI (3.61) and DMP (4213.63 kg/ha) was recorded in same LTS. This was chased by *Moringa oleifera* leaf extract. The peak pooled LAI value (4.19) was registered in combination of *Albizia lebbek* and *M. indica*.

Influence of different framing practices on straw and grain yield

A significant and positive effect on grain yield (Table 7) and straw yield (Table 8) due to *Vrikshayurvedic* farming practices were evident from the study. The duo, *Albizia lebbek* and *Mangifera indica* proved their superiority, severally and conjointly. Among BMT, *Albizia lebbek* produced higher yields (790.67 and 718.12 kg/ha, respectively) in first and second season, while as regards LTS, *M. indica* yielded 804.67 and 705.08 kg/ha, respectively. This same trend was noticed in pooled analysis also. Maximum yields (900 and 819.78 kg/ha, respectively) in both seasons were recorded in *Albizia lebbek* and *Mangifera indica* combination with a maximum

Table 6 — Effect of *Vrikshayurvedic* farming practices on dry matter production

Dry matter production (kg/ha)

BMT/LTS	First season						Second season						Pooled					
	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN
M_1	4157.45	4365.32	4905.65	4708.67	3357.45	4298.91	4063.68	4164.99	4818.45	4624.68	3205.73	4175.51	4110.56	4265.15	4862.05	4666.67	3281.59	4237.20
M_2	2934.56	3963.67	3656.67	4078.00	3207.34	3568.05	2769.67	3864.45	3506.34	4027.76	3188.19	3471.28	2852.11	3914.06	3581.50	4052.88	3197.76	3519.66
M_3	3963.34	3850.00	4623.23	4453.43	3941.34	4166.27	3759.00	3790.56	4579.32	4421.14	3748.89	4059.78	3861.17	3820.28	4601.27	4437.2	3845.11	4113.00
M_4	3820.00	3834.67	4035.00	3500.98	3410.56	3720.24	3596.10	3758.66	3876.40	3311.76	3276.27	3563.84	3708.05	3796.66	3955.7	3406.37	3343.41	3642.04
M_5	2630.95	3078.45	4279.00	4049.00	2603.65	3328.21	2515.09	2813.67	4100.31	3989.42	2491.60	3182.02	3167.54	3324.17	4067.65	3745.2	2951.08	3451.13
MEAN	3501.26	3818.42	4299.91	4158.02	3304.07		3340.71	3678.47	4176.16	4074.95	3182.14		3539.89	3824.06	4213.63	4061.66	3323.79	
	S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)			
M	120.81		278.58				111.38		256.85				132.98		369.15			
S	104.53		211.28				84.44		170.67				123.22		342.07			
M x S	241.46		505.24				202.31		426.37				321.54		636.65			
CPG	5046.60						4961.01						5003.81					
Zero Input	1719.99						1601.66						1660.83					

Main plot: Biomass Transfer Technique (BMT):
M1 – Albizia lebbek
M2 –Delonix regia
M3 – Gliricidia sepium
M4 – Peltophorum ferrugineum
M5 – Pongamia pinnata

Sub Plot: Leaf Tea Spray (LTS):
S1 – Aegle marmellos
S2 – Annona squamosa
S3 – Mangifera indica
S4 – Moringa oleifera
S5 - Morinda tinctoria

Table 7 — Effect of *Vrikshayurvedic* farming practices on grain yield

Grain yield (kg/ha)

BMT/LTS	First season						Second season						Pooled					
	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN
M_1	723.00	786.67	900.00	843.67	700.00	790.67	666.54	702.45	819.78	782.56	619.28	718.12	694.77	744.56	859.89	813.12	659.64	754.40
M_2	478.56	640.00	706.67	700.00	620.00	629.05	424.00	563.67	593.56	657.00	589.63	565.57	451.28	601.84	650.12	678.50	604.82	597.31
M_3	713.34	590.00	833.67	828.00	726.67	738.34	638.76	545.00	778.56	745.47	634.44	668.45	676.05	567.50	806.12	786.74	680.56	703.39
M_4	670.00	700.00	790.00	720.00	530.00	682.00	592.45	658.66	678.56	657.00	515.71	620.48	631.23	679.33	734.28	688.50	522.86	651.24
M_5	430.00	600.00	793.00	815.00	410.00	609.60	402.53	456.78	654.96	645.42	389.56	509.85	416.27	528.39	723.98	730.21	399.78	559.73
MEAN	602.98	663.33	804.67	781.33	597.33		544.86	585.31	705.08	697.49	549.72		573.92	624.32	754.88	739.41	573.53	
	S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)			
M	23.57		54.36				21.69		50.03				10.88		30.20			
S	17.47		35.32				16.39		33.12				14.64		40.64			
M x S	40.25		84.18				38.99		82.09				70.04		139.37			
CPG	923.00						865.67						894.33					
Zero Input	232.65						212.66						222.65					

