SEED POTATO PRODUCTION IN THE SUB-TROPICAL PLAINS OF INDIA[1]

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INTRODUCTION

The potato (*Solanum tuberosum* L.), introduced in India in the early decades of the 17th century, now covers an area of a little more than a million acres. The acreage in the sub-tropical plains of northern India accounts for about 90% of the potato acreage. The remaining 10% is divided between the mountainous regions in the north and the south, the northern mountain area being about four times greater than the southern area. The main potato growing areas in the country are shown in Fig. 1.

Adaptation of the potato to sub-tropical situations poses problems of variety, seed and its storage. Its development needs adequate technology, locally developed, to suit the specific needs of the crop's culture. As a consequence of intensive research, initiated here three decades ago, a large measure of success has been achieved in adopting this "problem crop" for the local needs. Varieties adapted to short-day environments have been developed and commissioned for commercial use. Their nutrition, cultural and irrigation needs have been broadly studied. While there have been some positive gains, the difficult problem of maintenance of healthy seed stock remained, till recently, unresolved.

Success in crop culture depends mainly on two factors: choice of the right variety and use of healthy seed. The problem of maintenance of health standards of seed in the sub-tropics assumes a special significance. Here the crop suffers from rapid degenerative effects. Large and contiguous areas become infected with mosaic (caused by viruses S, X, A and Y) and leaf roll. This results in sharp reductions in yield. Just three esasons of successive culture of a variety in the plains can reduce its yield potential by about 50%. The magnitude of this problem is graphically depicted in Fig. 2.

Temperate Hills as Source of Seed

Because of rapid degeneration of stocks in the plains of India, a system of seed trade between the hills and the plains gradually developed. This often necessitated quick movement of stocks over long distances within the limited period of sowing seasons. The high hills in north India (elevation 2,000 metres above sea level) gradually developed as prize areas for production of quality seed potatoes (2). Low temperature, high winds and continuous precipitation during the monsoon season are all factors unfavorable for rapid build-up of aphid populations. At these heights aphid vectors, responsible for transmission of virus diseases, appear only towards the maturity of the crop.

Through a graded system of multiplication from virus-tested foundation stock developed at the Central Potato Research Institute, the north Himalayan State of Himachal Pradesh has developed a thriving trade in seed potatoes which are now valued throughout the country (Fig. 3).

[1]Central Potato Research Institute, Simla, India. Accepted for publication February 15, 1967.

