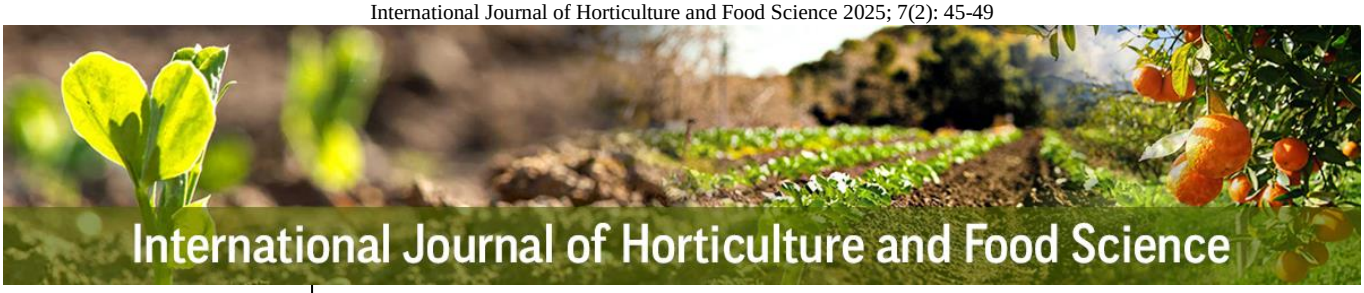

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Effectiveness of recommended chemical control of foliar diseases and pests in apple under high, mid, and low altitudes of Jammu and Kashmir

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Abstract
This study investigated the impact of adopting the recommended apple spray schedule on disease, pest problems, and profitability in three horticultural zones of Kulgam district, J & K (UT), India. Data was collected from 300 apple growers (150 adopters and 150 non-adopters) during 2022-23 and 2023-24. Results revealed that disease and pest problems varied among adopters and non-adopters, irrespective of the horticultural zone. Besides this, the zone of apple cultivation has a prominent effect on the disease and pest pressure. Weather conditions, scientific horticultural practice, and the use of specific agrochemicals contributed mostly to the yearly variation of disease and pest incidence among adopters and non-adopters. Scab along with other foliar diseases was lower in the case of adopters as compared to non-adopters irrespective of the study year. Scab disease was noticed 4.22% among adopters and 20.89% in non-adopters during 2022-23 while as during 2023-24 this value was 3.33% and 24% respectively among adopters and non-adopters irrespective of the zone. Just 2.67% adopters and 13.33% non-adopters faced scab problem in Manzgam during 2022-23 which was the lowest among zones. A similar trend was observed in other foliar diseases both in case of adopters and non-adopters with the minimum incidence in Manzgam and maximum in the Qaimoh zone. Yearly variation in disease and pest problems as observed during the current study highlights the impact of long-term adoption of recommended practices. Least leaf miner (0.67%) and mite infestation (2%) among adopters were observed in the Manzgam zone during 2022-23. However, Qaimoh zone proved better in terms of less infestation of Sanjose Scale (2%), beetles, and aphids than in other zones both in the case of adopters and non-adopters during a two-year study. Adopters exhibited significantly higher benefit-cost ratios i.e., 2.55 in Manzgam, 2.42 in Kulgam, and 2.35 in Qaimoh compared to non-adopters of the same zones due to reduced input costs, improved fruit quality, and higher yields. These findings emphasize the crucial role of proper plant protection spray scheduling in enhancing apple production and profitability in the region.

Keywords: Disease, pest, profitability, adopters, non-adopters, spray schedule, yield

Introduction
Apple (*Malus* x *domestica* Borkh) is the most important temperate fruit crop grown worldwide (Verma *et al.*, 2024) [32]. In J&K (UT), Kashmir valley contributes major junk of the total apple produce of India and generates 7000 crore revenues to the region's GDP (Rehman *et al.*, 2023) [22, 23]. In recent times, apple has faced huge challenges in terms of various foliar diseases and pests which has escalated the plant protection costs thereby decreasing this venture's profitability by affecting quality and yield (Sheikh and Baba, 2023) [25]. Plant protection costs include the cost incurred on use of various pesticides which include fungicides, insecticides, acaricides, rodenticides, chemosterilents, insect growth regulators, nematicides, and bactericides along with labour and energy (Zhang, 2018) [37]. Key foliar diseases affecting apple crops include scab, powdery mildew, Alternaria leaf spot, and Marsonina leaf blotch. Minor diseases include flyspeck, Sooty Blotch, Rust, and Black rot (Thapa *et al.*, 2020) [29]. However, these minor diseases have attained major status in recent years due to the changing climate and the introduction of new apple cultivars (Gautam *et al.*, 2013) [12]. In addition, some new emerging pests like apple blotch leaf miners and rosy aphids have become alarming and gained a strong foothold in apple-growing areas.

