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OCCURRENCE OF *SPONGOSPORA SUBTERRANEA* IN SOILS OF POTATO GROWING AREAS OF PAKISTAN

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Abstract

Powdery scab of potato caused by *Spongospora subterranea* (Wallr.) Lagerheim has been reported in Pakistan in 1980's. The fungus which is a vector of potato mop-top virus remains in soil for long period and is also seed borne. Once the pathogen is introduced in an uncontaminated area it is difficult to eradicate. The presence of *S. subterranea* has recently been confirmed in soil of Astak valley of Northern Pakistan. During a survey all the 6 potato production agro-ecological zones including Central Punjab (zone 2), Northern Punjab (zone 3), NWFP (zone 4), Kaghan, Kalam and Chitral valley (zone 6), Gilgit and Skardu (zone 7) and Balochistan (zone 8) were found infected with *S. subterranea*.The highest infested locations are in Chitral valley and in Northern Punjab. Gilgit has lowest infested locations. The soils of two major seed producing areas of Gilgit including Gupis and Yasin districts are still free of *S. subterranea*.

Introduction

Powdery scab, a fungal disease caused by *Spongospora subterranea* (Wallr.) Lagerheim has recently gained importance in Pakistan. This disease considerably lowers the market value of potato (Turkensteen, 1987). Recent investigations show that the disease can also reduce the total crop yield (Falloon *et al.*, 1998). Resting spores of the fungus are reservoir and vector of mop-top virus (Avery, 1983). This association has also been observed in certain areas of Pakistan (Turkensteen, 1987). Infected tubers develop dry rot during storage and serve as an avenue for tuber infection by *Phytophthora infestans* (Bhattacharyya & Raj, 1978).

The disease was first observed in Pakistan in 1986 from Attock, Okara and Faisalabad and later in 1987 in certain parts of Qalat division, Balochistan (Turkensteen, 1987, 1988). The report was based on visual observation of symptoms on tubers and light microscopy. Disease was again identified in 1990 after its interception in the imported seed potatoes at post quarantine stage (Iftikhar *et al.*, 1991). Later the presence of the pathogen in the soil of potato growing areas was confirmed on the basis of microscopy, bioassay and serology from Astak valley in Northern Areas of Pakistan (Ahmad *et al.*, 1996). *Spongospora subterranea* is an obligate parasite which survives in soil in the form of resting spores in the absence of its host. It infects the underground parts of the plants.

Confirmation of the presence of *S. subterranea* in soils of Northern Area of Pakistan is a threat for potato production especially for seed production. In the light of the above facts, concern was developed and a study carried out to determine the prevalence of *S. subterranea* in the soils of potato growing areas of Pakistan.

Materials and Methods

Soil sampling: Two hundred and thirty six soil samples were taken from 101 localities scattered in 24 areas of 6 potato production agro-ecological zones. The major areas surveyed include Central Punjab (zone 2), Northern Punjab (zone 3), NWFP (zone 4), Kaghan, Kalam and Chitral valley (zone 6), Gilgit and Skardu (zone 7) and Balochistan (8). Three to four sub-samples of soils were taken diagonally (3 cm layer was removed to avoid possible solarization effect) from each potato field. The sub-samples were thoroughly mixed and a composite soil sample of about 1 kg per field was formed. These samples were air dried at room temperature and then stored in a growth room at 18-20°C for further analysis.

In zone 2, twenty six soil samples from 23 localitions of Central Punjab were collected. These locations surveyed were Salarwala and NIBGE Potato Farm from Faisalabad area; Tahirabad, Raio Bagh, Salara Pindh, Rasool Nagar from Jhang area; Chunu Da Thatta, Nawaz de Khooi, Gogera Bangla, Parokian da Kot Chak-41, 51-2L Okara, 40-D Okara, Shoba Ram, Mazhar abad, Hujra Shah Muqeem from Okara area; Khoo Dolia Da 46-GD, Adda Khoria Shah 52- GD, Ratti Thibbi 6- R, Jahan Khan Joianh Da 29 SP- Chak from Sahiwal area; Kalar- Kala Shah Kako and Khana Marrian Da of Lahore and Daska of Sialkot area. Two soil samples from 2 locations, Lossar and Bathar Morgh (Rawalpindi) of Northern Punjab in zone 3 and seven samples from 5 locations (Kaloo Kalan, Hassan Abdal, Khaki Doraha (Attock), Bajna (Mansera) and Jano Mandi - Shinkiari) in NWFP of zone 4 were collected.