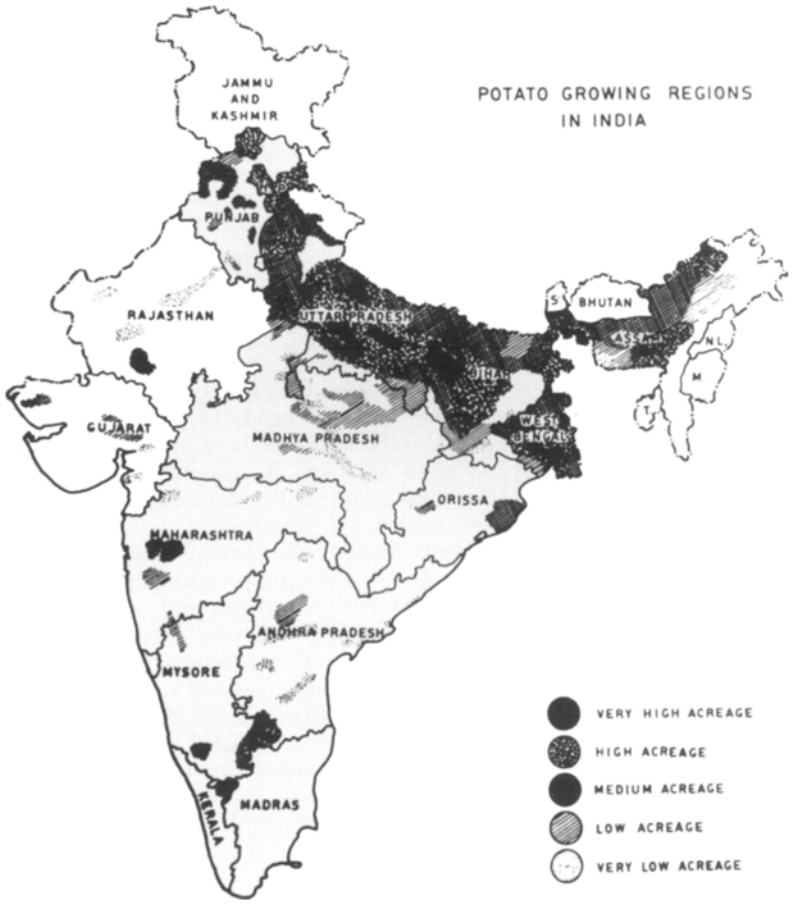

FIG. 1.—Potato growing regions in India.

To sustain productive potential, annual or at least periodic (depending on the situation), replacement of seed for use in the plains became unavoidable. Two, somewhat similar, systems have been developed in the country, one in the north Indian plains and the other in the southern Deccan Peninsular Plateau region (Fig. 4).

The significance of the two systems of seed trade on the productive potential of seed grown in the plains is considered later, but it is sufficient to indicate here the inescapable dependence of the ware-growing areas in the plains on the hill regions for seed. Continued dependence on hill areas for seed potato production poses some problems.

1) It became obligatory to develop varieties which would respond both to short-day sub-tropical and long-day temperate environments. Consideration of making available varieties for conflicting

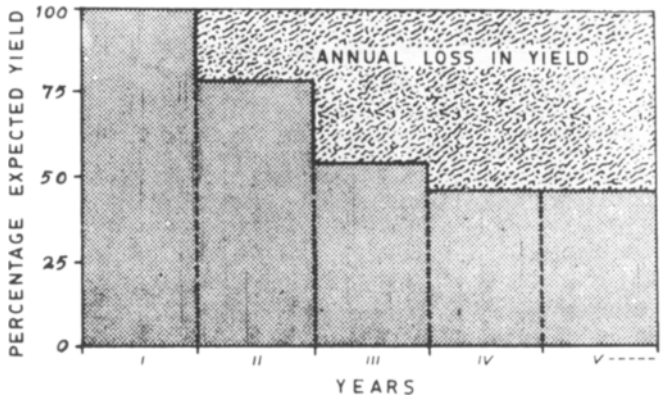

FIG. 2.—Annual reduction in yield through degenerative effects on seed in the sub-tropical plains of India.

FIG. 3.—Movement of seed potatoes from hills (Himachal Pradesh) to ware-growing (table stock) areas in the plains.

