Research Article

Significance and Implications of Farming Practices, Knowledge and Methods of Disease Management in Developing Countries: A Case Study of Peach Farmers in Pakistan

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Abstract | Sustainable development goals (SDGs) have been formulated by the United Nations to address global issues including food insecurity around the world. However, in developing countries, like Pakistan, a number of basic factors are the major impediments in implementation of these goals. Surveys were conducted in Peach (*Prunus persica* L.) producing areas of Malakand Division, Khyber Pakhtunkhwa, where peach production, a major income source, is facing a serious decline over the past decade. Peach growers were mostly owners in Swat and Chitral districts whereas in grower in rest of the districts were tenants (60-75%). Highest literacy rate was observed in Swat District, (high school/matriculates 55%), while illiteracy rate was highest in district Chitral (72%). We believe that along with lack of proper education, know how about the technology and its use in peach production, growing of decades old cultivars i.e., Elberta (No 6) might be responsible for this production decline. Due to poverty, practice of intercropping is common to maximize their profit (intercropping upto 100% in Dir and Shangla Districts). Peach rot and fruitflies, are prevalent in all peach growing areas. Thirteen diverse insecticides and 22 fungicides alone or in combination are used to manage this twin menace. The indiscriminate use of agrochemicals i.e., 24-30 sprays per season with no effective results; led us to believe that either the pest or pathogen or both might have developed pesticide-resistances. We conclude that i. lack of knowledge about pests and diseases, ii monocropping and use of decade's old cultivars, iii. lack of awareness about diseases, their ecology and epidemiology, iv. lack of knowledge about good phytosanitary practices and v. inability to choose the right pesticide/fungicide for better management are some of the contributing factors behind peach decline. Such situations are common in developing countries where lack of knowledge and awareness of farmers are playing a major role in food insecurity and perhaps in implementations of SDGs.

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Introduction

Production and marketing are the two pillars of agriculture that are inextricably intertwined with each other and their synergistic impact on agriculture lead to economic development. However, due to lack of education, availability of quality agricultural inputs and emergence and re-emergence of pests and diseases due to climate change, have badly affected the developing countries in both these areas (Peters *et al.*, 2014). Farmers' knowledge and practices play a key role in mitigating these issues and in order to ensure sustainability in agriculture production. In developing countries, however, the lack of education and lack of awareness about biotic and abiotic stresses, often leads to endemics that reduces crop profitability and ultimately the farmers' start abandoning certain crops and fruits (Sommer *et al.*, 2013).

Horticulture sector can provide opportunities to increase income, alleviate hunger and poverty and reduces socio-economic problems (Alam and Mujtaba, 2002). Several projects have been implemented by local and foreign donors in Malakand Division, in Pakistan for promotion of horticulture due to the diversified topography, agro-climatic conditions, good quality irrigation water and better soil type. Considering the scope and importance of fruits the government started Fruit Maximization Project in Khyber Pukhtunkhwa (KP) to promote the multiplication of fruits with the support of Swiss government i.e., The Pak/Swiss Malakand Fruit and Vegetable Development Project (MFVDP) and Pak-Swiss Project for Horticultural Promotion (PHP). Emphasis was given to the small landless farmersand women (Ali *et al.*, 2003). A number of peach cultivars *i.e.*, Indian Blood (8-A), Spring Crest, Elberta *etc.* were introduced in Malakand Division as a part of the project (Ahad *et al.*, 1999; Ayaz *et al.*, 2001). Ever since, the most promising peach cultivars have been widely adapted and cultivated in the Malakand Division, despite the fact that these varieties were prone to diseases and pests (Ayaz *et al.*, 2001). Monocropping over three decades has further exacerbated the production constraints. No evaluation- or follow-up study were conducted to evaluate the extent to which fruit production and multiplication has been done in the project area and to figure out how the new introduction of fruits crops have led to emergence and reemergence of pests and diseases. Moreover, the gaps in knowledge and practices of the farmers in Malakand Division, are widely unknown and has resulted in reduction of crop productivity due to the frequent outbreaks of pests and diseases. The low level of growth in fruit production in general and peach fruit production in particular shows that there is great room for improvement through improved management practices to maximize yield and improve the socio-economic status of the growers (Akçay and Uzunöz, 2006). Due to pre- and post-harvest diseases; improper storage and poor supply chain more than 40 per cent of the peaches produced, are wasted (Ahmada *et al.*, 2021). As a result, the per hectare production of fruit orchard is much lower when compared to other countries across the world (Bakhsh *et al.*, 2006; Memon *et al.*, 2015). Over the past three decades there has been a major upward shift in production per unit area for China (17.5tonnes from 2.5 tonnes) and Turkey (15tonnes increased from 12.5 tonnes), while in Pakistan a downward trend has been recorded (Figure 1), where the production has been reduced to as low as 5 tonne /ha from 10 tonnes (AMIS, 2021). There are many reasons behind this downward trend including lack of awareness of farmers, ignorance of policy makers and technological deficiency etc. (Ali *et al.*, 2008).

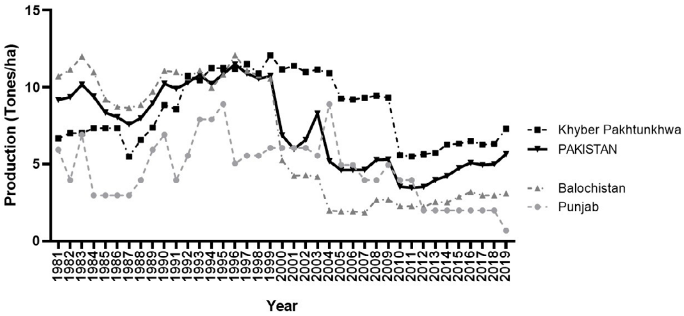

Figure 1: *Peach production statistics in Pakistan (1981-2019).*

The quality and quantity of peach is further affected by weather, biotic stresses and abiotic stress, pre and post-harvest crop management, variety grown as well as the production techniques used by the growers. The knowledge, attitude, infrastructure and resources are identified as factors contributing to post harvest losses. Numerous studies have addressed the sustainability issues, lack of farmers' know how and poor implementation of sustainable practices in major peach producing areas of Malakand Division, KP. Pakistan. However federal Government needs to initiate several steps to channelize these abundant quantities of fruits and vegetables to the international market and fetch back higher returns to the country (Ahmada *et al.*, 2021; Ali *et al.*, 1994). This study was designed to determine the knowledge and disease management

Figure 2: *Map of the study area.*

practices of farmers in northwest Pakistan. Our results have implication for fruit production in Pakistan specifically and elsewhere in developing countries in general.

