

Effect of foliar application of boron on apple yield and socio-economic status of farmers in cold desert region of North-Western Himalayas

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Abstract

Apple (*Malus domestica*) grown in the lower Spiti Valley in harsh climatic conditions is regarded as an important source of income for tribal farmers. Poor flower and fruit formation due to a lack of boron in apple orchards leads to lower productivity. Considering this issue, front-line demonstrations were conducted at farmers' orchards across various locations in the Spiti Valley from 2020 to 2021. The impact of boron foliar application on apple yield and the socioeconomic status of farmers in the region was then assessed. Front-line demonstrations demonstrated a yield increase of 21.32% and 9.14% in 2020 and 2021, respectively, over traditional practice (no boron application). Apple yield varied from 205 to 221 q ha⁻¹ and 262 to 275 q ha⁻¹ during 2020 and 2021, respectively, in demonstration plots. Average apple yield of 213.4 q ha⁻¹ (2020) and 267.4 q ha⁻¹ (2021) were recorded in demonstration plots. The technology gap was 86.6 q ha⁻¹ in 2020 and 32.6 q ha⁻¹ in 2021. The mean extension gap during 2 years of study was 22.9 q ha⁻¹, emphasizing the need to motivate and train farmers to adopt improved scientific practices. The technology index during the year 2020 was 20.9% and further, it reduced to 10.9% during 2021, showing higher feasibility of the demonstrated technology. Economic practices revealed higher net returns and benefit-to-cost ratios of 2.16 in 2020 and 3.53 in 2021, enhancing better awareness and adoption of improved practices, thereby increasing the socio-economic status of farmers.

Key words: Boron, apple, front-line demonstration, extension gap, technology gap and economics

Introduction

Apple (*Malus domestica*) holds the most dominant position among fruit crops by occupying about 49% of the total agricultural area and 79% of the whole fruit production of Himachal Pradesh (Negi, 2020). However, in recent years, there has been a gradual decline in its productivity. There are several factors responsible for this decline in apple productivity like expansion of apple cultivation to marginal areas, improper nutrient management, the prevalence of pests and diseases and changing climatic conditions (Nautiyal and Dimri, 2009). Of the various factors responsible for low productivity, nutrition is of significant importance in determining fruit quality.

Boron is an indispensable micronutrient for the normal growth and development of plants and its deficiency has become the most crucial constraint limiting nutrient use efficiency and crop yields. Boron deficiency has been reported to result in considerable yield reduction in annual, cereal, pulse, oilseed and perennial crops (Niaz *et al.*, 2007). The deficiency of boron is considered as the second most important micronutrient constraint in crops after that of zinc (Zn) on a global scale. Apple trees have been known to have high requirements for boron (Shorrocks, 1997). Poor fruit set and in turn reduced yielding are the first visual signs of boron deficiency since this nutrient plays a key role in reproductive growth. Deficiency of boron has been reported to cause many physiological disorders like the development of bitterpit, fruit

russetting, besides many vegetative disorders. Due to this the fruit quality is reduced and has lower consumer preference in the market, therefore, resulting in great economic loss to the fruit growers. Application of boron either in soil or through foliar spray is found to be effective in improving growth, fruit quality and production of apple (Ajender and Thakur, 2021).

Orchardists of Spiti Valley are growing apple based on the knowledge transmitted to them by their ancestors which is leading to unscientific agronomic, nutrient and pest management practices. They are applying only macronutrients (N, P & K) in their orchards and ignoring micronutrients especially boron which plays an important role in fruit setting and the quality of apples. Due to failure in the adoption of recommended scientific practices, orchardists often fail to achieve the desired quality and potential yield of apples in their orchards. Although the impact of boron nutrition on fruit crops is highlighted by many researchers earlier, however, no such studies were conducted in cold desert regions of Spiti Valley of Himachal Pradesh. This region is a very far-flung valley and its isolation from major markets hampers access to quality planting materials and agricultural inputs. Agriculture in Spiti valley is labor-intensive, compounded by the rugged terrain and small field sizes, limiting the use of modern machinery. Shallow soil with low water holding capacity coupled with declining snowfall poses challenges for irrigation and crop cultivation. Therefore, there was a need to demonstrate to the

orchardists about the scientific cultivation of apple to improve quality apple production to field, higher prices and enhance their income.