Main plot: Biomass Transfer Technique (BMT):
M1 – Albizia lebbek
M2 –Delonix regia
M3 – Gliricidia sepium
M4 – Peltophorum ferrugineum
M5 – Pongamia pinnata

Sub Plot: Leaf Tea Spray (LTS):
S1 – Aegle marmellos
S2 – Annona squamosa
S3 – Mangifera indica
S4 – Moringa oleifera
S5 - Morinda tinctoria

Table 8 — Effect of *Vrikshayurvedic* farming practices on straw yield

BMT/LTS	Straw yield (kg/ha)																	
	First season						Second season						Pooled					
	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN	S_1	S_2	S_3	S_4	S_5	MEAN
M_1	3434.45	3578.65	4005.65	3865.00	2657.45	3508.24	3397.14	3462.54	3998.67	3842.12	2586.45	3457.38	3415.79	3520.59	4002.16	3853.56	2621.95	3482.81
M_2	2456.00	3323.67	2950.00	3378.00	2587.34	2939.00	2345.67	3300.78	2912.78	3370.76	2598.56	2905.71	2400.83	3312.22	2931.39	3374.38	2592.95	2922.35
M_3	3250.00	3260.00	3789.56	3625.43	3214.67	3427.93	3120.24	3245.56	3800.76	3675.67	3114.45	3391.34	3185.12	3252.78	3795.16	3650.55	3164.56	3409.63
M_4	3150.00	3134.67	3245.00	2780.98	2880.56	3038.24	3003.65	3100.00	3197.84	2654.76	2760.56	2943.36	3076.83	3117.34	3221.42	2717.87	2820.56	2990.80
M_5	2200.95	2478.45	3486.00	3234.00	2193.65	2718.61	2112.56	2356.89	3445.35	3344.00	2102.04	2672.17	2156.75	2417.67	3465.67	3289.00	2147.84	2695.38
MEAN	2898.28	3155.09	3495.24	3376.68	2706.73		2795.85	3093.15	3471.08	3377.46	2632.41		2847.06	3124.12	3483.16	3377.07	2669.57	
	S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)				S.Ed		C.D (p≤0.05)			
M	100.13		230.89				86.58		199.65				17.53		48.65			
S	71.26		144.02				82.25		166.24				28.94		80.33			
M x S	174.17		368.42				185.92		371.72				32.45		139.63			
CPG	4123.60						4095.34						4109.47					
Zero Input	1487.34						1389.00						1438.17					

Main plot: Biomass Transfer Technique (BMT):
M1 – Albizia lebbek
M2 –Delonix regia
M3 – Gliricidia sepium
M4 – Peltophorum ferrugineum
M5 – Pongamia pinnata

Sub Plot: Leaf Tea Spray (LTS):
S1 – Aegle marmellos
S2 – Annona squamosa
S3 – Mangifera indica
S4 – Moringa oleifera
S5 - Morinda tinctoria

pooled mean grain yield of 859.89 kg/ha. Next best combination in respect of proso millet grain and straw yields was *Albizia lebbek* with *M. oleifera*. Similar trend was noticed in straw yield also with a maximum pooled mean straw yield of 4002.16 kg/ha in *Albizia lebbek* and *M. indica* combination. A similar finding[13] was reported in *Pongamia pinnata* and *Moringa oleifera* combination in black gram.

Results of GCMS analysis of best performing LTS *viz., Mangifera indica* and *Moringa oleifera* indicated that Peak compounds identified based on area percentage in *M. indica* (Fig. 1) were 15.50% - Catechol (retention time – 13.24 min) and 15.05% - cyclohexanone 2- pentyl (16.98 min). In *M. oleifera,* peak compounds identified based on area percentage (Fig. 1) are 26.50% - 2- piperidinone (retention time: 12.57 min) and 11.92% - 2 – pyrrolidinone (retention time: 9.464). These compounds might have contributed in physiological and metabolic processes in proso millet growth.