Materials and Methods

Universe of the study

Environmental Protection department divided Khyber Pukhtunkhwa (KP) in three zones like Northern, Central and Southern zones. The Northern zone covers Hindu Kush and Western Himalayas ranges. District Swat, Buner, Dir upper, Dir lower, Shangla and Chitral which are favorable agro-ecological zones for Peach growth. All peach growers in five peach growing districts of Malakand division were considered for the studies (Khan *et al*., 2018).

The study sample

Comprehensive surveys were conducted in five districts of northern areas of Khyber Pukhtunkhwa (KP) to investigate the epidemiology and management of insects-fungal diseases in peach orchards. Eleven locations were randomly selected from Swat, nine from Dir, seven from Chitral, five from Shangla and four from Buner (Figure 2). About 36 respondent were evaluated for knowledge and practices for pests and disease management in peach orchards.

Data collection

Questionnaire was used for collection of data from the respondent. Data were arranged in excel file and analyzed through SPSS software. Descriptive statistics including percentages based on the number of farmers were evaluated. Chi-square test was used to check the association between geographical locations and major variables of interest (Khalil *et al*., 2014).

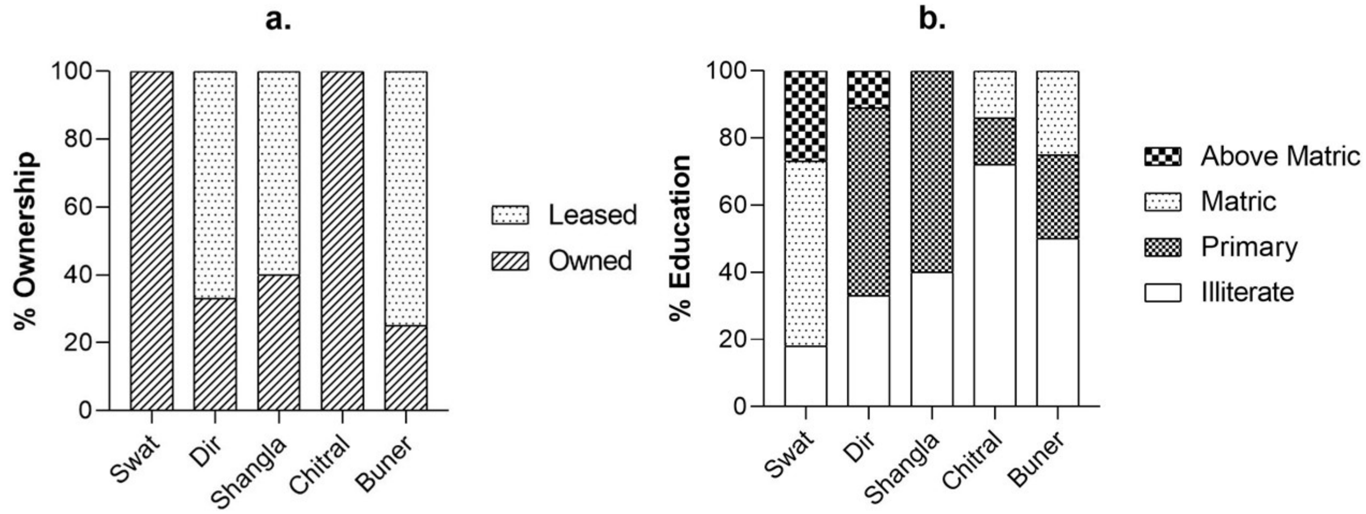

Figure 3: *Regional differences of farmers in (a) Ownership (b) Education.*

Results and Discussion

Ownership

The data indicated that in all districts the interviewed peach growers had the prestige of land and orchard ownership (P<0.05). A significantly high percentage of the respondents (67%) were land owners as compared to tenants or lease growers (33%). In Swat and Chitral districts, almost all peach growers (100%) were land owners, while in Buner, Dir and Shangla districts the ownership was reduced to 25%, 33% and 40%, respectively (Figure 3a).

Education level

The educational level of the farmers is one of the crucial determinants of farmer's level of adoption of new technology. There were significant differences (P< 0.05) between the levels of education in different districts. The farmers in the Malakand Division (district Swat), peach growers did not pursue even the formal education (18%), 55% had only secondary school (SSC) level while only 27% of the farmers attained SSC or above level of education. In district Dir, 33% were illiterate, 56% went to primary school and 11% were at having SSC level or above. Similarly, in district Shangla 40% were illiterate and 60% attained primary level of education while in district Chitral 72% have no education, 14% were having primary and matric level. In district Buner illiteracy was 50%, only 25% achieved primary and matric level. This data pointed out that the respondent must be educated to higher level so that they may have the knowledge about the use of proper techniques. Among the five districts, Swat has the highest literacy rate followed by Dir, Buner, Chitral and Shangla (Figure 3b).

Source of irrigation

Irrigation system in Pakistan is one of the largest irrigation system all over the world. It stretches throughout Pakistan and is backbone of crop production and sustainable growth. Approximately three fourth of the land is cultivated under this largest canal system and is considered as the best substitute for the shortage of rainfall (Usman, 2016).

There was a significant association (P < 0.05) of districts with irrigation source. The main sources of irrigation in all five districts of Malakand Division were rivers, springs and some areas were partially rainfed. Among the different irrigation types, largest numbers of areas were (58%) irrigated with river water followed by (25%) spring irrigation and about 17% were partially rainfed. In district Swat, highest percentage (73%) of fields were irrigated through river, which is also the highest value among all five districts of Malakand division followed by 56% in district Dir and Chitral while lowest 40% were observed in district Shangla. Similarly, 27% and 44% fields were partially rainfed in district Swat and Chitral while 43% orchards were spring irrigated in district Dir followed by 60% and about 50% in shangla and Buner (Figure 4a) respectively.