Diseases and pests that were considered minor recently have become the main culprits affecting apple production in the last few years (Moinina *et al.*, 2019) [17].

During the past two decades, there has been a substantial increase in the use of pesticides in terms of both volume and value particularly in apple sector (Naqash *et al.*, 2019) [19, 20]. The demand for agrochemicals depends upon the type of crops grown, farmer's knowledge about technologies and their profitability and also upon the availability, affordability and ease in accessing the input and output markets (Naqash and Wani, 2019) [19, 20]. Among different crops grown in Jammu & Kashmir, apple cultivation is highly capital-intensive in terms of pest control measures (Mir *et al.*, 2018) [15]. In the apple-growing belt of the valley, chemicals are being used indiscriminately without considering scientific recommendations (Baba *et al.*, 2017) [3]. The choice of chemicals/brand preferences is steered by traders and market functionaries (Baba *et al.*, 2010) [4]. The excessive/ indiscriminate use of pesticides not only increases the cost of apple cultivation but also results in many problems *viz*., problems related to human health, environmental contaminations, natural imbalance, problems of pest resurgence, pesticide resistance, and soil-related problems (Mir *et al.*, 2017) [14]. Moreover, these problems are accentuated by the use of spurious chemicals and the existence of a chain of functionaries/unlicensed dealers between firms and farmers. The judicious application of pesticides, adoption of recommended commercial products, with other recommended technological interventions in apple, should, therefore, be the concern of all stakeholders, researchers, and policy and decision-makers (Baba *et al.*, 2010) [4]. Time of application, spray coverage, resistance management, weather conditions, and environmental impact influence a particular pesticide's effectiveness (Nansen *et al.*, 2015) [18]. This paper will explore the effectiveness of recommended chemical control measures for foliar diseases and pests in apple orchards across different altitudes in Jammu and Kashmir.

Materials and Methods

This study was undertaken during the years 2022-23 and 2023-24 covering Manzgam, Kulgam, and Qaimoh horticultural zones of district Kulgam. Hundred farmers using simple random sampling covering 20 villages (5 farmers from each village) from each horticultural zone were surveyed during the study. In total 60 villages from 3 studied horticultural zones comprising 300 respondents of which 150 were adopters and 150 were non-adopters were selected for analysis. Respondents were selected using proportionate sampling (taking area as auxiliary information). The ultimate unit of sampling (farmer) was selected randomly taking the sample size of 180 respondents, from whom data was collected. Only essential sprays with the recommended dosage, growth stage, and volume of spray were considered for categorizing respondents as adopters or non-adopters. Essential sprays in apples consisted of 11 sprays with 8 fungicides, 2 insecticides, and 1 acaricide (Baba *et al.*, 2017) [3]. Adopters sprayed all 11 sprays with similar brand names mentioned in the recommended schedule at the proper stage with the recommended concentration and volume. The presence of various foliar diseases, mites, and insects was collected at the farmer's field and was converted to the percentage value. Besides this, the benefit-cost ratio of each grower was calculated on gross returns after estimating production and marketing costs at the farmer's field. Data was presented in the form of various tables as shown in the results and discussion section of the paper.

Results and Discussion

From the data shown in Table 1, it is visible that scab was lower in case of adopters (4.22%) as compared to non-adopters (20.89%) during the year 2022-23. Among the adopters, scab was the lowest in the Manzgam zone (2.67%) whereas, the same zone proved better in terms of least scab among non-adopters (13.33%). A similar trend was observed in other foliar diseases both in the case of adopters and non-adopters with the minimum value in Manzgam and maximum in the Qaimoh zone. Irrespective of the horticultural zone, sooty blotch and Flyspeck were found significantly less in the case of adopters (0.44% & 1.55%) when compared with non-adopters (14.55% and 19.11%) as evident from Table 1. Variations in foliar disease incidence among zones may be attributed to differences in microclimate, air drainage, primary infection incidence, etc. as reported by Moinina *et al.* (2019) [17]; Saurabh *et al.* (2020) [24]; Bui *et al.* (2021) [6]. In Manzgam, the BC ratio for adopters was 2.55, whereas non-adopters had a ratio of 1.92. This trend was consistent in Kulgam and Qaimoh, suggesting that adopting better horticultural practices leads to reduced disease incidence and higher economic returns. A higher BC ratio in the Manzgam zone among both adopters and non-adopters may be attributed to lower plant protection costs and better market value due to superior quality as reported by Badiu *et al.* (2015) [5]; Yilmaz *et al.* (2015) [35]; Tona *et al.* (2018) [30]; Rehman and Mubarak (2023) [22, 23]; Antal *et al.* (2024) [2].