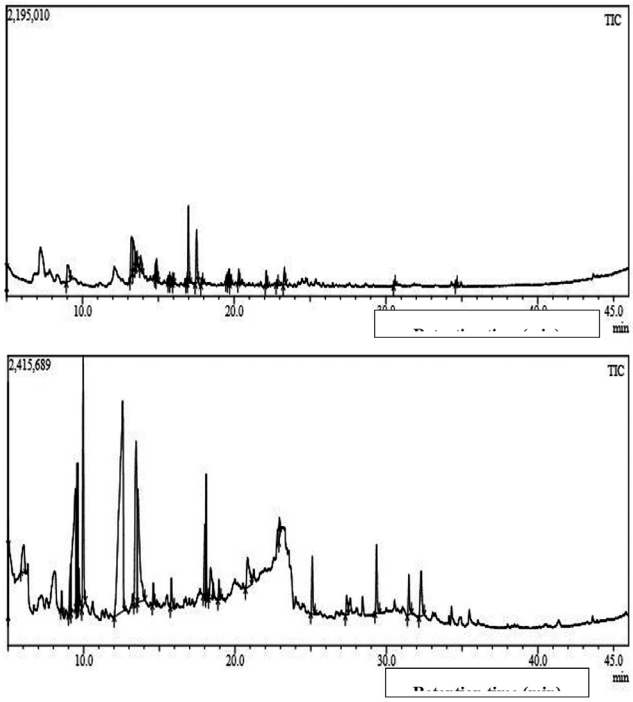

Fig. 1 — GCMS graph of *Moringa oleifera* and *Mangifera indica*

Comparing three systems

Yield comparison of proso millet under three systems is presented in Figure 2. Grain yield of proso millet under Crop production guide (CPG) recommendation was 923 kg/ha and 865.67 kg/ha during first and second season, respectively with pooled mean grain yield of 894.33 kg/ha. While do-nothing practice yielded just quarter of CPG practice. Comparison of best performing compared to CPG practice, *Vrikshayurvedic* farming practices showed a yield reduction of below 10% during both seasons but showed 70% increased yield compared to do-nothing farming. Combination *Albizia lebbek* as BMT and *Mangifera indica* as LTS has practically yielded equally to CPG practice with a yield penalty of just 3.85%. *Moringa oleifera* LTS also faired well, with 72.8% yield upsurge compared to do-nothing practice and 9.08% yield decline compared to CPG practice.

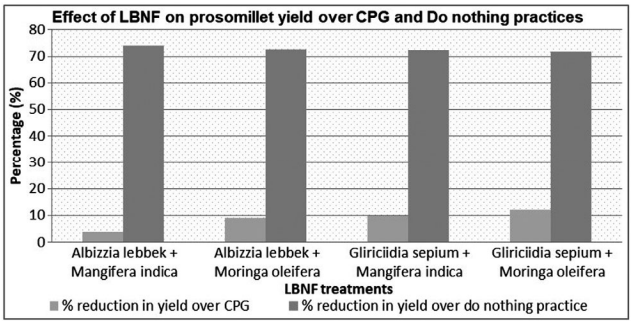

Fig. 2 — Comparison of proso millet yields in three systems

Performance of *Gliricidia sepium* as BMT was also good in combination with *Mangifera indica* and *Moringa oleifera*. Between seasons, grain yield exhibited a decreasing trend over seasons, which is the theory of every organic farming system. However, yield would increase from third season/year onwards and in a span of 3-4 years, this system will produce yield matching to the yield from conventional production systems. Proso millet straw yield showed the same trend. The largest pooled straw yield was 4109.47 kg/ha. Adopting the practice of fallowing for two seasons before cultivating the field will also contribute to better performance of proso millet under *Vrikshayurvedic* cultivation practices.