In zone 6 twenty-eight soil samples were collected from 13 locations of Kaghan valley (Bela, Poludran, Batal, Naran, Sahoch, Sohni, Pehli Batakundi, Batakundi, Upper Batakundi, Khor, Jaba, Dabook and Batakundi Farm). Twenty-four soil samples were collected from 13 locations of Kalam valley (Chirat, Ushuran, Palir, Bhan, Utror, Gabral, Gujar-Gabral, Gulabad, Gorkun, Bafar Ushu, Ushu, Mataltan and Kalam Khas) and 36 soil samples were collected from 6 locations of Chitral valley (Lowari Top, Garam Chashma, Bamboret, Bumi, Torkhu and Madaklasht).

Thirty six soil samples were collected from 20 locations of Gilgit (Sust, Morkhon, Galapan, Khyber, Passu, Gulmit, Shiskat, Karimabad, Aliabad, Murtazabad, Nasirabad, Nagar, Thol of Gilgit and Hunza valley; Naltar Bala, Naltar Paeen and Nomal of Naltar valley; Gupis proper of Gupis district; Yasin proper, Burkut and Hundur of Yasin district). Forty-seven soils samples were collected from 7 locations of Skardu (Astak, Chunda, Shigar, Harikun, Khaplu, Sarmu and Saltaro).

From zone 8 twenty-six soil samples were taken from 12 locations of 6 areas of Balochistan (Khud Kucha and Mangochar of Mustung, Kalat proper, Kanozai of Pishin, Kan-Metherzai and Zarghoon Kanozai of Qila Saifullah, Zarahd, Chanan, Karvi Kuch and Ziarat proper of Ziarat, Quetta proper and Urak of Quetta.

Pathogen detection through bioassay: Tomato bait plants were raised by growing seeds of cv. Montfavet H 36-5 (Swiss variety) for 3 weeks in sand with irrigation of 3 fold dilution of stock nutrient solution (NS) (Merz, 1989). Pots were kept under fluorescent light in the growth room with 15 hr light (12,000 lux, cool white fluorescent tubes) at 19-20°C and 9-hours' dark period at 17-18°C. After three weeks, roots were washed, trimmed and then transferred to plastic containers (23x18x5 cm). Twelve seedlings/ container were held in holes of the tray covers by inserting seedlings in slits of sponge (Fig. 1). Seedlings were supplied with 500 mL of nutrient solution and kept for 1 week in the growth room. Inoculum for test was prepared by homogenizing hundred grams of soil in 500 mL nutrient solution at 4000 rev/ min^{-1} for 5 minutes.