Table 1: Presence of various foliar diseases in apple orchards of adopters and non-adopters in percentage of different horticultural zones during the year 2022-23

Disease type	Adopters (%)			Average	Non-Adopters (%)			Average
	Manzgam	Kulgam	Qaimoh		Manzgam	Kulgam	Qaimoh	
Scab	2.67	4	6	4.22	13.33	20.67	28.67	20.89
Powdery mildew	5.33	3.33	2	3.55	10.67	9.33	7.33	9.11
Alternaria leaf spot	2	6	7.33	5.11	8	16	24.67	16.22
Marsonina leaf blotch	1.33	5.33	8.67	5.11	12	14	32	19.33
Sooty blotch	0	0	1.33	0.44	6	16.33	21.33	14.55
Flyspeck	0	1.33	3.33	1.55	9.33	18	30	19.11
BC ratio	2.55	2.42	2.35	2.44	1.92	1.62	1.40	1.65

As observed during the current study, fewer pesticides sprayed during the growing season along with a lower volume of spray per plant resulted in better disease management and is in concordance with the findings of

Ozkan (2009) [21]; Miranda *et al.* (2015) [16]; Xun *et al.* (2022) [34]; Warneke *et al.* (2023) [33]. Due to the difference in the adoption level of the proper apple spray schedule, a huge difference in BC ratio was observed among adopters and non-adopters as evident in Table 1.

Data in Table 2 shows the presence of major foliar disease during the year 2023-24 in the apple orchards of the same respondents. It is clear from the data that the foliar diseases decreased among adopters while an increasing trend was observed among non-adopters as compared to 2022-23. The lower rates of powdery mildew, Alternaria leaf spot, and Marsonina leaf blotch in adopters' orchards indicate that integrated disease management is critical in limiting disease spread. The BC ratio rose further in the case of adopters, while lower values of the BC ratio were observed among non-adopters during the year 2023-24. Scab was lower in case of adopters (3.33%) as compared to non-adopters (24%). Among adopters, Manzgam zone proved better in terms of less scab (2%), Alternaria leaf spot (0.67%), Marsonina leaf spot (0%), sooty blotch (0%), and flyspeck (0%) with higher BC ratio (2.82) when compared to other studied zones during the year 2023-24 as shown in Table 2. Similarly, the Manzgam zone again proved better in terms of the least foliar disease incidence with a significantly better BC ratio (1.71) among non-adopters during the year 2023-24 which could be due to less primary infection, better air drainage, less humidity as reported by Badiu *et al.* (2015) [5]; Tona *et al.* (2018) [30]; Moinina *et al.* (2019) [17]; Saurabh *et al.* (2020) [24]; Rehman and Mubarak (2023) [22, 23].

Table 2: Disease incidence (%) in apple orchards of adopters and non-adopters of different horticultural zones during the year 2023-24

Disease type	Adopters (%)			Average	Non-Adopters (%)			Average
	Manzgam	Kulgam	Qaimoh		Manzgam	Kulgam	Qaimoh	
Scab incidence	2	3.33	4.67	3.33	18	24	30	24.00
Powdery mildew	2.67	0	0	0.89	15.33	12	8.67	12.00
Alternaria leaf spot	0.67	4	4.67	3.11	6	18	24	16.00
Marsonina leaf blotch	0	0	4	1.33	14	16	22	17.33
Sooty blotch	0	0	0	0.00	8	18	25.33	17.11
Fly speck	0	2	4	2.00	14.67	22	34	23.56
BC ratio	2.82	2.65	2.45	2.64	1.71	1.32	1.1	1.38

In addition to disease incidence as presented in Table 1 and Table 2, mite and insect infestation was also recorded in the same farmer's sample and presented in Tables 3 and 4. The highest insect infestation except for leaf miner in both adopters and non-adopters was observed in the Manzgam zone as represented in Table 3 during 2022-23. However, mite infestation was observed in 4.67% of orchards of adopters and 18.67% of orchards of non-adopters in the Qaimoh zone and could be attributed to higher humidity with favorable temperature in this zone of Kulgam district during peak mite infestation period. A strong correlation between congenial conditions in terms of temperature and humidity for insect and mite populations has been reported by Amjad *et al.* (2022) [1]; Sheikh *et al.* (2021) [26]; Devi *et al.* (2019) [9, 10]; Sood and Gupta (2005) [27]. In addition, pesticides sprayed need specific atmospheric conditions for their action and in Manzgam conditions their effectiveness may be less. The highest level of wooly apple infestation was observed in case of non-adopters in Manzgam zone. From the table, it can be seen that some minor pests were found in the orchards of non-adopters while as their prevalence was found very low in case of adopters. Variation in case of minor pests was observed in the orchards of adopters of different horticultural zones as evident from the Table 3 and it may be attributed to differences in micro-climate, orchard sanitation, need-based sprays, presence of spurious chemicals in the market etc. Insect and mite population dynamics, the effectiveness of particular insecticide and acaricide along with the population of natural enemies, predators, and parasitoids is highly correlated with climatic parameters as reported by Duale *et al.* (2005) [11]; Chinniah *et al.* (2007) [7]; Christos *et al.* (2008) [8]; Sorribas *et al.* (2012) [28]; Devi and Challa (2019) [9, 10], George *et al.* (2019) [13], Vashisth *et al.* (2022) [31], Zhang *et al.* (2022) [36].