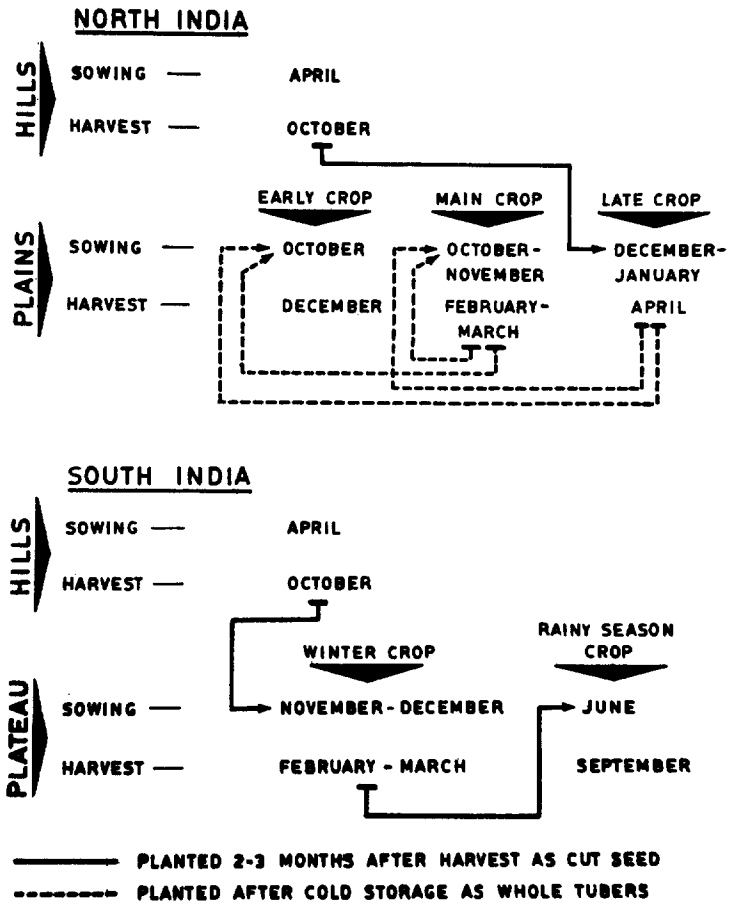

FIG. 4.—Existing seed potato trade systems in north and south India.

demands of photo-adaptability has imposed serious restrictions in breeding work and slowed down its progress.

2) For reasons of dormancy hill-produced seed cannot be used for all situations of culture in the sub-tropical plains. Nearly 70% of the total cropped area sown in the country still depends on plains-grown virus-riddled seed preserved in cold or country storages.
3) Regions suitable for seed potato production in the high hill areas cannot meet more than 25% of the existing seed requirements of the country.
4) Transport of seed tubers over long distances and over a limited period (Fig. 3) creates great strain on road and rail transport systems.

It became apparent that growth of the potato industry would be restricted unless alternate sources of seed were created. The only other alternative lay in annual import of seed potatoes from foreign sources;

a course hardly alluring both from technical and economic considerations. India had, therefore, to produce its own seed in the inhospitable virus-infested sub-tropical plains.

The New Technique of Seed Potato Production in Sub-Tropical Plains

A brief account of the method through which seed potato development in the sub-tropical plains has been possible follows. The first phase of work (1952-60) covers the field studies conducted to explore possibilities of developing a seed production system on scientific lines in the plains (3). The second phase (1960-66) of work consisted of pilot studies designed to fully assess, at field level, the merits of a new technique and extend the findings to a commercial system of seed production. Later it also became necessary to develop and standardize procedures for building up seed at various stages of its development.

Materials and Methods

Early Investigations

Four virus diseases, leaf-roll, viruses Y, X and S, were, as a result of an extended survey, determined to be responsible for degeneration of the seed potatoes in the country. About 80% of the problem of degeneration could be associated with viruses Y and leaf-roll. *Myzus persicae* was found to be the chief vector concerned with the transmission of these viruses in the field.

Virus Y is by far a more important cause of degeneration than leaf-roll. By itself or in combination with other viruses (crinkle with X and rugose mosaic with A), losses caused by this virus are rather heavy. The relative importance of viruses leaf-roll, Y and X, in bringing about reductions in yield of common commercial stocks, worked out under controlled conditions, is given in Table 1.

Table 1.—*Losses caused by common viruses on commercial varieties of potato.*

Variety	Percentage loss in yield due to		
	Virus X	Virus Y	Leaf-roll
Phulwa	24.0	80.8	50.1
Darjeeling Red Round	19.3	70.9	.....
Up-to-Date	15.5	82.9	26.0
President	14.1	79.8	.....
Great Scot	.....	81.7	.....
Kufri Kuber	10.9	88.5	.....

Contrary to the common belief a preliminary survey conducted in 1952 at Patna Station of the Institute showed that *Myzus persicae* was not prevalent in the plains of India throughout the crop season. Aphid population curves in relation to crop seasons in the plains of India were subsequently determined. As a result of this study, extending over several years, remarkable consistency in seasonal behavior of aphids in the plains has been observed.

Aphid infestation in relation to crop seasons: General pattern o aphid development on the potato crop under conditions in the plains i shown in Fig. 5.

When aphid population graphs from widely different areas extending from north-western plains (Jullundur) to north-eastern plains (Patna) were compared, the general pattern in the seasonal build up of aphids showed variation of only a limited magnitude. The main differences being

1) The time of appearance in north-western plains (at Jullundur) was about a fortnight later than the eastern plains (at Patna)
2) While the population per 100 leaves varied from place to place it took about three weeks from the date of first appearance to build up to a population of 20 aphids per 100 leaves — a level considered to be critical from the degeneration point of view (1).