Intercropping

Intercropping in peach orchards showed significant effect (P < 0.05) in all districts. In Malakand Division, farmers intercropped Peach orchard with *Hordeum vulgare*, *Pennisetum typhoides* and *Sorghum bicolor* L. About 42% orchards were without any other crop while 25% were intercropped with *Pennisetum*, 19% with *Hordeum vulgare* and 14% with *Sorghum bicolor* L. Among the districts, Swat was leading (100%) with

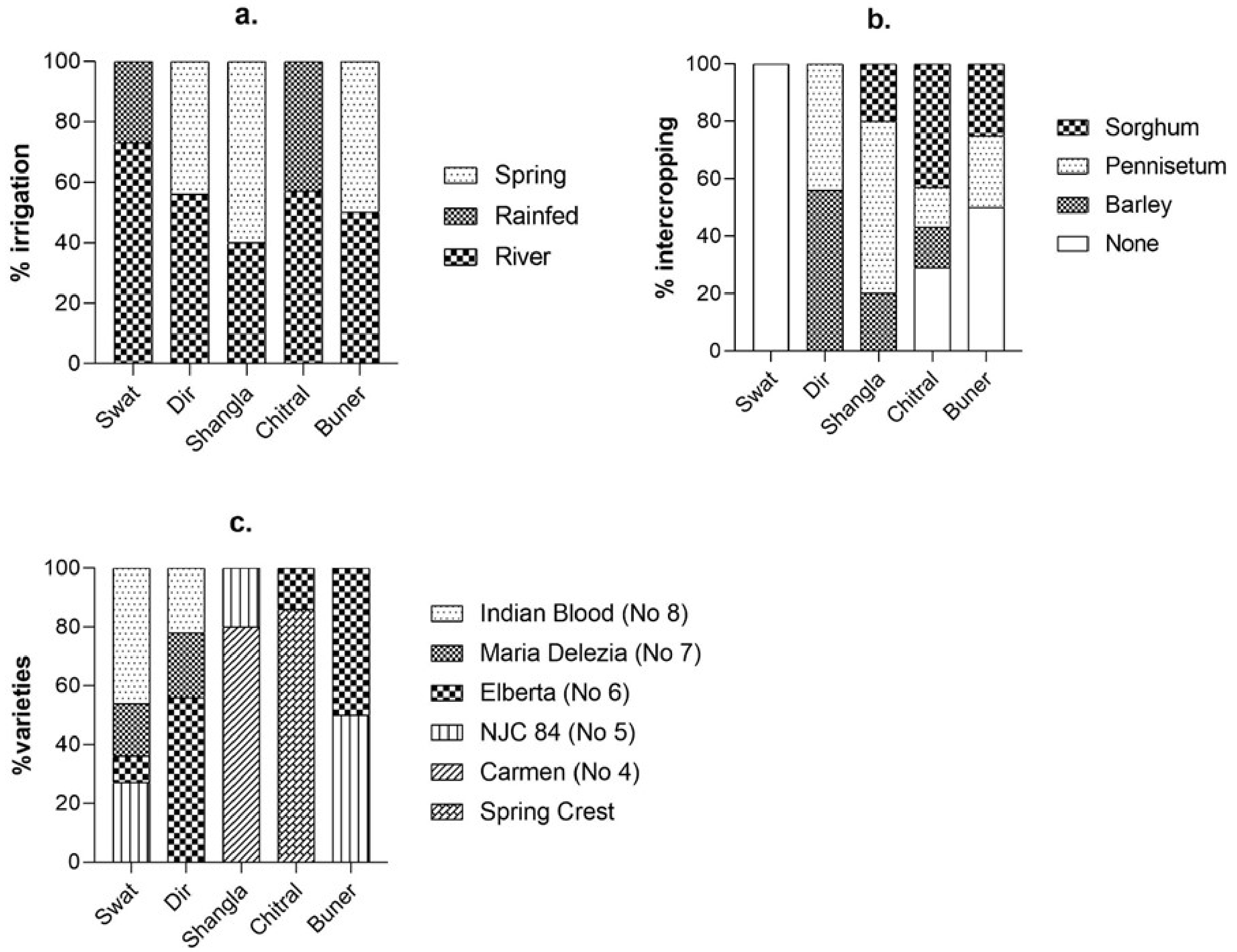

Figure 4: *(a) Percent irrigation types (b) percentage of intercropping (c) percentage of varieties cultivated.*

no intercropping followed Buner (50%). In district Dir, 56% fields were intercropped with *Hordeum vulgare* and 44% with *pennisetum typhoides.* Additionally, in district Shangla 56% were intercropped with *Pennisetum typhoides*, 20% with *Hordeum vulgare* and *Sorghum bicolor* L. while in Chitral district intercropping with *Sorghum bicolor* L. were noted at 43% locations whereas in 14% fields intercropping was done with *Pennisetum typhoides* and *Hordeum vulgare*. In district Buner, 25% orchards were found intercropped with *Pennisetum typhoides* and *sorghum bicolor* L. (Figure 4b). To our knowledge, little research study has been conducted to determine the effect of intercropping mostly on limitations of flowering, fruiting and fruit production of growing trees within varying agro-climatic circumstances (Figure 4b).

Varieties

The data about different varieties used in five districts of Malakand division shown in Figure 4c. In different districts, Elberta (No. 6) was common (25 %) followed by (19%) Indian Blood (No. 8), a late season variety, whereas the least common (17%) were both NJC84 (No. 5) and spring crest which are considered as mid and early varieties respectively. Late season variety Maria Delezia were grown at 11% localities. In district Swat the most popular peach varieties were Indian Blood (No. 8) and NJC 84 (No. 5) (46% and 27% growers respectively). In district Dir, maximum (56%) growers reported variety Elberta (No. 6), while 22% were growing Maria delezia (No. 7) and Indian Blood (No. 8). In district Shangla early variety Carmen (No. 4) was reported by 80% growers and only 20% were having NJC 84 (No. 5). In district Chitral 86% growers reported early variety Spring Crest and 14% Elberta (No. 6) while in district Buner two varieties NJC 84 (No. 5) and Elberta (No. 6) were reported by 50% growers.

Farmer's Knowledge about Pests/ diseases

Data regarding knowledge about pest and diseases mentioned in Figure 5a and 5b showed significant

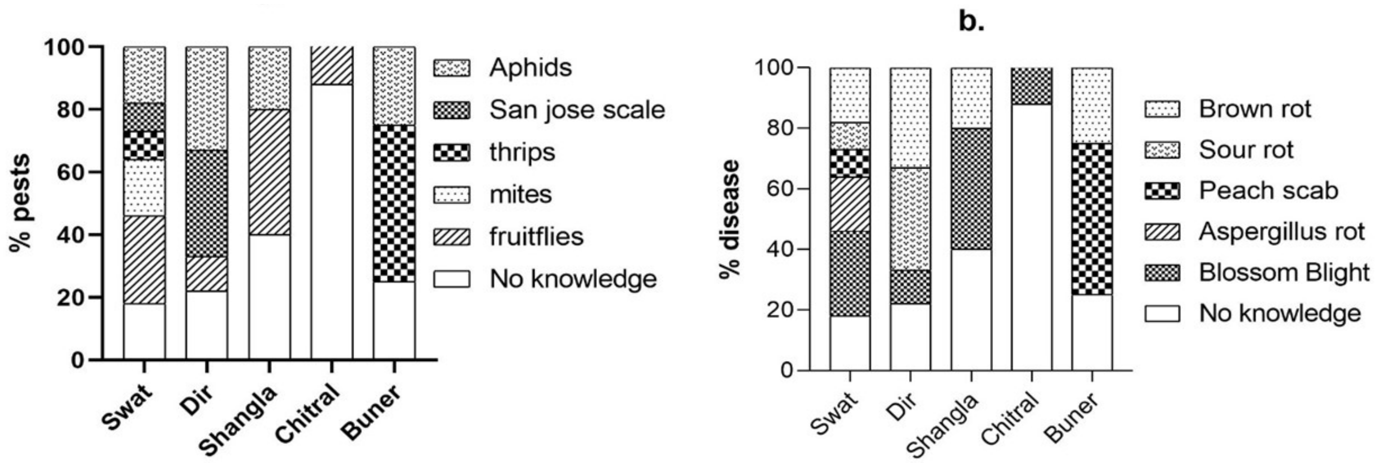

Figure 5: *Regional differences in Farmers' Awareness (a) Farmers knowledge about insects pests (b) knowledge about fungal diseases.*