The study aims to evaluate the impact of foliar boron application on apple yield and quality in the cold desert region of Spiti Valley, Himachal Pradesh. Through front-line demonstrations on farmers' orchards, it seeks to showcase the benefits of scientific cultivation practices in addressing nutrient deficiencies, particularly boron, to improve fruit set and productivity. Additionally, the study assesses economic outcomes, including net returns and benefit-to-cost ratios, to highlight the socio-economic benefits for orchardists. By identifying technology and extension gaps, it aims to promote the adoption of sustainable practices for enhanced apple production and farmer livelihoods.

Materials and methods

Study site: The front-line demonstrations were conducted for two years 2020 and 2021 in different villages of Spiti Valley district Lahaul & Spiti, Himachal Pradesh, India. Agro-climatically, Spiti Valley represents the true arid cold temperate climate of North–West Himalayas, which is characterized by high diurnal temperature variation, negligible rainfall (<200 mm annually), high wind velocity, high evaporation losses during summers, heavy snowfall and harsh winters with very low minimum temperature (-20 to -30 °C). Spiti Valley is high altitude region with an altitude above 3000 meters above mean sea level.

In 2019, scientists conducted surveys in major apple-cultivating villages of the lower Spiti Valley and identified widespread issues with poor flower and fruit formation, resulting in reduced apple yields. Boron, a key nutrient essential for pollen germination, pollen tube formation, and activation, was found to be deficient in many orchards, contributing to the problem. To address this, four villages—Tabo, Qurith, Nidang, and Poh—were selected to demonstrate the effect of foliar boron application on improving fruit setting and apple yields. The agro-climatic details of these villages are provided in Table 1.

Table 1. Agro-climatic zone (Dry temperate and high hills) details of selected villages for front-line demonstration

Village	Altitude (amsl)	Geographical coordinates	Number of demonstrations
Tabo	3270 m	32° 05.32' N, 78° 23.04' E	3
Qurith	3290 m	32° 04.38' N, 78° 20.54' E	2
Nidang	3336 m	32° 03.50' N, 78° 20.06' E	3
Poh	3340 m	32° 02.20' N, 78° 31.77' E	2

Critical inputs and technologies provided: The front-line demonstration was carried out in 10 selected orchards in above mentioned four villages of Spiti Valley where the problem of poor flower and fruit formation and low yield was observed. All the selected orchards had similar cultivation practices and similar climatic conditions. The demonstration consisted of two treatments only viz., T₁- (Demo) and T₂- (Check). Treatment T₁ (Demo) was the application of boron @ 0.1% at the pink bud stage and treatment T₂ (Check) was Farmers' practice where no boron was applied.

Twenty-five apple trees cv. Royal Delicious aging 20 to 25 years spaced at 4 x 4 m under each treatment were selected for conducting demonstration and out of that five trees each under

both treatments were selected randomly for recording the yield data for further analysis. The soils of the demonstration sites were shallow, sandy loam in texture, low in organic matter, neutral to alkaline in reaction, having low water holding capacity, low in nitrogen and medium to high in phosphorus and potassium. The recommended package of practices as per the University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh India were followed during the cropping season. The recommended dose of NPK @ 700:350:700 gram per tree was applied in both treatments. Entire quantities of P and K were applied in tree basins during the month of February through single superphosphate and muriate of potash, respectively. Nitrogen was applied through urea in two splits, half before 15 days of flowering and the remaining half after 1 month of first application. In the demonstration boron @ 0.1% through boric acid was applied as a foliar spray at the pink bud stage. These inputs (fertilizers) were provided to farmers by KVK. All the cultivation practices were performed under the guidance of scientists of KVK and routine field visits at orchards were conducted to check the progress of the demonstration.

Data analysis: Yield data was recorded at the harvest from the selected trees under both treatments at each location to calculate the mean apple yield of every location and average apple yield. Data on the cost of cultivation and gross returns in both treatments was collected from the farmers. From this data technology gap, extension gap, technology index, net returns, and benefit to cost (B:C) ratio were calculated. The data were processed using Microsoft Excel 2010 package. The means and coefficient of variation were evaluated using the Web Agri Online Package (WASP) online data analysis portal, CCARI (<https://ccari.res.in/wasp2.0/index.php>). Technology gap, extension gap and technology index were calculated by the formulae given by Matharu and Tanwar (2018).