Table 3: Insect and mite detection in apple orchards of adopters and non-adopters of different horticultural zones during the year 2022-23

Insect and mite type	Adopters (%)				Non-Adopters (%)			
	Manzgam	Kulgam	Qaimoh	Average	Manzgam	Kulgam	Qaimoh	Average
Sanjose Scale	4	3.33	2	3.11	20	16	12	16.00
Wooly aphid	7.33	6	6	6.44	23.33	22	17.33	20.89
Green aphid	3.33	2	2	2.44	8	6	5.33	6.44
Black aphid	4.67	2.67	1.33	2.89	8.67	6	0.67	5.11
Rosy aphid	2	2	0.67	1.56	5.33	2	3.33	3.55
June beetle	2	2	1.33	1.78	4.67	8	4	5.56
Bark Beetle	1.33	0.67	0	0.67	2	2	2	2.00
Leaf Miner	0.67	2.67	4	2.45	12	12.67	18	14.22
European Red Mite	2	3.33	4.67	3.33	13.33	14	18.67	15.33
BC ratio	2.55	2.42	2.35	2.44	1.92	1.62	1.40	1.65

Data in Table 4 represents the level of insect and mite infestation during 2023-24 among the same set of farmer's samples. Table 4 shows that Qaimoh again proved better in terms of less insect infestation during the year 2023-24 in both adopters and non-adopters. Leaf miner and mite infestation followed a similar trend as observed during the year 2022-23. The highest mite infestation accounting 5.33% of orchards of adopters and 20.67% of orchards of

non-adopters was observed in the Qaimoh zone during the year 2023-24. The highest infestation during the year 2023-24 of wooly aphids was observed in non-adopters of the Kulgam zone (23.33%). Almost 14.67% of apple orchards of non-adopter respondents of Manzgam zone were infested with leaf miner during the year 2023-24 which was found minimum as compared to Kulgam (16%) and Qaimoh (20.67%) as evident from Table 4. In general, the higher incidence of insect and mite infestation during 2023-24 compared to 2022-23 may be due to differences in weather parameters, and primary infestation resulting in varied effectiveness of insecticide/acaricide.

Table 4: Insect and mite infestation (%) in apple orchards of adopters and non-adopters of different horticultural zones during the year 2023-24

Insect and mite type	Adopters				Non-Adopters			
	Manzgam	Kulgam	Qaimoh	Average	Manzgam	Kulgam	Qaimoh	Average
Sanjose Scale	4.67	3.33	4	4.00	17.33	16.67	13.33	15.78
Wooly aphid	7.33	8	6	7.11	20	23.33	18.67	20.67
Green aphid	8	4	2.67	4.89	14	10	9.33	11.11
Black aphid	6.67	5.33	2.67	4.89	10.67	9.33	6.67	8.89
Rosy aphid	4	2.67	2	2.89	13.33	10	6	9.78
June beetle	4	3.33	0	2.44	8	11.33	4.67	8.00
Bark Beetle	2	2	0	1.33	6.67	12	6	8.22
Leaf Miner	5.33	6	8	6.44	14.67	16	20.67	17.11
European Red Mite	0.67	3.33	5.33	3.11	15.33	18	20.67	18.00
BC ratio	2.82	2.65	2.45	2.64	1.71	1.32	1.1	1.38

Conclusion

The study revealed lower disease incidence (scab, powdery mildew, etc.) and pest infestation (mites, aphids, etc.) among adopters compared to non-adopters across all zones. The Manzgam zone consistently demonstrated the lowest disease and mite and leaf miner infestation, likely attributed to favourable microclimatic conditions. Adopters exhibited significantly higher benefit-cost ratios than non-adopters due to reduced input costs, improved fruit quality, and higher yields. These findings emphasize the crucial role of proper spray scheduling in better disease and pest management, enhancing apple production and profitability in the region.

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