Main conclusions that could be drawn from the study of aphid population curves are:

1) There is a remarkable consistency with respect to the time of appearance of *Myzus persicae*. Depending on situation, the aphids appear near the end of December and the beginning of January.
2) The populations build up slowly in the month of January and reach a peak level towards the end of January and beginning of February.
3) High aphid infestation lasts only about a month and by the end of February the populations show a sharp decline and usually by the end of March only a few aphids may be noticeable in the crop.

Significance of aphid infestation in relation to crop seasons: In the plains of India between mid-September and April three crops of potatoes are raised. The crop seasons being:

Early Crop (Autumn Crop)

Sown in mid-September to early October, the harvest of this crop is usually completed by the end of December. The produce is utilized entirely for ware purposes.

Main Crop (Winter Crop)

This crop is planted any time between mid-October and mid-November. Generally medium late varieties are planted during this crop season. The crop is harvested in March and is partly used for table purposes and partly as seed for the next season.

Late Crop (Spring Crop)

Planted in December-January, this crop is harvested in March and April. Normally it is planted after harvest of the early crop in the same land. Seed potatoes secured from the hill regions are used to raise this crop. The produce is mostly preserved in cold storage for use as seed for next early and main crops.

The relation of the three crop seasons in the plains with respect to aphid incidence is shown in Fig. 6.

The following conclusions could be drawn from a study of the graph in Fig. 6.

1) Early crop harvested in December is not usually exposed to aphids under field culture.

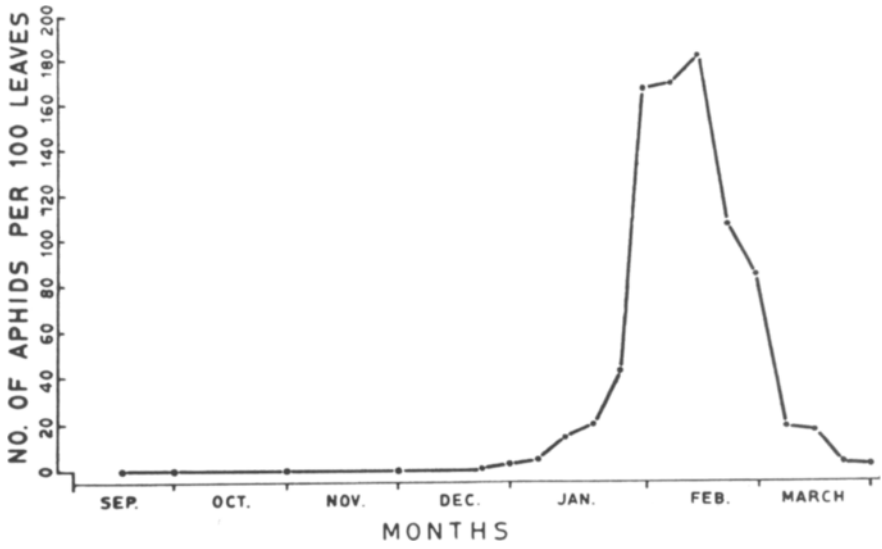

FIG. 5.—Average weekly population of aphids per 100 leaves in the plains.