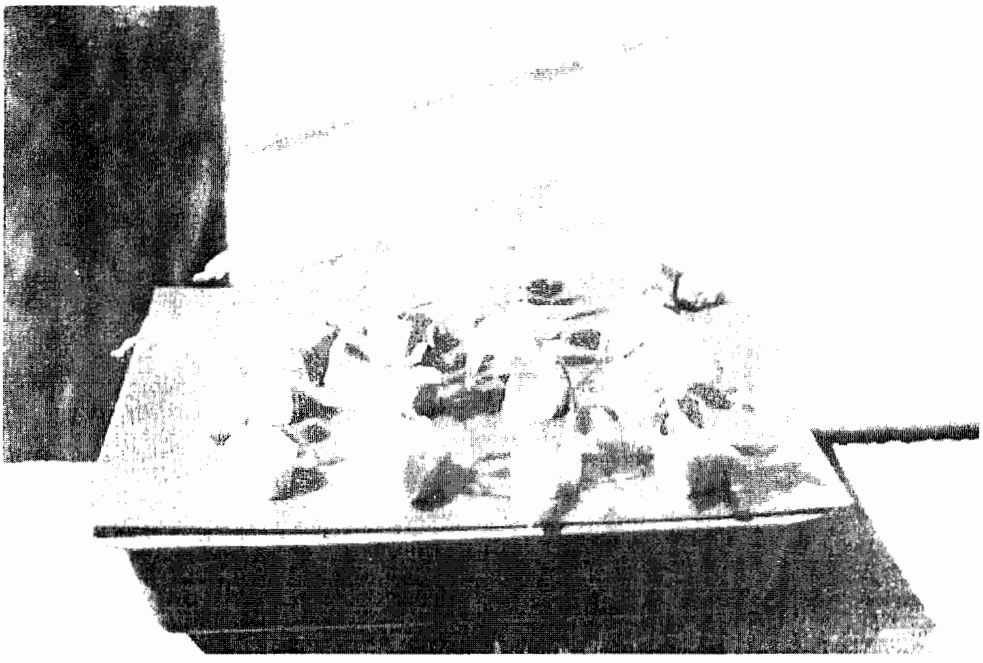

Fig. 1. Tomato bait plants used in bioassay test for detection of *Spongospora subterranea*.

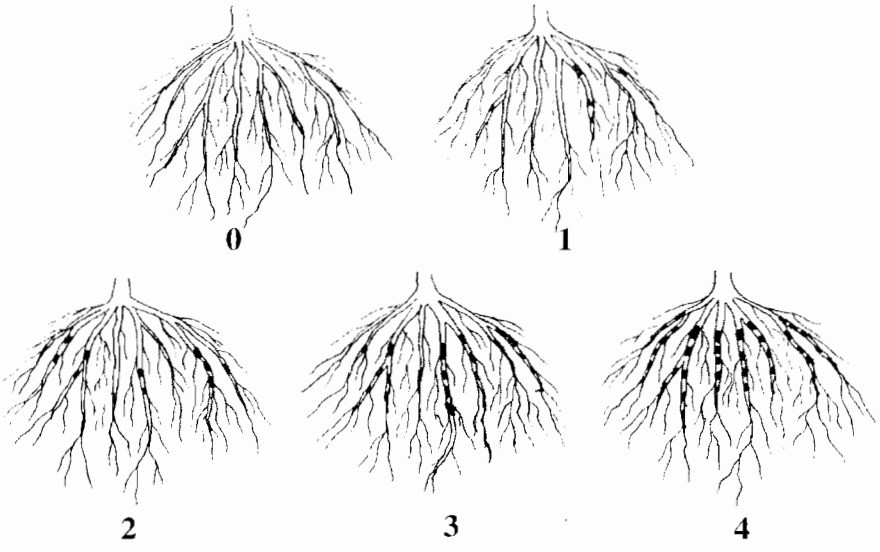

Fig. 2. Standard area diagram for assessment of root infection with zoosporangia by *Spongospora subterranea* on 0–4 scale.

For bioassay studies roots of the 4-week-old tomato seedlings from the containers were used as bait. These seedlings were washed and incubated with soil inoculum (100 g/L distilled water) with 15 hours of light at 19-20°C and 9-hour dark period at 17-18°C. After 10 days of baiting period, roots of the bait plants were again washed and transferred to fresh trays containing 1-liter fresh nutrient solution (NS) for 7 days of cultivation period with same conditions as in baiting period. Root system was harvested, washed and stained. Before staining roots were cleaned in absolute ethanol/ chloral hydrate/ water (1:1:1, w/w/w) for 10 minutes at 60°C and then stained for 5 minutes at 60°C in a staining solution containing 3 % formaldehyde, 6 % lactic acid, 3.5 % phenol, 87.2 % ethanol/water (1:1, v/v), and 0.3 % water blue (w/w). The solution was heated once at 80°C before use. The root were then fixed in lactic acid for 5 minutes and stored in sterilized distilled water at 4 °C before evaluation of root infection (Merz, 1989). For evaluation, the roots of 6 plants per tray (one treatment) were taken. They were suspended in sterilized distilled water in a 16 cm diameter Petri plate and observed under a stereomicroscope 20 X magnification for the presence of blue stained zoosporangia in root hairs and epidermal cells. Rating of root infection was done on 0-4 scale (Merz, 1989), where 0= no sporangia, 1= only a few sporangia, 2= several roots with sporangia, 3= sporangia regularly present or moderate infection, 4= sporangia regularly present or heavy infection (Fig. 2). The bioassay was repeated three times for each sample.

