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Assessing the growth and yield of *Lepidium sativum* in a peach-based medicinal agroforestry system

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Abstract
The study was conducted in a peach orchard within the Department of Fruit Science and the field of medicinal and aromatic plants at Dr. YSP UHF Nauni, Solan, Himachal Pradesh, from 2016 to 2018. *Lepidium sativum*, commonly known as Chandrshoor, is a medicinal plant. The experiment encompassed nine treatments involving different combinations of *Lepidium sativum*, peaches, organic manures, and inorganic fertilizers. The results highlighted the effectiveness of vermicompost at 4t/ha as the optimal organic manure dose, leading to maximum straw yield (13.74 q/ha and 11.20 q/ha), seed yield per plant (2.98 g and 2.37 g), and total seed yield (9.93 q/ha and 7.90 q/ha), recorded in treatment T_6 (*Prunus persica* + *Lepidium sativum* + RDF NPK 60:30:30 kg/ha) over the two years. The highest cost of cultivation (Rs. 1,17,624.2/ha and Rs. 1,16,124.2/ha) was associated with vermicompost at 4t/ha when *Lepidium sativum* was grown under peach trees. Maximum net return (Rs. 1,52,166/ha and Rs. 1,27,556/ha) was obtained in T_6 (*Prunus persica* + *Lepidium sativum* + RDF NPK 60:30:30 kg/ha), with the highest benefit-to-cost ratio (2.46 and 2.12) found under peach trees in both years. The results demonstrated that *Lepidium sativum* performed well within the horti-medicinal agroforestry system compared to sole cropping, with no adverse effects on the growth, yield, or physiological attributes of medicinal herbs due to the presence of peach trees.

Keywords: Growth, yield, *Lepidium sativum*, peach-based, medicinal agroforestry

1. Introduction
Medicinal plants have historically played a vital role in healthcare, especially in developing nations, where traditional herbal remedies were relied upon to treat human and livestock ailments. *Lepidium sativum*, also known as salio, garden cress, halo, halim, chandrshoor, and more, is an underutilized edible medicinal plant belonging to the Brassicaceae family. This plant, commonly cultivated as a salad in India during the winter season, offers a rich source of nutrients, including protein (24%), vitamins A and C, iron, calcium, folic acid, amino and galactanic acid (19.3%), and leucine (8.21%). It contains a substantial amount of alpha-linolenic acid (30.2%) and a minimal quantity of erucic acid (3.9%). Additionally, its bran boasts a high dietary fiber content (74.3%) with excellent water-holding capacity.

Lepidium is believed to have originated primarily in the highland regions of Ethiopia and Eritrea, with secondary centers of origin in Europe and western Asia. Various parts of the plant, including seeds, leaves, and roots, hold economic value. The seeds are known to contain a light yellow fixed oil and alkaloids such as lepidin and glucotropeolin, in addition to sinapin and sinapic acid.

Lepidium sativum finds applications in multiple traditional medicinal systems, including Ayurveda, Unani, and Siddha, where it is used for its thermogenic, depurative, galactogogue, tonic, aphrodisiac, ophthalmic, antiscorbutic, anti-asthmatic, and diuretic properties. Fresh leaves and young seedlings are utilized as a spice and are rich sources of glucosinolates, commonly used in salads. The bitter and acrid roots have been historically employed in the treatment of secondary syphilis. Moreover, the mucilage found in the seed coat is used to alleviate irritation of the intestinal mucous membrane in cases of diarrhea and dysentery. Chandrasur is also used as an insect repellent and for treating insect bites through fumigation.

Traditional agroforestry systems in Himachal Pradesh demonstrate the benefits of mixed cultivation, with farmers integrating multiple tree layers into their fields, promoting biodiversity and conservation. The region's mid-hills are known for their abundance of stone fruits, with peach being a significant crop. Peach orchards have been established by farmers in Himachal Pradesh, and agroforestry practices have proven beneficial.

In horti-medicinal systems, the interplanting of medicinal and aromatic plants with stone fruit crops offers an effective strategy for growers to generate income while simultaneously improving the environment.