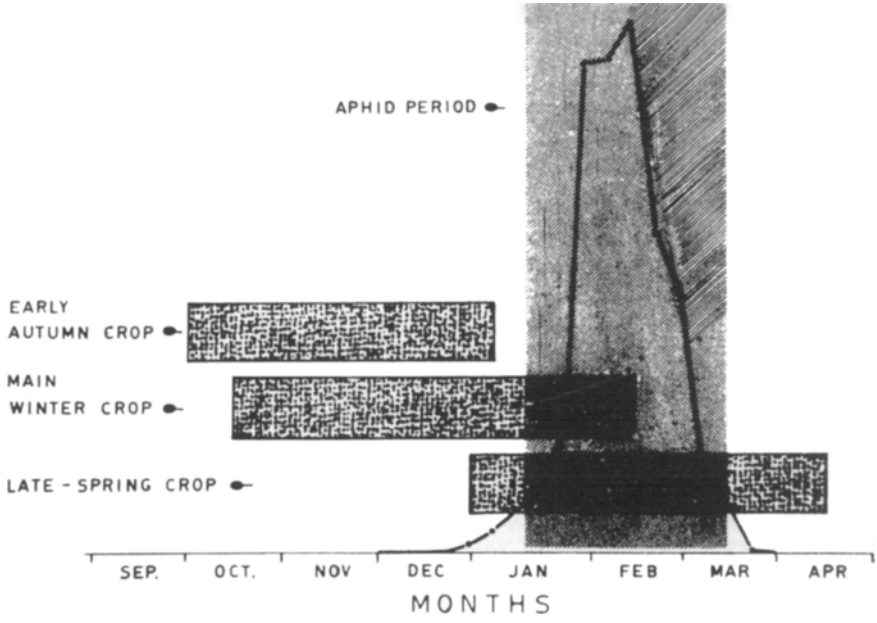

FIG. 6.—Crop seasons in relation to aphid incidence.

2) Main crop is exposed to aphids in the field. Transmission of viruses is possible towards the end period of the crop.
3) Late crop is fully exposed to aphid infestation and virus transmission is possible throughout the crop season.

Under the present system of culture in the country, the late spring crop, along with some part of the produce of the main crop, is utilized for seed the next season, both the early (autumn) and the main (winter) crops. Therefore, it is to be expected that the crops so grown would be infected with viruses. The expected gains through the use of comparatively healthy seed potatoes, derived from hill areas are, therefore, only marginal.

The 'Seed Plot Technique': The situation indicated above leads to the conclusion that if the existing system of seed circulation in the country is not corrected, there is limited possibility of improving yields per acre and extending potato culture in the country. Means of bringing about needed change, through adoption of the seed plot technique have been developed (3). The main features of the scheme are:

1) For seed purposes, plant the crop (using healthy seed foundations) in the autumn, as early as possible, preferably by the first week of October.
2) Plant at a close spacing and on not too rich a soil. This practice ensures a large percentage of seed-sized tubers.
3) During the growing season, examine the seed plots at least twice and remove any 'rogues' or otherwise 'unhealthy' looking plants.
4) Towards mid-December, when the crop has tuberized well, restrict irrigation and later withhold it completely so that haulms wilt and fall over before the aphids build up in mid-January. If the crop is still green, remove or kill the haulms.
5) Harvest the stocks, store in a cool situation and later transfer the stocks to cold storage to be used as seed in subsequent autumn season.

Recent Investigations

In the course of commercial exploitation of 'seed plot technique' some questions and doubt about effectiveness of the technique at field level developed. These needed verification and testing. Results of these, rather varied aspects of the study, are presented below:

Results

Annual incidence of virus diseases in crops raised through 'seed plot technique': To compare the virus incidence of stocks raised in the hills with those raised in the sub-tropical plains under the 'seed plot technique,' virus-free seed stocks of a few varieties secured from the Institute's Seed Development Centre at Kufri were planted and crops raised in the plains at Jullundur during the aphid-free period between October and December. Some of the same stock was also planted during the summer season in the high hills at the Institute's Seed Production Centre at Kufri at an elevation of 9,000 feet. Incidence of virus Y and leaf-roll was recorded through close visual examination of the growing plants and viruses X

TABLE 2.—*Incidence of virus diseases on crops raised at Jullundur (sub-tropics) and Kufri (high hills) during 1964.*

Variety	Sub-tropics (Jullundur)			High hills (Kufri)		
		No. infected with			No. infected with	
	No of plants tested	Mild or imperceptible mosaic viruses X & S	Severe mosaic virus Y and leaf roll	No of plants tested	Mild or imperceptible mosaic viruses X & S	Severe mosaic virus Y and leaf roll
Up-to-Date	172	2	1	75	2	0
Great Scot	107	2	1	213	2	1
Craigs Defiance	18	1	0	128	2	0
Others	253	1	0	235	0	0
Total percentage infection	100.0	1.1	0.4	100.0	0.9	0.2

and S through diagnostic procedures of tests with bivalent antiserum of these viruses. The results are given in Table 2.