Results

Soils of 24 potato-growing areas of 6 potato production agro-ecological zones including Central Punjab (zone 2), Northern Punjab (zone 3), NWFP (zone 4), Kaghan, Kalam and Chitral valley (zone 6), Gilgit and Skardu (zone 7) and Balochistan (zone 8) were analysed through solution culture bioassay. Out of 24, 21 areas were found infested with *S. subterranea* while the pathogen was not found in 3 areas *viz.* Shinkiari in NWFP (zone 4), Gupis and Yasin in Northern Areas (zone 7). Out of 101 locations, 79 locations showed the presence of *S. subterranea* in their soils. Location wise, the highest infested locations of 100 % were observed in Chitral valley (zone 6) and in Northern Punjab (zone 3) followed by 92.3 % in Kaghan valley (zone 6), 91.66 % in Balochistan (zone 8), 85.71 % in Skardu (zone 8), 84.6 % in Kalam valley (zone 6), 80 % in NWFP (zone 4), and 69.5 % in Central Punjab (zone 2). The lowest infested locations (55 %) were found in Gilgit Area (Fig. 3). Out of 236 soil samples, 157 samples showed infestation with *S. subterranea*. Sample wise 100 % infested soil samples were found in Northern Punjab (zone 3) followeed by 83.5, 71.4, 66.6, 61.5 and 48.1 in zone 6, 4, 2, 8 and 7 respectively (Table 1). The detail of probed soil samples of each location in their respective areas are as follows.

Eighteen soil samples of 23 locations of Central Punjab showed presence of *S. subterranea*. One soil sample, out of 3 samples of 2 locations (Salarwala & NIBGE Potato Farm) of Faisalabad area and one sample out of 5 soil samples of 4 locations (Tahirabad, Raio Bagh, Safara Pindh & Rasool Nagar) of Jhang area showed infestation with *S. subterranea*. Out of 9 samples of 9 locations 6 samples of 6 locations (Chunu da Thatta, 51-2L - Okara, 40-D- Okara, Shoba Ram, Mazhar abad & Hujra Shah Muqeem) of Okara area were found infested with the pathogen. All locations of other areas including 5 samples from 5 locations (Khoo Dolia Da 46-GD, Adda Khoria Shah 52-GD, Ratti Thibbi 6-R, Punjab Seed Corporation & Jahan Khan Joianh Da 29 SP-Chak) of Sahiwal area, 2 samples from 2 locations (Kalar, Kala Shah Kako & Khana Marrian da)

of Lahore area and 3 samples from 1 location (Daska) of Sialkot area showed infestation with *S. subterranea*. The highest bioassay score (2.58) was observed in soils of 51-2L - Okara followed by Jahan Khan Joianh Da 29 SP-Chak (1.9), Punjab Seed Corporation (1.83), 40 D-Okara (1.83), Shoba Ram (1.83) and Khana Marrian da (Mureed) (1.66).

Two samples from 2 locations (Lossar and Bathar Morr) of Northern Punjab (zone 3) were found infested with *S. subterranea* and their infestation level was 2 & 4 on 0-4 scale. Out of 7 soil samples of 5 locations namely Kaloo Kalan, Hassan Abdal, Khaki Doraha (Attock), Bajna (Mansrha) and Jano Mandi (Shiankiari) of NWFP (zone 4) showed soil infestation. The highest root infection was found in soils of Kaloo Kalan (Attock) (2.16) followed by Khaki Doraha (1.83) and Hassan Abdal (1.58). The lowest root infection (1.38) was found in Bajna.

Total 28 soil samples of 13 locations of Kaghan valley (zone 6) were tested by bioassay. Pathogen was found in soils of twenty-one samples of twelve locations (Bela, Poludran, Batal, Naran, Sahoch, Pehli Batakundi, Batakundi, Upper Batakundi, Khor, Jaba, Dabook, Batakundi Farm). The highest bioassay score was observed in soil sample of Jaba (2.41) followed by Bela, Poludran, Dabook, Khor, Naran and BataKundi Farm (2.18, 1.66, 1.58, 1.39, 1.22 and 1 respectively). Only soil of Sohni was found free of pathogen.