Technology Gap = Potential yield - Demonstration yield

Extension Gap = Demonstration yield - Farmer's yields

Technology Index (%) = [Technology Gap/ Potential yield] x100

The economic analysis of the experiment was carried out by considering the prevailing prices of inputs used. The various formulae used in the study are given as under:

Gross returns (Rs ha⁻¹) = Apple fruit yield (kg ha⁻¹) x Price of apple fruit (Rs kg⁻¹)

Net returns (Rs ha⁻¹) = Gross returns (Rs ha⁻¹) - Cost of cultivation apple (Rs ha⁻¹)

Benefit cost ratio = [Gross returns (Rs ha⁻¹)/Cost of cultivation of apple (Rs ha⁻¹)]

Results and discussions

Yield: Apple fruit yield was recorded at the harvest of crops during 2020 and 2021. Apple yield varied from 205 to 221 q ha⁻¹ and 262 to 275 q ha⁻¹ during 2020 and 2021, respectively, with foliar application of boron @ 0.1% at different locations under demonstration plots (Table 2). The average yield in the demo plot was 12.32% and 9.14% higher than the farmer's practice (Check) in 2020 and 2021, respectively (Fig. 1). The average yield in the demo plot was 213.4 q ha⁻¹ whereas in farmers' practice (Check) it was 190.0 q ha⁻¹ during 2020. During the year 2021 average yield in the demo was 267.4 q ha⁻¹ and in check, it was 245 q ha⁻¹. Higher yield in the demo over check may be attributed to the

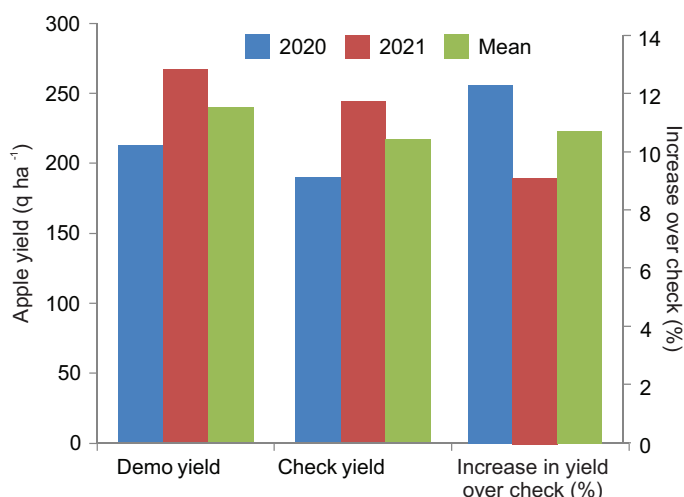


Fig. 1. Apple average yield and % increase in yield in demo plots over farmers' practice (check)

application of boron at pink bud stage which helps in increased fruit set, retention and yield as a continuous and ample supply of boron was required for pollen tube growth and subsequent fruit set. These results highlighted that the foliar applications of boron before full bloom increase fruit set and fruit yield of apple trees (Peryea *et al.*, 2003; Wojcik *et al.*, 2008; Sharma, 2016). Dar (2017) reported that the boron during flowering increased the growth of the pollen tube and the development of the flowering and fruiting stages. Boron foliar sprays to boron-deficient fruit trees under dry conditions delay bloom and increase fruit set and final fruit number per tree. The present study further support these findings in cold desert regions where dry conditions prevail. Sofi *et al.* (2019) and Ajender and Thakur (2021) also reported improved fruit set, fruit retention and yield of apples with boron application.

Table 2. Apple yield of demonstration during 2020 and 2021

Year	Demonstration yield (q ha ⁻¹)		CV (%)
	Range	Average	
2020	205 – 221	213.4	2.66
2021	260 – 275	267.4	1.84

Technology gap: The average productivity of apple in India is about 8 to 10 t ha⁻¹ but this may vary from location to location. Traditionally apples were planted at 6-8 meter distance but due to advancements in propagation techniques, improved training and pruning systems the plant population per hectare has increased many folds and therefore the productivity is higher in these orchards. The orchards selected under study were under medium density planting system with spacing of 4m x 4m (625 plants per hectare) and the potential average yield with similar spacing is about 300 q ha⁻¹. The technology gap is the difference between the potential yield and demonstration yield and during the year 2020 it was 86.6 q ha⁻¹ and during 2021 it was 32.6 q ha⁻¹ (Table 3). The technological gap may be attributed to the soil fertility variations, weather parameters, and pest and disease incidence during the study years (Arunkumar *et al.*, 2023). The average technology gap during 2 years of demonstration plots was 59.6 q ha⁻¹. These results were conformity to the earlier finding of Mishra *et al.* (2007) who also reported that technological gap may be attributed to the dissimilarity in the soil fertility status, proper seed rate and spacing, marginal land holdings and other