2. Material and Methods

The research described in this study was carried out at the Department of Fruit Science, within the premises of the College of Horticulture, as well as at the Medicinal and Aromatic Plant Research Farm and Laboratory of the Department of Forest Products, housed within the College of Forestry. These research activities were conducted at the Dr YSP University of Horticulture and Forestry, located in Nauni, Solan (HP), during the Rabi period spanning 2016 to 2017.

Both the experimental farm of the Department of Fruit Science and the Department of Forest Products are positioned in the mid hills of Himachal Pradesh at an elevation of 1270 meters above sea level. This geographical location marks the transitional zone between the sub-tropical and sub-temperate regions. Specifically, the research site is situated approximately 15 kilometers to the southeast of Solan town.

The research comprised two essential structural and functional elements: the first being the presence of peach trees (*Prunus persica* L. var. July Elberta), which are classified as woody perennials, and the second encompassed the cultivation of medicinal plants as intercrops. Furthermore, the study examined the influence of three distinct organic manures and fertilizers on the growth and yield of these medicinal plants, both when grown in conjunction with peach trees and in isolation.

The experiment involved nine distinct treatments as follows: T_1 (*Prunus persica* + *Lepidium sativum* + FYM 2t/ha), T_2 (*Prunus persica* + *Lepidium sativum* + FYM 4t/ha), T_3 (*Prunus persica* + *Lepidium sativum* + Vermicompost 2t/ha), T_4 (*Prunus persica* + *Lepidium sativum* + Vermicompost 4t/ha), T_5 (*Prunus persica* + *Lepidium sativum* + Jeevamarutha 500 l/ha), T_6 (*Prunus persica* + *Lepidium sativum* + RDF 60:30:30 NPK kg/ha), T_7 (*Prunus persica* + *Lepidium sativum*), T_8 (*Lepidium sativum* + RDF 60:30:30 NPK kg/ha), and T_9 (Control). The seeds were sown in lines with a spacing of 30 x 20 cm during the last fortnight of October for two consecutive years. Data related to growth and yield was systematically recorded. The collected data underwent statistical analysis utilizing a Randomized Block Design, and an analysis of variance was conducted. Critical differences at a 5 percent level of significance were calculated with the assistance of up-to-date computer software.

3. Result and Discussion

Upon reviewing the data in Table 1, it is evident that the plant height of *Lepidium sativum* during the harvesting stages was significantly affected by varying dosages of organic manures and fertilizers. In the 2016-2017 period, the tallest average plant height (69.50 cm) was observed in T_6, while the shortest (45.20 cm) was noted in T_9 (the control group) at the harvesting stage. In the subsequent year, 2017, T_6 (*Prunus persica* + *Lepidium sativum* + RDF NPK 60:30:30 kg/ha) exhibited the highest average plant height (64.50 cm) at the harvesting stage, while T_9 (control) recorded the lowest average plant height (41.50 cm). It's worth noting that plant height was generally greater in 2016 compared to 2017, and T_6 consistently outperformed other treatments during both years.

Regarding the number of branches per *L. sativum* plant, significant differences were observed among the various treatments. The maximum number of branches per plant (15) was documented in T_6, which was treated with *Prunus persica* + *Lepidium sativum* + RDF (NPK 60:30:30 kg/ha), while the minimum number (8.60) was observed in T_9 (control) in the absence of fertilizers and organic manures during 2016. In 2017, a similar trend was observed, with T_6 displaying the highest number of branches per plant (11.46). These findings align with prior research conducted by Suresh *et al*. (2004) [10] on *Achyranthes aspera* under *Peltophorum petrocarpum* and *Prosopis cineraria* and Akhtar *et al*. (2003) [1] on *Pisum sativum*. Additionally, the results are in accordance with Lakra *et al.* (2017) [5], who reported a higher number of branches in tomato plants when NPK was applied at a rate of 100%.

The highest estimated straw yield was observed in T_6 (*Prunus persica* + *Lepidium sativum* + RDF NPK 60:30:30 kg/ha) at 13.75 q/ha, which was statistically superior in 2016. Conversely, the minimum estimated straw yield was found in T_9 (control) at 8.50 q/ha, where neither peach, organic manures, nor fertilizers were applied. In 2017, the maximum estimated straw yield was also associated with T_6 at 12.01 q/ha, which significantly outperformed the other treatments. T_9 (control) displayed the lowest estimated straw yield in 2017, measuring 6.63 q/ha.