Out of 27 soil samples collected from 13 locations of Kalam valley (zone 6), 21 soil samples of 11 locations including Chirat, Ushuran, Palir, Bhan, Utror, Gabral, Gorkun, Bafar Ushu, Ushu, Mataltan and Kalam Khas was found infested with *S. subterranea*. The maximum bioassay score 1.75 was found in soil samples of Palir followed by 1.45, 1.08 and 1.06 of Usharan, Utror and Chirat respectively. Pathogen was not found in soil samples of two locations namely Gujar Gabral and Gulabad.

Out of 36 soil samples, 34 samples of 6 locations of Chitral valley (Lawary Top, Garam Chashma, Bamboret, Buni, Torkhu and Madak Lasht) showed the presence of *S. subterranea*. The range of bioassay score was 1.19 to 0.52. The highest root infection was found in soils of Madaklasht (1.19) followed by Buni (1.13), Garam Chashma (1.04), Torkhu (0.93), Lowari Top (0.79) and Bamboret (0.52).

Thirty six soil samples of 20 locations of Gilgit area, 16 samples of 11 locations namely Sust, Morkhon, Galapan, Gulmit, Shishkat, Aliabad, Nasirabad, Nagar, Thol, Naltar Bala and Naltar Paeen showed infestation with *S. subterranea*. The highest bioassay score 1.56 was observed in soils of Nagar followed by Thol (0.75), Galapan (0.58), Aliabad (0.55) and Nasirabad (0.53). Soils of 9 locations Nomal, Murtazabad, Karimabad, Passu, Khyber, Gupis proper, Yasin proper, Burkut and Hundur were found free of *S. subterranea*..

Out of 47 soil samples of 7 locations of Skardu Area (zone 7), 24 samples of 6 locations (Astak, Chunda, Shigar, Harikun, Sarmu and Saltaro) were found infested with *S. subterranea*. The highest bioassay score (1.78) was observed in soil samples of Astak valley followed by the samples of Chunda (1.5), Saltaro (0.55), Harikun (0.54) and Shigar (0.51).

In Balochistan area, out of 26 soil samples of 12 locations *S. subterranea* was present in 16 soil samples of 11 locations (Khud Kucha, Mangochar, Kalat, Khanozai, Kan Metherzai, Zarghoon, Zarahd, Chanan, Karvi Kuch, Ziarat and Quetta). Only one location Urhak was found free of pathogen. The highest bioassay score (1.8) was found in Ziarat followed by Kan Metherzai, Karvi Kuch and Zarahd (1.7, 1.62 and 1.41 respectively).