relationship (P<0.05) in all districts. When enquired about the diseases 36% farmers had no knowledge about specific diseases in their peach orchards (Figure 5a and 5b). The most frequently reported diseases were Blossom blight (20% of respondent and brown rot (19 %). Other infections of pronounced economic significance have been sour rot and peach scab reported by 11% and 8% respondent, respectively. With respect to insect pest's management, again 36% farmers had no idea about insects. Of the farmers interviewed, 20% reported fruitflies that caused serious losses in production. Up to 19% declared infestations of aphids, 11% reported San Jose scale while, thrips and mites were mentioned by 8% and 7% of respondents respectively.

Insect pest management

It is revealed from the survey that farmers were using different insecticides for management of pests. They had confusion over the name of active ingredients, implying that a single active ingredient might be repeatedly used with different commercial names. The most commonly used insecticides were having synthetic pyrethroids and organophosphates as active ingredients. Eleven active ingredients were used to control thrips, mites, fruitflies, aphids and San Jose Scale.

Thrips: Figure 6a that shows the lack of effective thrips management due to lack of awareness (P>0.05). Among the farmers interviewed in district Chitral and Shangla, 100% orchards were without any treatment. In district Buner, 75% were without any treatment while 25% were treated with dimethoate. In district Dir 89% fields were given no treatment while 11% were treated with Admiral (pyriproxyfen). In district Swat 36% orchards were not given any treatment, 18% were treated with dimethoate and 46% with Admiral (pyriproxyfen).

Mites: The Figure 6b shows the data regarding mites management in five districts of malakand division. It was found that except Swat, the mite management is either poorly practiced or there is lack of awareness or resources (P<0.05). The grower's response revealed that maximum (100%) orchards without any treatment were found in district Chitral. In district Buner 75% were with no treatment while 25% were treated with Curacran (profenfose). Almost, 60% orchards were with no treatment in district Shangla and 40% were treated with Aldrin while in district Dir 67% orchards were without treatment, 22% with Curacran (profenfose) and 11% were treated with Larsbin (chlorpyrifose). Similarly, in district Swat 9% orchards had no treatment, 36% were given Larsbin (chlorpyrifose) treatment and 27% with Curacran (profenfose) and Aldrin respectively.

Aphids: In Pakistan, Peach cultivation originated in Swat and pesticide companies are more active due to big market as compared to other districts. Therefore, it is not surprising to observe that Aphid management in Swat district and to some extent in Dir district, is more widespread as compared to other districts (Figure 6c and Table 2). Grower's response revealed that maximum (100%) orchard were without treatment for aphids in district Chitral and Buner, while in district Shangla 80% were with no treatment and 20% were treated with dimethoate. In district Dir maximum (67%) orchards were without treatment followed by 11% and 22% treated with dimethoate and Furadan (Carbofuron). In district Swat 18% orchards were without any treatment while 55% were treated with dimethoate followed by 27% were given treatment with Furadan (Carbofuron) (Figure 6c).