Table 1: The data recorded *Lepidium sativum* under peach based Agroforestry system in 2016.

Characters / Treatments	Plant height (cm)	Number of ranches/plant	Straw yield/ha (q)	1000 Seed wt (g)	Seed yield/plant (g)	Seed yield/ha (q)
T_1	57.50	12.00	11.20	1.75	2.50	8.30
T_2	64.90	12.75	12.10	1.84	2.61	8.70
T_3	61.70	11.49	11.75	1.83	2.52	8.35
T_4	66.20	13.80	12.90	1.86	2.76	9.20
T_5	56.00	11.00	10.90	1.74	2.40	7.91
T_6	69.50	15.00	13.75	1.90	2.98	9.95
T_7	50.90	9.20	9.36	1.71	2.31	7.70
T_8	52.70	9.80	10.04	1.76	2.48	8.29
T_9	45.20	8.60	8.50	1.69	1.85	6.16
Mean	58.28	11.51	11.16	1.78	2.49	8.28
CD at 5%	0.68	0.22	0.17	0.01	0.03	0.10

The 1000 seed weight of *Lepidium sativum* showed statistical variations among different treatments (Table 1 and Table 2). The maximum 1000 seed weight (1.90 g) was recorded in T_6 (*Prunus persica* + *Lepidium sativum* + RDF NPK 60:30:30

kg/ha), and this result was statistically superior to all other treatments. In contrast, the minimum 1000 seed weight (1.69 g) was noted in T_9 (control) during the 2016.

The trend for 1000 seed weight in 2017 echoed the findings from the previous year. In this period, T_6 exhibited the maximum 1000 seed weight at 1.88 g, and this outcome was also statistically better to the other treatment groups. Conversely, T_9 (the control) displayed the lowest 1000 seed weight at 1.59 g. Notably, the 1000 seed weight was greater in the initial year of the study (1.90 g) in comparison to the second year (1.88 g).

The data presented in the table demonstrates that the application of fertilizers and organic manures led to increased straw yield under the peach-based cultivation system when compared to the sole crop. These results align with the findings of reported that the yield of safed musli increased with the use of organic manures by Paturde *et al.* (2002) [8].

Table 2: The data recorded *Lepidium sativum* under peach based Agroforestry system in 2017.

Charecters / Treatments	Plant height (cm)	Number of branches/plant	Straw yield/ha (q)	1000 Seed wt (g)	Seed yield/plant (g)	Seed yield/ha (q)
T_1	52.50	10.83	9.56	1.78	1.91	6.23
T_2	60.10	10.35	10.45	1.81	2.03	6.75
T_3	56.90	9.43	10.04	1.80	1.90	6.45
T_4	61.60	11.15	11.23	1.82	2.16	7.25
T_5	49.00	7.65	8.88	1.73	1.78	5.94
T_6	64.50	11.46	12.01	1.88	2.87	7.92
T_7	46.81	6.72	7.44	1.70	1.77	5.74
T_8	49.27	7.30	8.06	1.75	1.89	6.35
T_9	41.50	5.46	6.63	1.59	1.19	4.95
Mean	53.57	8.92	9.36	1.76	1.94	6.39
CD at 5%	0.79	0.22	0.18	0.01	0.04	0.08

The highest seed yield per plant (2.98 g) for *Lepidium sativum* was achieved in T_6, and this result was statistically superior to the other treatments. In contrast, the lowest seed yield per plant (1.85 g) was observed in T_9 (the control), where plants were grown without peach trees and devoid of organic manures and fertilizers during the 2016 period. During 2017, the maximum seed yield per plant (2.87 g) was attained in T_6 (*Prunus persica* + *Lepidium sativum* + RDF NPK 60:30:30 kg/ha), which also held statistical superiority. The minimum seed yield per plant (1.19 g) was recorded in T_9 (no *Prunus persica* + no fertilizers + no organic manures).

The seed yield of *Lepidium sativum* across various treatments revealed that the maximum average estimated seed yield (9.95 q/ha) was achieved in T_6, a statistically superior result. The minimum seed yield (6.16 q/ha) was recorded in T_9 (control) during the 2016. where no fertilizers or manures were applied, and the crop was not intercropped with *Prunus persica*. Similar observations for seed yield were made during 2017. T_6 exhibited the maximum seed yield (7.92 q/ha), which was statistically superior. This was followed by T_4 (7.25 q/ha) and T_2 (6.75 q/ha), with T_3 (6.45 q/ha) being statistically on par with T_1 (6.23 q/ha). Treatment T_8 (6.35 q/ha) outperformed T_5 (5.94 q/ha), while the lowest seed yield (4.95 q/ha) was recorded in T_9 (control).