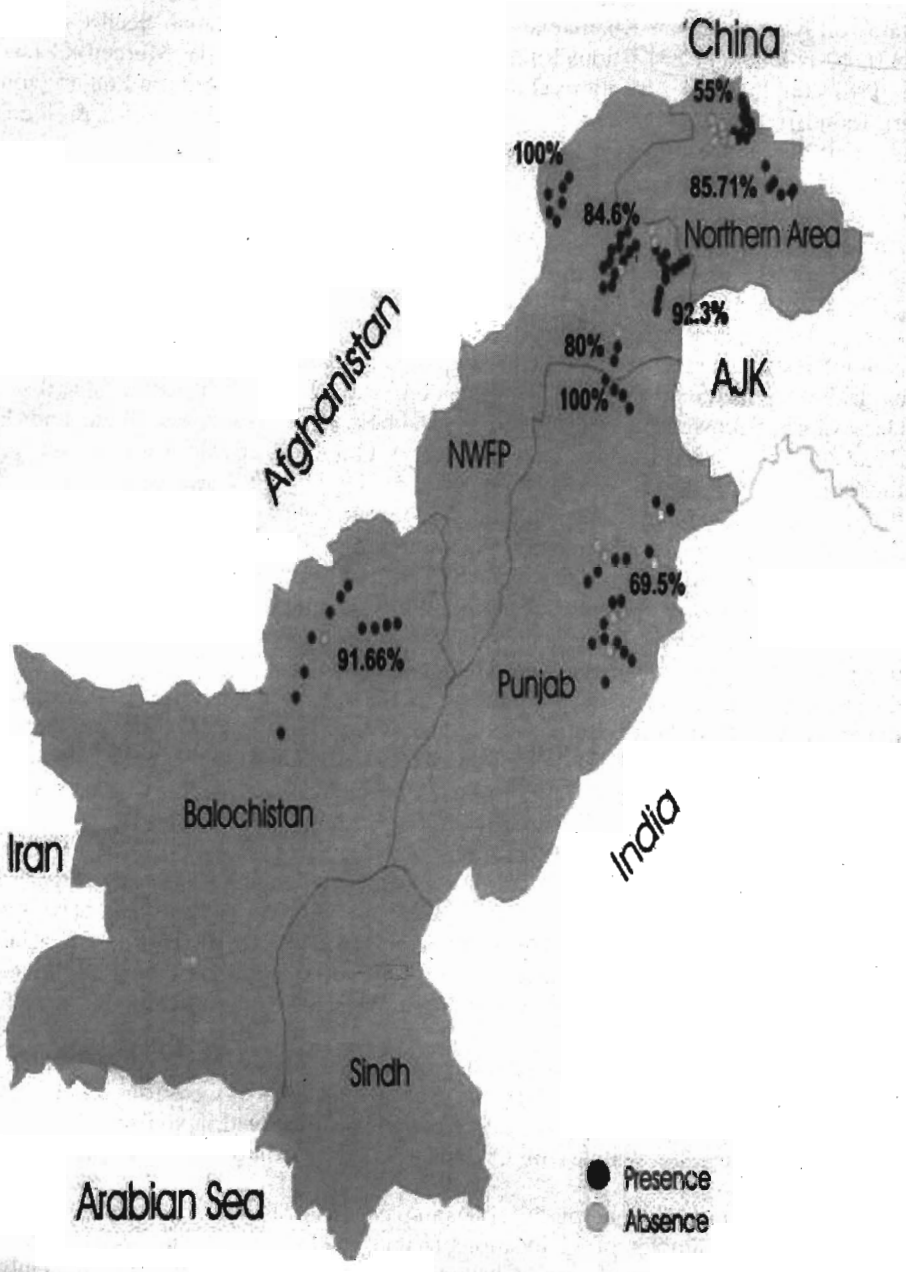

Fig. 3. Prevalence of *Spongospora subterranea* in different potato growing areas of Pakistan.

Table 1. Mean prevalence of *Spongospora subterranea* in soils of potato growing areas of different potato production agro-ecological zones of Pakistan (1996-2000).

Agro-ecological zone	Number of areas surveyed	Prevalence* (%) of *S. subterranea* (area wise)	Number of locations surveyed	Prevalence** (%) of *S. subterranea* (location wise)	Number of samples collected	Prevalence*** (%) of *S. subterranea* (sample wise)
2	6	100	23	65.2	27	66.6
3	1	100	2	100	2	100
4	3	66.6	5	80	7	71.4
6	3	100	32	90.6	91	83.5
7	5	60	27	62.9	83	48.7
8	6	100	12	91.6	26	61.5
Total	**24**		**101**		**236**	

*Mean percentage of areas having *Spongospora subterranea*
**Mean percentage of locations having *Spongospora subterranea*
***Mean percentage of soil samples having *Spongospora subterranea*

Discussion

In Pakistan, powdery scab has emerged as a problem during the last ten to fifteen years. It originated through imported seeds which were infected (Ahmad *et al.*, 1996). Wide distribution of powdery scab was observed during a survey (Ahmad *et al.*, 1991). Due to seed and soil borne nature of the pathogen, it is possible that the disease was introduced at inconspicuous levels of incidence and severity and with the passage of time its inoculum potential built up gradually in the soil till it became conspicuous. That shows the stepping of potato production to high potential risk especially seed production. Therefore, more information on its spread was needed. In current study surveys were planned to probe the soils of potato producing areas. During 1996-2000 soil samples were collected to assess the prevalence of pathogen in soils of different potato production agro-ecological zones of Pakistan. From these samples *Spongospora subterranea* was detected through bioassay test by using tomato bait plants.