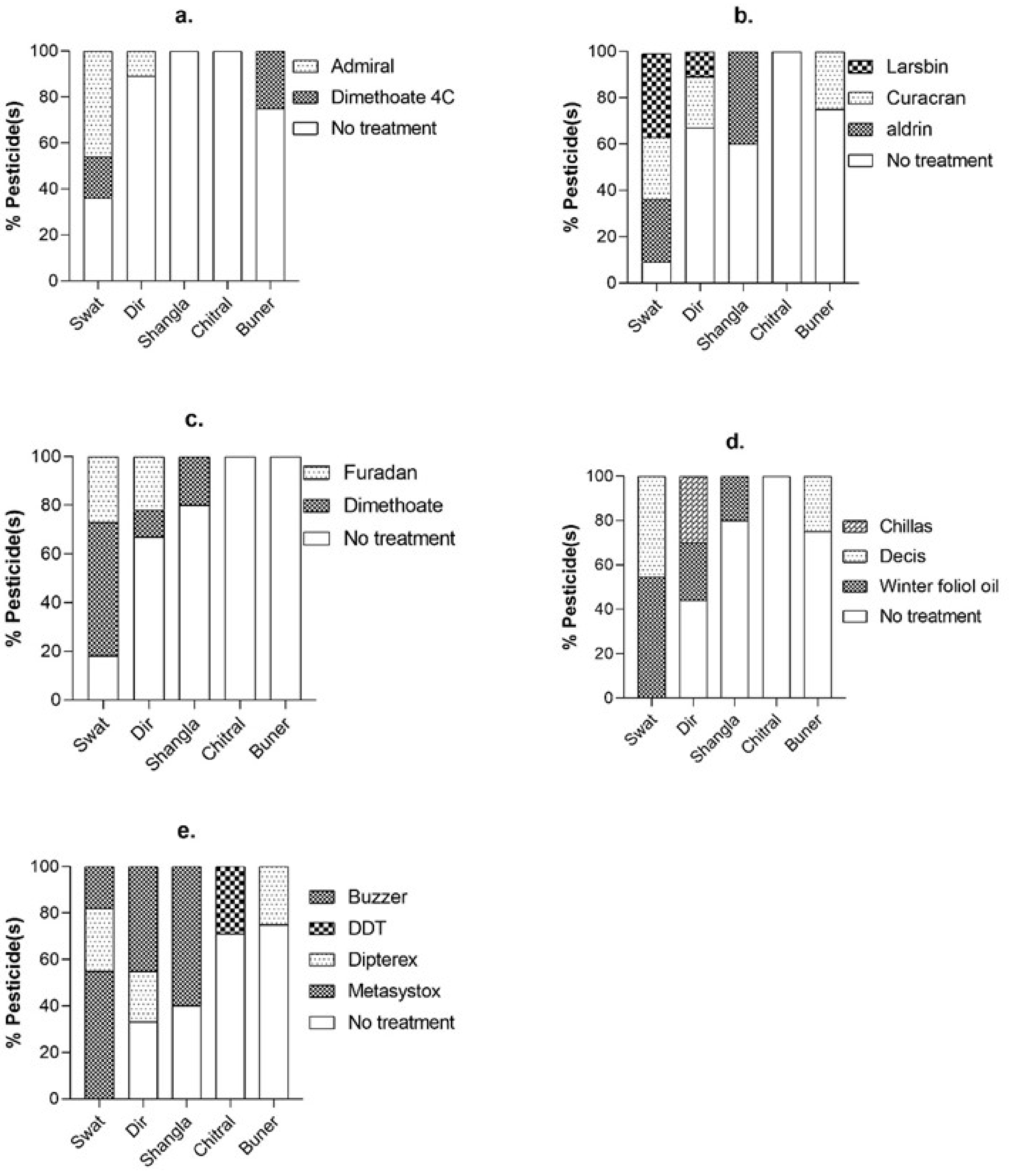

Figure 6: *Chemical control of insect Pests. Insecticides used for the control of (a) thrips, (b) mites, (c) aphids (d) san jose scale and (e) fruitflies in the study area.*

San jose scales: A pattern of San Jose Scale management, similar to aphids' was observed in all districts (Figure 6d and Table 2). In Malakand Division, no systematic San Jose Scale management was carried out. The growers response revealed that 100% orchards were without treatment in district Chitral, followed by district Shangla (80%), although 20% peach orchards were treated with winter foliol oil. In district Buner 75% orchards were not given any treatment whereas 25% were treated with Decis (deltamethrin). The percentage of untreated orchards in district Dir was 44% while 26% were treated with winter foliol oil and 30% with Chillas (Cypermethrin). Similarly in district Swat 55% were treated with winter Foliol oil while in 45% Decis(deltamethrin) was used.

Fruitflies: Fruitflies are considered as a serious pest in fruits and vegetables in Malakand Division. The use of chemicals for its management existed, to a varying degree in all districts (P<0.01).

The farmers' feedback revealed that maximum number of orchards (36%) were without any treatment while 25% were treated with metasystox (Oxydemeton methyl), 17% each were treated with dipterex (Trichlorphon) and buzzer (Cypermethrin). 6% of the orchards were given treatment with Dichlorodiphenyltrichloroethane (DDT) which is banned in Pakistan but still was in use. Highest 60% orchards in shangla and 55% in Swat were treated with metasystox (Oxydemeton methyl) and Dipterex (Trichlorphon) respectively. Another important finding that Dichlorodiphenyltrichloroethane (DDT) (29%) was still used in district Chitral (Figure 6e).

Table 1: *Chi-squared test, Association of districts with education, ownership, irrigation, intercropping and varieties.*

	Pearson chi square value	Df	P-value
Education level	24.072[a]	12	0.020*
Ownership	18.225[a]	4	0.001**
Source of irrigation	16.675[a]	8	0.034*
Intercropping	38.600[a]	12	0.000**
Varieties	73.059[a]	20	0.000**
Knowledge about pests	31.7[a]	20	0.046*
Knowledge about fungal diseases	31[a]	20	0.04*

Table 2: *Geographic (Districts-Wise) Association With Imperative Determinants Of Pest Management By Peach Fruit Growers in the Target Population.*

Insects Pests	Pearson Chi Square value	Df	P-value
Thrips	16.088[a]	8	0.041*
Mites	23.253[a]	12	0.026*
Aphids	18.274[a]	8	0.019*
Fruitflies	37.606[a]	16	0.002**
San Jose scale	26.343[a]	8	0.001**

Management of fungal diseases. For the effective control of both insect and disease it is essential to apply pesticides using appropriate method and in right dose. It was revealed during the survey that respondents were completely unaware about the proper time of pesticide application. They applied pesticides at all stages of growth. Farmers reported the use of several active ingredients to control blossom blight, *Aspergillus* rot, *Alternaria* rot, Peach Scab, Sour rot and Brown rot. A total of twenty seven fungicides belonging to the classes of benzimidazoles, strobilurins and triazoles being used and were recorded while conducting the survey.

Blossom Blight: The Figure 7a, illustrate data of blossom blight management in the peach orchards. Highly significant relation (P < 0.01) was noted in all districts where farmers in districts like Swat and Dir had significant awareness of the control measures and tools, while in the rest of districts the measures were scares of below effective level.

Again it was revealed that no control measures were taken against blossom blight in district Chitral. In district Buner 75% orchards were without any treatment whereas in 25% orchards plants were sprayed with Metalaxyl+ Mancozeb P4L. In shangla only 40% orchards were treated with Amistar Top (Azoxystrobin in combination with difenconazol) to control blosson blight. In district Dir 45% orchards were not receiving any treatment, 33% were sprayed with Metalyxal+ Mencozeb P4L while 11% orchards were treated with Cabrio Top (pyraclostrobin), and Amistar Top (azoxystrobin + difenconazol). Metalyxal+ Mancozeb P4L were applied in 37 % of the orchards, 36% were treated with Cabriotop (pyraclostrobin) and 27% with Amistar Top (azoxystrobin +difenconazol).

***Aspergillus* Rot:** Data about management of *Aspergillus* rot disease in peach orchards showed highly significant relation for fungicide use (P<0.01) in Swat and Dir Districts. Again no control measures were taken in all the orchards of district Chitral to control *Aspergillus*. In district Shangla Kocide (copper hydroxide +inert ingredients) was used in 20% areas while in the rest of the orchards no treatment was given., In district Buner 50% orchards were without treatment, 25% were treated wtih Contaf Plus (pyraclostrobin) and kocide. In addition district Dir were 33% orchards were with no treatment followed by 33% with kocide and Contaf Plus (pyraclostrobin) while in district Swat 37% orchards treated with thiophanate methyl, 27% with kumulus and kocide, 9% with Contaf Plus (pyraclstrobin) (Figure 7b).