Table 3. Comparative assessment of technology gap, extension gap and technology index of demonstration and check

Year	Technology Gap (q ha ⁻¹)	Extension Gap (q ha ⁻¹)	Technology Index (%)
2020	86.6	23.4	28.9
2021	32.6	22.4	10.9
Mean	59.6	22.9	19.9

environmental factors.

Extension gap: The extension gap found between demo and farmers' practices (check) is presented in Table 3. Data revealed that the extension gap was 23.4 q ha⁻¹ in 2020 and 22.4 q ha⁻¹ in 2021. The mean extension gap during 2 years of study was 22.9 q ha⁻¹. The extension gap in the study emphasizes that there is a need to motivate and train farmers in the adoption of improved scientific practices for apple cultivation through various extension activities to reduce the wider extension gap. These results conformed with the earlier findings of Kapoor *et al.* (2022), Arunkumar *et al.* (2023) and Ghosh *et al.* (2024).

Technology index: The technology index generally shows the viability of the technologies to be adopted in the farmers' fields. The technology index during the year 2020 was 20.9% and further, it reduced to 10.9% during 2021 (Table 3). This reduction in the technology index shows the higher feasibility of the demonstrated technology (Arunkumar *et al.*, 2023). The lower range of the technology index shows high efficacy of the right conduct of technological interventions with more feasibility and applicability.

Economics: The impact of front-line demonstration on the socio-economic status of farmers was also studied. Economic analysis was worked out for each year and data for two years is presented in Table 4. From the data, it is evident that foliar application of boron @ 0.1% (Demo) affected the profitability of apple crops over farmers' practice. Higher cost of cultivation per hectare ₹ 593316/- and ₹ 606018/- were recorded in demo plots during 2020 and 2021, respectively. Higher cost of cultivation in a demonstration over check was due to the extra cost incurred for purchasing water-soluble boron fertilizer. Kapoor *et al.* (2022) also reported higher costs in demo due to high cost of input materials. Gross returns and net returns were highest in demonstration plots over farmers' practice (check) in both years. Similarly, the highest benefit-to-cost (B:C) ratio of 2.16 and 3.53 during 2020 and 2021, respectively, was recorded in demonstration plots. The highest economic returns and B:C ratio with foliar application of boron were due to higher fruit yields which *etc.* higher market prices. These results conform with the earlier work done by Nautiyal *et al.* (2017), Sofi *et al.* (2019) and Kour (2020). Further, the positive feedback of farmers also showed that the demonstration was successful in changing the outlook of the farmers towards the adoption of scientific technology for improving their livelihood and enhancing their income. Hence, the awareness and adoption of the recommended scientific package of practices have increased the socio-economic status of the farming community.

In conclusion, the incorporation and adoption of scientific and improved cultivation practices associated with the active participation of farmers significantly increased the yield and monetary return of apples to the farmers of Spiti Valley. Higher production under front-line demonstration over farmers' practices

Table 4. Economics of the front-line demonstrations and check

Year	Economics of demonstration (₹ ha ⁻¹)				Economics of check (₹ ha ⁻¹)			
	Gross cost*	Gross returns	Net returns	B : C ratio	Gross cost	Gross returns	Net returns	B : C ratio
2020	593316	1280400	687084	2.16	590671	1140000	549329	1.93
2021	606018	2139200	1533182	3.53	603373	1960000	1356627	3.25
Mean	599667	1709800	1110133	2.84	597022	1550000	952978	2.59

*All kinds of costs including the fixed costs have been considered in working out the cost of cultivation.

has created better awareness among the farmers and motivated other farmers to adopt suitable technology. The technological and extension gap that existed in the present study can be reduced by popularizing the recommended package of practices for apple cultivation through various extension activities like group discussions, trainings, campaigns, demonstrations and field days.

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