The wide prevalence of *S. subterranea* in hilly as well as in plains of potato producing areas has never been observed. This more than expected widespread occurrence of pathogen in soils is due to built up of inoculum after its introduction through infected seeds and then regular use of susceptible cultivars, poor crop rotation and lot of irrigation in irrigated zones because the disease problem may develop rapidly from such soils with initially low infestation. The wide prevalence is also due to local potato seed flow channels, as the unrestricted seed flow system of the country provides ideal conditions for a rapid build up of soil inoculum in a previously uncontaminated or relatively less contaminated area.

Out of 24 areas scattered in six potato production agro-ecological zones, pathogen was detected in 21 areas while the rest of the three areas namely Shinkiari in NWFP (zone 4), Gupis and Yasin in Northern Area (zone 7) *S. subterranea* was not found . Gupis and Yasin districts are among the major seed producing areas.

Detection of *S. subterranea* from soils of potato growing areas of central Punjab (zone 2) confirms the report of Turkensteen's survey in 1986. Turkensteen (1987) reported the disease from isolated pockets of Okara and Faisalabad districts on the basis of symptomology and microscopy. Presence of pathogen in the soils of Punjab area confirms the earlier findings that powdery scab is being introduced in this area through imported seeds and also due to infected seeds from Balakot mandi (Ahmad *et al.*, 1991). But due to non-availability of suitable conditions (zone having hot summer) disease could not establish to the epidemic level. Endemic level of *S. subterranea* also correlates with the observations of Munir *et al.* (1994) that there is a deficiency of many micronutrients particularly Zinc and Boron in the soils of Punjab area. Previous observations that application of zinc is effective in reducing the severity of powdery scab (Burgess *et al.*, 1992) also support the reason of endemic level. As Punjab (zone 2) is the main seed producing area in plains of Pakistan, about 20-80 % of the potato crop of Pakistan is produced in this zone and supplies the seeds to other part of the country. Therefore, the presence of pathogen in the soils is a serious threat for seed production in this area because resting spores of *S. subterranea* can survive in the soils for number of years and these can contaminate the tubers with no visible symptoms (de Bore *et al.*, 1982; Burnett, 1991). So the risk of pathogen transfer from this contaminated area to other potato growing areas does exist.

Presence of *S. subterranea* in the soils of potato growing areas of Northern Punjab (zone 3) and NWFP (zone 4) confirms the previous report of Turkensteen (1987) of powdery scab observation in Attock. The pathogen has established in this area, perhaps due to little rotation of crop or monocropping in consecutive seasons (autumn and spring) in the same fields for long period. Farmers are used to have extensive irrigations to compensate high salt content of soil and also to counterbalance night frost that lead to excessive wet conditions. Another reason of pathogen presence in these areas might be the continuous use of uncertified seeds (contaminated seeds) from local mandi.

Kaghan valley (zone 6) is observed as the second highest in soil infestation (next to Chitral valley). Potatoes are grown here between 1,900 and 3,000 m heights. Powdery scab was not observed in this valley in the past as noted by Turkensteen (1986) during his survey of potato diseases in this area. Presence of pathogen in the soils of four locations was previously observed in 1995 (Rattu *et al.*, 1999). Our result of soil probing also confirms the presence of *S. subterranea* in reported locations in addition to eight other locations. From these observations, it can be speculated that pathogen had been introduced in this valley through contaminated seeds, may be through new germplasm, which are continuously being tested at Potato Research Station, Batakundi and Sharan. After introduction, pathogen established in the soil of these areas due to monocropping. Secondly, conditions (cool and wet) are most suitable in these areas, which are provided by the monsoon and heavy irrigation in the lower part of the valley. Current soil probing shows that the disease has become a serious threat for seed production in the valley.