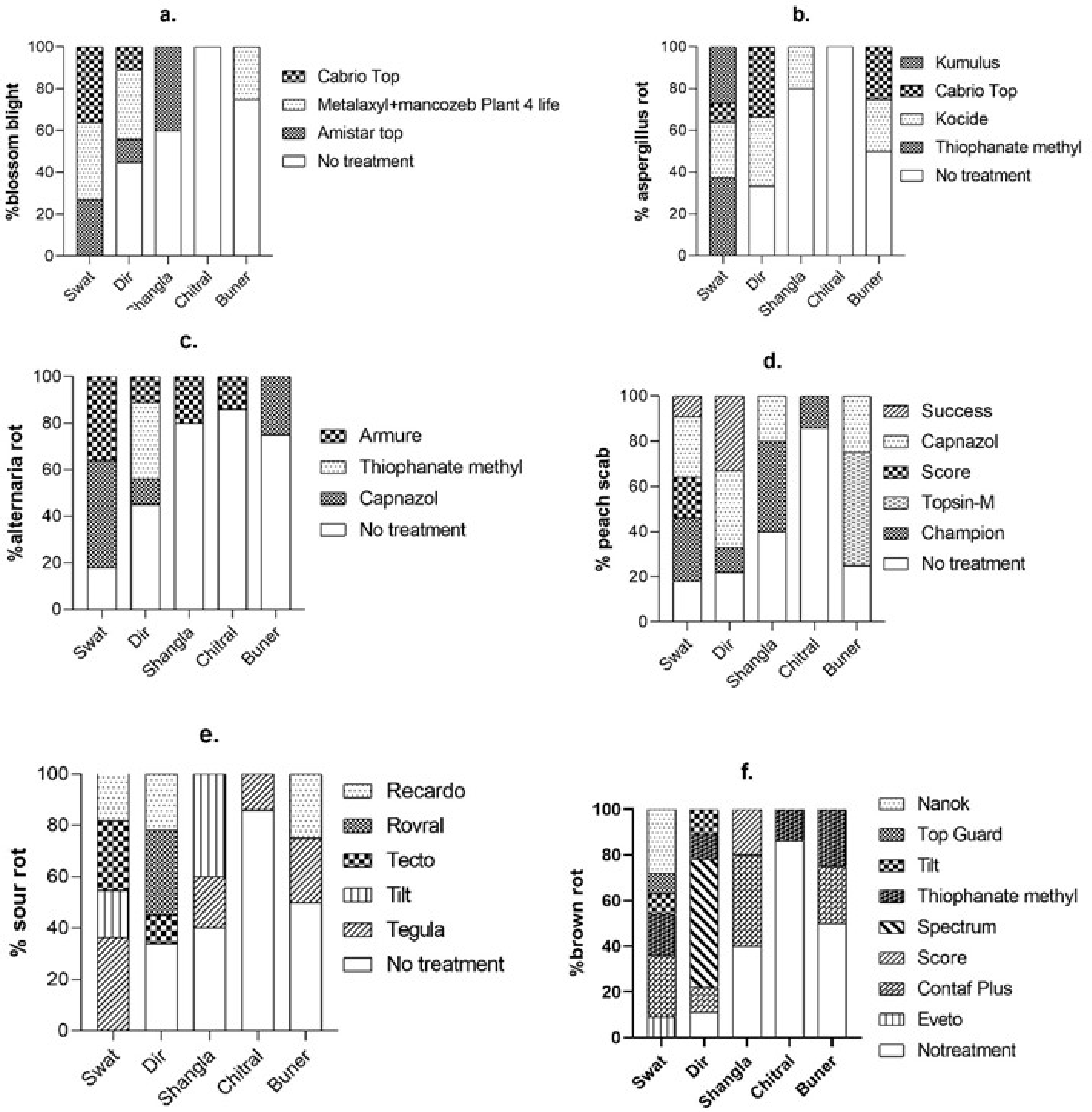

Figure 7: *Chemical control of (a) blossom blight, (b) Aspergillus rot, (c) Alternaria rot (d) peach scab (e) sour rot and (f) brown rot in the study area.*

***Alternaria* Rot:** Grower's response showed that in district chitral 86% orchards were without any treatment and 14% were treated with Armure (Propiconazole + Difenoconazole). In district Shangla 80% were without treatment, only 20% received treatment with Armure (Propiconazole + Difenoconazole). In district Buner 75% orchards were untreated and 25% were treated with Captnazol (Captan + hexaconazol). In district Dir 45% fields received no treatment, 33% were treated with thiophanate methyl and 11% with Armure (Propiconazole + Difenoconazole) and Captnazol (Captan + hexaconazol) while in district Swat 18% orchards were without any treatment followed by 46% treated with Captnazol (Captan + hexaconazol) and 36% with Armure (Propiconazole + Difenoconazole) (Figure 7c and Table 3).

Peach Scab: Grower's revealed that in district chitral 86% orchards were without treatment and 14% were using Champion (Copper sulfate) to control peach scab. In Shangla 40% growers were no using any control measures whereas 40% used Champion

(Copper sulfate) and 20% treated their orchards with Capnazol (Captan + hexaconazol). In district Buner 25% were without treatment, 50% were treated with Topsin-M and 25% with Capnazol (Captan + hexaconazol). In district Dir 22% orchards were without treatment, 34% were treated with Capnazol (Captan + hexaconazol), 33% and 11% were treated with Success (Chlorthalonil) and Champion (Copper sulfate) repectively. In district Swat 18% fields were without treatment, 28% were treated with Champion (Copper sulfate) and 27% with Capnazol (Captan + hexaconazol) whereas 18 and 9% orchards were treated with Score (Difenconazol + other) and Success (Chlorthalonil) respectively (Figure 7d and Table 3).

Sour Rot: In district Chitral 86% orchards were without any treatment and only 14% were treated with Tegula (tebuconazol) to control sour rot. 40% of the orchards in district Shangla,were without any treatment, 40% were treated with Tilt (propiconazol) and 20% with Tegula (tebuconazol). In district Buner 50% orchards were without treatment, 25% were treated with Tegula (tebuconazol) and rest of the 25% were treated with Recado. In district Dir 34% orchards were without treatment, 33% were treated with Rovral (iprodine), 22%with Recado (Azoxystrobin, Difenconazol) and only 11% with Tecto (thiabendazole). In case of district Swat 37% were treated with Tegula (tebuconazol) followed by 27% with Tecto (thiabendazole) and 18% each with Recado (Azoxystrobin, Difenconazol) and Tecto (thiabendazole) respectively (Figure 7e and Table 3).

Table 3: *Geographic (Districts-Wise) Association with Imperative Determinants Of Fungal Disease Management By Peach Fruit Growers in the Target Population.*

Fungal diseases	Pearson Chi Square value	df	P-value
Blossom blight	24.984[a]	12	0.015*
Aspergillus Rot	34.220[a]	16	0.005**
Alternaria Rot	23.489[a]	12	0.024*
Peach scab	37.586[a]	20	0.010*
Sour Rot	34.980[a]	20	0.020*
Brown rot fruit stage	50.712[a]	32	0.019*

Brown Rot Fruit Stage: Survey results revealed that in district chitral 86% orchards were without any treatment and 14% were treated with thiophanate methyl. 40% of orchards were not given any treatment in district Shangla, 40% were treated with Contaf Plus (hexaconazol) and 20% with Score (difenconazole). In district Buner 50% were without treatment followed by 25% with Contaf Plus (hexaconazol) and 25% with thiophanate methyl. In district Dir 11% orchards were without any treatment, 56% were treated with Spectrum (propiconazol), 11% each with Tilt, Contaf Plus (hexaconazol) and thiophanate methyl. In district Swat 28% were treated with Nanok followed by 27% with Contaf Plus (hexaconazol), 18% with thiophanate methyl, 9% with each Top Guard, Evito and Tilt respectively (Figure 7f and Table 3).