Discussion

This research was conducted to utilize traditional natural resources and knowledge to increase the productivity and quality of food grains, particularly proso millet, from traditional agricultural practices and also to produce on a sustainable basis equivalent to modern scientific agriculture. Crop growth and physiological parameters are measured by recording data on germination, plant height, tiller no./plant, LAI and dry matter production of crop. Present study exposed that all the above parameters were high when *Albizia lebbek* was used for BMT technique (green leaf biomass) combined with foliar sprays with *Mangifera indica* and *Moringa oleifera* leaf extracts. Research evidences showed that moringa leaf extract at 5% enhanced germination in cowpea[18] which might be due to micronutrients[19] and presence phenolic compounds, organic acids, proteins and alkaloids in botanicals[20]. On the contrary, lowest values were observed in *Aegle marmellos* and *Morinda tinctoria* leaf extracts fortification, which may be due to presence of unsuitable phytochemical substances in leaves. This might be because decomposing green leaf biomass continuously supplies and makes soil nutrients available, which encouraged cell division and elongation and hence enhanced plant growth[21]. This finding agreed well with the findings of[22], Nivethadevi *et al.* 2022, when *Moringa oleifera* was tested as foliar spray in maize and in black gram[23].

Enhancement in crop field emergence by botanical leaf extracts could be due to the activation of cells, which led to an increase in mitochondrial activity and ultimately the formation of high-energy compounds and vital biomolecules made available in the early germination phase[24]. Application of *Moringa oleifera* leaf extract @ 10% augmented pod number and dry weight, and shelling percentage in mungbean[25]. Grain and straw yield is an output of a crop in return for the inputs. Increased yields and yield parameters in *Moringa oleifera* leaf extract might be due to the presence of zeatin, a growth hormone, which influenced yield upto 10-45%. In addition, it also comprises enough micronutrients, which influences growth and yield of cereals to oilseeds[26]. This result may be due to presence of active compounds in both *Mangifera indica* and *Moringa oleifera.*

Combination of *Albizia lebbek* as BMT and *Mangifera indica* as LTS yielded an almost equal reduction of only 3.85% in CPG practice. This could be promoted by mobilising and converting organically bound nutrients into inorganic form through decomposition activity of the applied manure by microorganisms, leading to an increase in soil organic carbon and improving soil health. In *Vrikshayurveda* practice, which involves incorporating green leaf manure and facilitating its decomposition for six weeks in combination with spraying of tree leaf extracts, the absorption of nutrients by the plant could be high. This enhanced photosynthetic activity and nutrient availability during the flowering and pod filling phases, increasing biomass production and N supply[27]. Foliar application of leaf extracts which have macro nutrinets as well as micronutrients and also growth hormones promote nutrient uptake from soil and also increase plant metabolic activity as reported[28]. Another plausible reason is that in *Vrikshayurvedic* agricultural practices, The best physical and chemical characteristics of the soil, increased microbial activity, nutrient mobilization, and root activity in rhizosphere soil are the reasons for the highest available nutrient levels. Microorganisms convert organically bound nutrients into inorganic ones during mineralization, resulting in higher nutrient availability[29,30], besides phytocompounds contained in leaf extracts might have

influenced seed germination and enzyme activities during early emergence[31].

Conclusions

Vrikshayurvedic farming practices recommend that production of quality food grains free from agrochemicals in proso millet is achievable by following biomass transfer (BMT) practice of soil enrichment / incorporation of leaves of *Albizia lebbek* (L.) Benth and *Gliricidia sepium* (Jacq.) Steud on nitrogen equivalent basis and giving LTS with tree leaf extracts of *Mangifera indica* (L.) and *Moringa oleifera* Lam at 5% concentration with a yield reduction of less than 10% compared to conventional CPG practice, besides maintaining soil properties and keep the soil healthy.

Scientific validation of traditional knowledge, *Vrikshayurveda*, would help in developing a contemporary crop production system free from agrochemicals, fertilizers and pesticides, as negligence in promoting indigenous knowledge leading to a three-fold acceleration. Furthermore, scientific validation of traditional technologies and refinement with modern scientific technologies aids in sustainable agriculture.

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Conflict of Interest

Authors declare that there is no conflict of interest.

Author Contributions

Conceptualization, implementing and writing both original drafts, reviewing & editing is done by CS; Lab study performed by RSA. Field studies were done by PN, RSA & RSU. Formal analyses were done by PN & RSA; Resources organized by RDS.

Data Availability

The authors confirm that all the data supporting the findings of this study are available within the manuscript only.

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