In Kalam valley (zone 6) of Swat Area, potatoes have been introduced 30 years back and have replaced the traditional maize and wheat crops. Today, potato has acquired the status of highly paid main crop being sown up to the elevation of 2700 m. *Spongospora subterranea* has first time observed in the soils of this valley because previously disease was not observed by Turkensteen (1986) during his survey of hilly areas in 1985 and pathogen was also not detected after probing of soils of potato fields by Rattu *et al.* (1996). But present investigation revealed that out of thirteen locations, soils of eleven locations are infested with *S. subterranea*. However, the low infested soils indicated that disease might be introduced recently through infected seeds. In this area farmers have a common practice to buy new seeds every year from Mingora bazaar of lower Swat, where seed comes from different parts of the country (Geiser, 1988). The low infestation of soils in the valley is understandable and the reason is that the pathogen has recently been introduced in the valley. Therefore, attention should be paid to check the further build up of inoculum in these soils.

In Chitral valley (zone 6) the main potato growing areas are around Drosh, Buni, Torkoh, Chitral, and Garam Chashma etc. These areas are at average height of 1500 m and have cool temperature with mild summer and cold winter. Previously no survey on potato diseases was performed in this area. The reason might be the access to these valleys due to rough and difficult tracks. Potatoes are grown for local consumption not for seed purpose but now they are grown on a commercial scale to some extent. Therefore, previously no one bothered about the potato diseases and their effect on potato production. Hundred percent of surveyed locations have shown pathogen presence in the soils. The prevalence of pathogen in all locations indicates that pathogen was introduced at a time in the valley through contaminated seeds and with the passage of time established there especially due to mono cropping (Zanoni, 1991) and due to local (desi) varieties cultivation.

Gilgit is another seed producing area in Northern part of Pakistan, which falls in zone 7. Since 1984 seed companies selected these Northern areas for production of certified seed because of relatively low disease problems, the reason might be due to low humidity, low precipitation and high altitude of the area (Turkensteen, 1986). Powdery scab was first time reported in 1996 from Astak valley of this area on the basis of microscopy, bioassay and serology (Ahmad *et al.*, 1996). During present probing of twenty locations, soils of eleven locations were found infested with *S. subterranea*. The low number of infested soils in the area indicates that disease has been introduced recently through infected seeds. The survival of the pathogen might be due to heavy irrigation because dry conditions compel irrigation wherever possible for the good crop and that provides favorable conditions. Gupis and Yasin are two other major seed producing areas in Northern Area where *S. subterranea* were found in the soils of potaqto fields.

In Baltistan potatoes are grown in surrounding villages of Skardu. In this area of Baltistan farmers are growing potatoes for their own consumption at very small scale. Due to sowing of their own unhealthy seeds of local varieties and uncertified seeds, purchased from local market or provided by seed producing companies, numbers of seed and soil borne diseases have been introduced. This was observed by Turkensteen in 1988 and CDRI's pathologists during their survey in 1995 (Ahmad *et al.*, 1995). Present investigation shows that all locations of Skardu area are infested with *S. subterranea* except one location at Khaplu. The reason being that in Khaplu potato crop is grown at two different altitudes and during current survey soil samples were collected only from lower altitude, where climatic conditions during the crop period were not as favorable as required for the establishment of the pathogen. Now the presence of pathogen in the soils of this area is a big threat for seed production as Skardu is among the seed producing areas where seed companies have recently introduced seed production.

In Balochistan (zone 8) all valleys are irrigated and irrigation is through tube wells or Karazes. Area is located at the altitude of about 1500 to 2500 m.a.s.l. Potatoes are an important cash crop covering up to 30 % of the land holding (Zanoni, 1991). The climate is from arid to semi-arid continental with large differences between the lowest temperature in December and January and the highest temperature in July. The disease was first reported by Turkensteen (1988) from Kalat in this area. He observed disease on potato tubers and confined to selected areas but present investigation revealed the widespread occurrence of *S. subterranea*, which shows that prevalence of disease has increased since its first report (Turkensteen, 1988). The highest infested soils were found in Ziarat area. Ziarat has cool and wet climatic conditions, which provide a suitable environment for the establishment of inoculum in the soil. Low infestation was found in soils of Quetta proper, Zarghoon and Kalat, and this low infectivity is understandable as climatic conditions are not conducive for establishment of the pathogen (during day period, temperature is rather high and moisture is normally a major constraint). But the presence of *S. subterranea* in these locations shows that the pathogen is surviving in the area. The reason might be the irrigation and seed source as most of the seeds used come from the upper vallies.

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