Lack of education, non-availability of quality agricultural inputs and emergence and re-emergence of pests and diseases due to climate change are the reasons why developing countries lagging far behind compared to developed countries in achieving sustainable development goals (Mugambiwa and Tirivangasi, 2017). Among these, farmers' knowledge and practices play a key role in mitigating these issues, in order to ensure sustainability in agriculture production. In 1980s, Pakistan took initiatives to improve the horticulture sector with support from Swiss government, in Malakand Division, KP, Pakistan (Figure 1). New improved peach cultivars were introduced and evaluated for improved productivity (Ahmad, 1985). However, due to the lack of follow-up studies and the natural course of emergence and re-emergence of diseases has led to a quick decline in peach production in recent years (Figure 1). Systematic studies to understand the production dynamics are lacking due to several factors, including terrorism (Ali, 2010; Khalid, 2020) and global crises (Papaioannou *et al*., 2020). Secure and legal land ownership offer an opportunity to the farmer for more incentives, including risk free investment and easy access to agriculture credit (Chalamwong and Feder, 1986; Feder, 1987).

In Malakand Division, peach growers were mostly owners (*i.e*., Swat and Chitral districts), while in Buner, Dir and Shangla districts the ownership was 25%, 33% and 40%, respectively. The production per unit area was 9.7, 6.4, 9.07, 11.37 and 7.38 tonnes/ha for Buner, Chitral, Dir, Shangla and Swat, respectively (Anonymous, 2020). Feder (1978) proposed that ownership insecurity causes lower farm productivities because investment incentives are absent and access to credit is limited. However, in our case, the landownership in Swat and Chitral ranked the highest (100%) while on the basis of production per unit area, Swat and Chitral ranked the lowest *i.e*., 4^{th} and 5^{th}. Therefore, it is assumed that the factors contributing to low productivity in peach is equally affecting the owners and the tenants. Peach growers in all districts had access to pesticides, fertilizers and other inputs. However, the lack of knowledge, poor financial status and lack of swift access to agriculture credit due to its complex process, results in dependence of small-scale farmers on local agrochemical business. Although, soil fertility as whole is not the contributing factor to low productivity, but the deficiency of micronutrients is a major issue for agriculture sector. The use of pesticides increased from 23,212 tons in 1994 to over 69,897 tons in 2002 (Bao *et al*., 2019). Regrettably, even during 1980s to the 1990s, a large number of chemicals were introduced in the agricultural region of Punjab, Pakistan. The selling and marketing of pesticides has been shifted from the government to the private companies which resulted in five times more use of chemicals within a short span of only one year, that too without any major effects on crop yields. In peach orchards, farmers are applying as high as 24 applications of pesticides in a single season (Fazal Maula, Personal Communication). This alone point towards the increase in various types of cancers in Swat district (Ejaz *et al*., 2004; Salam *et al*., 2021). As a result, the private sector was misdirected and coaxed to use unnecessary fertilizers (NPK) that adds to the input cost. Regarding irrigation types, there have been more cases (58%) of river irrigation in all districts followed by 25% spring and about 17% were partially rainfed (Figure 4a; Table 1). In all peach growing areas, water availability is the least of the problems and is met from rivers, followed by natural springs *etc* (Akbar, 2020).

Education and training enhance farmers' ability and willingness to make successful changes to their management practice that leads to national economic well-being and growth. In peach growing zone of Malakand Division, highest literacy rate was observed in Swat district where the high school/matriculates were 55%, while illiteracy rate was highest in district Chitral (72%) (Figure 3b; Table 1). Lack of education and poor economic status of the tenants may be one of the contributing factor to lower productivity (Flood, 2010). A substantial increase crop productivity requires formal trainings of the farmers in agriculture technology and food security. Crop statistics of KP (Anonymous, 2020) revealed that despite highest literacy rate, the production per unit area in Swat district was lowest (7.38 tonnes/ha) as compared to Buner, Dir and Shangla (9.7, 9.0 and 11.35 tonnes/ha, respectively) (Anonymous, 2020). Although, the disease pressure and pests may be the leading factor, but training through farmer field schools (FFS) and technology transfer projects can play a crucial role in the better control of plant diseases and in the growth of agriculture. In Malakand Division, FFS activities for farming community about modern techniques and guidance to increase productivity in agriculture, is scarce. Therefore, despite formal school and college education, high post-harvest losses and low productivity in agriculture are perhaps due to poor management and farmers' lack of knowledge. Countries with higher levels of income generally have higher levels of education; human capital, which includes both formal education and informal on-the-job training, is a major factor in explaining differences in productivity and income level between countries (Hicks, 1987). Famer's information about pest control and improved production is only possible through education and agricultural trainings. For Peach growers, training programs through Farmer Field Schools (FFS) can be an effective strategy to minimize yield losses in peach (Kilpatrick, 2000) and is evident from such activities in different crops in various parts of Pakistan (Ali and Haider, 2012; Bajwa *et al*., 2008; Butt *et al*., 2015; Mallah and Korejo, 2007).

Intercropping is not only sustainable and environmentally friendly but also offers economic benefits to both small scale farmers and commercial agriculture. The practice in young orchard, before fruit bearing stage can be beneficial for the small scale farmers. The intercropping becomes impracticable in fully grown, fruit bearing orchards. Despite this fact, a higher percentage of farmers (58%) still practiced growing *Pennisetum* (25%), *Hordeum vulgare (19%)* and *Sorghum bicolor* (14%) mainly as feed for domestic cattle (Figure 4b; Table 1). Studies have described positive, neutral, and negative treatment effects on yield (Zhang and Li, 2003). Unfortunately, few studies have examined how intercropping practices influence farm income. There is no evidence that yields and gross income for intercropping treatments increase when leguminous intercropping combinations are practiced, however, it can be advantageous for sustainable agricultural practice (Himmelstein *et al*., 2017). We believe that replacement of monocot forage with legume crops can have dual impact i.e., overcoming nitrogen deficiency and providing feed to the cattle (Giller, 2001).