The data suggests that the use of fertilizers and organic manures alongside peach cultivation significantly increased the estimated seed yield per hectare for *L. sativum* when compared to the control group, where *L. sativum* was cultivated without *prunus persica* trees, and no fertilizers or manures were applied. The estimated seed yield per hectare was also notably maximum in the first year compared to the second year. These findings are consistent with the results of Makinde *et al.* (2016) [6], who reported that maximum plant height was achieved with NPK fertilizers. This observation aligns with Fashina *et al.* (2002) [4], who reported that the availability of adequate growth nutrients from inorganic fertilizers enhances cell activities, cell multiplication, and growth. Additionally, Olaniyi (2006) [7] emphasized that providing plants with the right type and amount of fertilizer at the correct time allows them to exhibit their genetic potential. The increase in plant height with 100% inorganic fertilizers may be attributed to the direct impact of higher nitrogen levels, which are essential components of protein and chlorophyll molecules. Paul and Driscoll (1997) [9] noted that nitrogen deficiency primarily affects the growing meristem of plants and reduces photosynthetic activity, leading to decreased plant heights. This could explain the lower values observed throughout the period with no fertilizer input.

The economic performance of *Lepidium sativum* within the context of a peach based medicinal agroforestry system, involving the cultivation of medicinal plants as an intercrop, was assessed. The cost of cultivation, gross returns, and net returns of *L. sativum* were computed separately for situations with and without peach trees to evaluate the economic viability of this tree-crop combination.

The highest gross return, amounting to Rs. 1,28,590, was achieved for *Lepidium sativum* in the peach based medicinal agroforestry system under treatment T_6. Among the various treatments, the lowest gross return, totaling Rs. 79,710, was observed in T_9 during the 2016. In the following year, 2017, the maximum gross return, Rs. 1,10,100, was recorded in T_6, while the lowest gross return, Rs. 55,080, was reported in T_9 (control). It is worth noting that the average gross return from *L. sativum* was significantly higher during the first year of the experiment compared to the second year of the study.

Table 3: Economic analysis of *Lepidium sativum* under peach based under agroforestry system 2016.

Characters / Treatments	Gross return from intercrop (Rs/ha)	Cost of cultivation (Rs/ha)	Net return from intercrop (Rs/ha)	Average net return from Peach (Rs/ha)	Total net return from AF system (Rs/ha)	B:C Ratio
T_1	1,06,100.00	60,124.15	44,975.85	84,950	1,29,926.00	2.16
T_2	1,12,600.00	63,624.15	47,975.85	84,950	1,32,926.00	2.09
T_3	1,07,400.00	86,624.15	19,775.85	84,950	1,04,726.00	1.21
T_4	1,19,100.00	1,16,624.2	1,475.85	84,950	86,426.00	0.74
T_5	1,02,200.00	57,624.15	43,575.85	84,950	1,28,526.00	2.23
T_6	1,28,590.00	60,374.15	67,215.85	84,950	1,52,166.00	2.52
T_7	99,600.00	56,624.15	41,975.85	84,950	1,26,926.00	2.24
T_8	1,07,400.00	55,374.15	51,025.85	-	-	1.94
T_9	79,710.00	51,624.15	27,085.85	-	-	1.54
Mean	1,06,966.67	67,624.15	38,342.52			1.85

Table 4: Economic analysis of *Lepidium sativum* under hotri based medicinal agroforestry system 2017.