Farmers in general (36%) have no knowledge about specific diseases in their peach orchards (Figure 5a and 5b). With respect to insect pest's management, farmers in general (36%) have no knowledge about insects. During the survey 20% farmers reported fruitflies, causing losses in production whereas 19% declared infestations of aphids, 11% reported San Jose scale, whereas thrips and mites were mentioned by 8% and 7% of respondents respectively. Among diseases, the most frequently reported diseases were Blossom blight (20% of respondent) and brown rot (19 %). Other infections of pronounced economic significance have been sour rot and peach scab according to 11% and 8% respondent respectively.

Peach is highly susceptible to a multitude of pests and diseases (Williams and Crocker, 2000) thus necessitating the use of agrochemical for insect/disease management. In recent years, fruitflies and Peach rot have been ranked as the most serious pest in fruits and vegetable (Solangi *et al*., 2011). Fruit breeding is a long and complex process (Byrne, 2001) and require persistent efforts and substantial investments. In the absence of host resistance, the management practices mostly rely on agro-chemical *i.e*., fungicide and pesticides. However, the practice of synthetic pyrethroids and organophosphates, alone is a major concern, since these classes of pesticides are known threat to environment and human (Nicolopoulou-Stamati *et al*., 2016). unjudicial use (Commission, 2012) of these agrochemicals have detrimental impact, not only on the environment but also on human and other organism (Uddin, 2018). In this study, we found that in some districts *e.g*., Chitral the lack of formal education or knowledge about pests, diseases and their management can reduce the economic return (Figure 5; Tabl 1) Peach is highly perishable fruit and post-harvest losses can be serious, if fruits are exposed to pests and diseases in orchards. Bad handling, poor storage, poor transportation, and the involvement of large numbers of intermediaries and the lack of information about better preservation methods are the break-up of these losses due to poor management facilities and practices (Kader, 2009).

For the safety of humans and environment, pests and diseases should be managed through good phytosanitary and cultural practices. The correct pruning and sanitation tactics are adequate alone to control damage to peach fruits in small farming especially in earlier spring, and are the basis of integrated pest management (IPM) strategy. Early harvesting and removal of affected plant parts helps to reduce fruit damage and the entry of harmful insects into peach orchards. These findings are in correlation with results of (Iqbal, 2005) and (Haye, 2016; Hussain, 2003). In addition, removal of weeds is much more than simple control strategy because it competes for water and nutrients with peach plants. Our findings are in agreement with those of (Fadamiro, 2009). Alternative control measures i.e., proper net covers, yellow sticky traps *etc*. are just being introduced in various peach growing areas, however, the adaptation and wide use will take its course (Miller *et al*., 2021).

Fungal pathogens can infect pre- and post-harvest fruit, resulting in significant damage. These fungi are all heterotrophic and need water for growth (Adaskaveg *et al*., 2008). Since, torrential rain and hailstorm are common during March, April, July and August (Nizami *et al*., 2020) in Malakand Division therefore, it can be assumed that dampness and humidity can provide conducive environment for fungal pathogens, enhancing disease incidence and severity in Peaches. Farmers were generally unaware of various diseases. Their understanding that the flower drying and drop (blossom blight) and fruit rots was commendable, however, they were not aware of the causal agent and proper control measure. Various fungicides are available to inhibit the development of stone fruit rot and can lead to effective control, especially of blossom blight (Sholberg, 2008). Farmers reported the use of several active ingredients to control blossom blight, *Aspergillus* rot, *Alternaria* rot, Peach Scab, Sour rot and Brown rot. A total of twenty seven fungicides belonging to the classes of benzimidazoles, strobilurins and triazoles were recorded (Figure 7a-f; Table 3). Brown rot fungi are dominated by the benzimidazole group of fungicides, including Benomyl, Carbendazim, Thiabendazole and Thiophanate-methy (Hetherington, 2005).

In developing countries, more poisoning cases are reported due to mishandling, bad implementation practices and inadequate management of pesticides (Bhanti, 2004). In addition, the use of certain classes of fungicides could lead to an increased severity of infection by other fungi or pests that are not explicitly targeted. The use of benomyl and related fungicides to combat *Monilinia*, for example, can lead to *Rhizopus* peach fruit infection (Koffman, 1975). Due to health and environmental issues, chemical fungicides, widely used to manage post-harvest diseases, are frequently

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checked (Sarks, 1995; Warlop, 2007). Owing to potential toxicological threats, some fungicides are no longer used for post-harvest treatment or have been entirely withdrawn from the market (Adaskaveg, 2002). Synthetic fungicides for post-harvest applications are banned in many European countries, such as France and Italy (Bonaterra *et al*., 2003; Gregori, 2007; Warlop, 2007).

It is evident that continuous monocropping, and lack of introduction of new peach cultivars, the production per unit area in Swat district has drastically reduced over the two decades, however, Swat district still enjoys the highest production owing to the area on which peach orchards are grown. The results of this survey on peach production practices in the region of northwest Pakistan have undoubtedly highlighted that peach trees are vulnerable to insect, pest and diseases. Survey results revealed that farmers are generally less aware of the pathogens affecting their orchards, and have no idea of management practices. Growers are more addicted to expensive chemicals.

The following public mediations should be considered to encourage the peach development sector in northwest Pakistan. (1) Training farmers to improve their knowledge of pests and diseases 2) farmers need training to increase technical knowledge, and also need finance and pure chemical products for better protection. (3) Strict supervision of sellers of pesticides to provide peach farmers with simple and standard information to prevent confusion between pesticides and active ingredients. 4) They should be made aware of bio-control and there is a need to track the pest population periodically, in particular at the peak time of insect / pest emergence, in order to encourage bio-control rather than chemicals. Together with the experts from Plant Pathology and Entomology, the role of Extension worker will be a key in this perspective. It is possible to begin pathological laboratory research in order to find the most promising solutions for micro-level infestation control. However, requirements to understand farmers' perception and knowledge should be recognized that could be served for better adaptation of technology regarding integrated pest management (Hashemi and Damalas, 2010).

To cater for the need of peach growers, research system play a role in providing technological knowledge and advice on pest and disease management. However, with an overlapping and over-active private agrochemical companies, the farmers are lefts in the middle of nowhere and confused about management of various pests and disease. Therefore, this study was conducted to evaluate impact of Pak-Swiss Malakand Fruit and Vegetable Development Project and Pak-Swiss Project for Horticultural Promotion MFVDP/PHP on Peach production and understand current knowledge and practices by peach growers to control diseases in Peach and highlight the factors contributing to peach production decline.

Novelty Statement

This the first comprehensive analysis of Peach production constraints faced by peach farmers in Malakand Division.

Author's Contribution

Palwasha: Performed interviews and collected and analysed the data.
Siraj-ud-Din: Prepared and reviewed the first draft.
Muhammad Fahim: Conceived and planned the experiments, edited and approved the final manuscript and supervised the research.

Conflict of interest
The authors have declared no conflict of interest.

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