Characters / Treatments	Gross return from intercrop (Rs/ha)	Cost of cultivation (Rs/ha)	Net return from intercrop (Rs/ha)	Average net return from Peach (Rs/ha)	Total net return from AF system (Rs/ha)	B:C Ratio
T_1	86,580.00	58,624.15	26,955.85	73,830	1,00,786	1.72
T_2	94,280.00	62,124.15	31,155.85	73,830	1,04,986	1.69
T_3	88,260.00	85,124.15	2,135.85	73,830	75,966	0.89
T_4	1,00,300.00	1,15,124.2	-15,324.2	73,830	58,506	0.51
T_5	82,520.00	56,124.15	25,395.85	73,830	99,226	1.77
T_6	1,10,100.00	58,874.15	50,225.85	73,830	1,24,056	2.11
T_7	79,720.00	55,124.15	23,595.85	73,830	97,426	1.77
T_8	88,120.00	54,374.15	32,745.85	-	-	1.62
T_9	55,080.00	50,624.15	3,455.85	-	-	1.09
Mean	87,217.78	66,235.26	20,038.07			1.46

The total sum of return within the agroforestry framework was determined by combining the net return from intercropping and the tree component cultivated under the horti-based medicinal agroforestry system. Among the different treatments, the highest total net returns from the agroforestry system, amounting to Rs. 1,52,166 in 2016 and Rs. 1,24,056 in 2017, were achieved in T_6. In T_6, *Lepidium sativum* was grown alongside peach trees with the application of fertilizers (NPK 60:30:30 kg/ha). Conversely, the lowest net return was recorded in T_9, totaling Rs. 27,085.85 in 2016 and Rs. 3,455.85 in 2017-18. In T_9, *Lepidium sativum* was grown without peach trees and received no fertilizers or organic manure.

The benefit-cost ratio data for *Lepidium sativum* plants revealed that when cultivated alongside peach trees, the higher benefit-cost ratios (2.52 and 2.11) were recorded in T_6 during 2016 and 2017, respectively. In contrast, the minimum ratios (0.74 and 0.51) were observed in T_4 during the same years. These results suggested that the use of fertilizers and organic manures under peach cultivation was more profitable compared to cultivating *Lepidium sativum* as a single crop.

This finding aligns with similar results reported by various studies, such as Chauhan *et al.* (1997) [3] in *Citronella java* under *Eucalyptus*, Suresh *et al*. (2004) [10] in *Achyranthes aspera*, Thakur and Raj Kumar (2006) [12] in *Tagetes minuta* and *Ocimum basilicumun* under *Leucaena leucocephala* and *Morus alba*, and Yu Guangming *et al.* (1998) [13] in Peony. The data demonstrated that *Lepidium sativum* cultivation in a peach-based agroforestry system (*Prunus persica* + *Lepidium sativum*) resulted in maximum yields and returns compared to growing it as a single crop, which is consistent with findings reported by Thakur *et al.* (2016) [11] in *Ocimum* species under teak-based silvi-medicinal systems.

4. Conclusion

A two-year investigation (2016 and 2017) evaluated the impact of organic manures and fertilizers on *Lepidium sativum* growth and productivity when intercropped with peach trees in agroforestry. The study aimed to assess the potential for growing medicinal plants in fruit-based agroforestry to diversify and boost farmers' income.

The results indicated that the application of fertilizers and organic manures significantly improved *Lepidium sativum* growth parameters, including plant height and the number of branches per plant, in the agroforestry system. The higher straw yield (13.75 q/ha and 12.01 q/ha) and seed yield per plant (2.98 g and 2.87 g), as well as seed yield (9.95 q/ha and 7.92 q/ha), were observed in treatment T_6 (*Prunus persica* + *Lepidium sativum* + RDF NPK 60:30:30 kg/ha) during both years.

While the maximum cost of cultivation was found in vermicompost (4t/ha) when *Lepidium sativum* was grown under peach trees, the highest total net return was obtained in T_6 (Rs. 1,52,166/ha and Rs. 1,24,056/ha). The benefit-cost ratio was also maximum under peach trees in both years (2.52 and 2.11).

These results demonstrated that *Lepidium sativum* performed well in the horti-medicinal agroforestry system, and its growth, yield, and physiological attributes were not negatively affected by the presence of *prunus persica* trees. Intercropping medicinal plants with peach was more beneficial than cultivating them as a sole crop. The peach based medicinal agroforestry system proved to be more profitable, as fertilizers and organic manures improved soil properties and nutrient availability, ultimately enhancing medicinal herb yields. The use of NPK fertilizers increased nutrient availability to the plants. In conclusion, *Lepidium*

sativum can be successfully cultivated in a peach-based medicinal agroforestry system to achieve higher economic returns.

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