Similar tests made in 1965 with nine varieties produced results similar to those reported above (Table 3).

TABLE 3.—*Incidence of viral diseases in different varieties: Material planted at Jullundur during 1965.*

Varieties/ Hybrids	No. of plants tested	No. of diseased plants	
		Viruses Y and leaf-roll	Viruses X and S
Kufri Kumar	124	0	1
Craigs Defiance	122	0	0
Kufri Kisan	60	0	0
Magnum Bonum	45	0	0
Up-to-Date	38	0	2
Kufri Sindhuri	35	0	0
Hybrid 1202	21	0	0
Great Scot	14	0	0
Arran Victory	5	0	0
Percentage infection		0.0	0.6

Combined results of two seasons showed that when potatoes were grown in the aphid-free period, the incidence of aphid transmissible virus Y and leaf-roll in the sub-tropical plains is not more than 0.2%. The rate of spread of virus during aphid-free period in the plains is indeed low and compares very favorably with high hill regions where the rate of spread of viruses Y and leaf-roll recorded was on an average 0.2%.

Infection through contact transmissible viruses S and X, at Jullundur and at Kufri was also similar. At both these locations not more than 1.0% infection was recorded during the crop growing season.

From the technological point of view, it became clear that the health standards of varieties developed during the aphid-free period in the sub-tropical plains can hardly be expected to be inferior to those developed in the high hill temperate regions. These preliminary, rather limited, findings required testing under commercial conditions of seed raising.

Rate of degeneration in seed crops raised during low-aphid periods: Fifteen hybrids, representing advance breeding lines, were raised at Jullundur in large bulk plots during the low-aphid period for three to four successive generations. The incidence of virus infection caused by mild mosaic (viruses X and S), severe mosaic (virus Y, crinkle and rugose mosaic) and leaf-roll, recorded through visual examination of crops and check testing for mild mosaic at the end of three or four seasons of repeated culture, is shown in Table 4.

TABLE 4.—*Virus infection (percentage) in potato hybrids grown over 3-4 generations in the plains during low-aphid period.*

Period of culture	Hybrid number	Percentage of virus infection: Leaf roll	Severe mosaic	Mild mosaic	Total	Annual rate of infection
4 years	B.2190	2.0	3.3	0.0	5.3	1.3
	B.2191	1.6	6.6	0.0	8.2	2.1
	A.5196	0.6	4.0	0.0	4.6	1.15
	A.2235	2.3	0.6	0.0	2.9	0.72
	A.2708	2.1	2.1	1.0	5.2	0.3
	A.3773	2.3	3.6	0.0	5.9	1.5
	A.3803	6.0	1.3	0.0	7.3	1.8
3 years	B. 572	0.12	1.3	0.1	1.52	0.5
	A.3649	0.0	4.0	0.6	4.6	1.5
	B.7195	0.8	0.0	0.0	0.8	0.3
	B.7208	0.0	0.0	0.0	0.0	0.0
	B.7218	0.3	0.1	0.0	0.4	0.1
	C.1	1.3	2.7	1.2	5.2	2.3
	C.156	0.09	0.4	0.0	0.49	0.2
	C.4621	2.6	6.6	0.0	9.2	3.1
		Average				1.19

An annual average rate of about 1.2% virus infection (only about 1.0% as far as severe mosaic and leaf roll are concerned) in seed crops, when grown normally as bulks, is indeed low. The incidence of mild mosaic (mostly viruses X and S) was remarkably low. The crops get infected by aphid-transmitted viruses (virus Y and leaf-roll) mainly towards the end period of their growth, or sometimes through the secondary growth put up by the plants after haulms have been removed. For seed raising, if the practice of field inspection and roguing of infected plants, twice during crop growth season is followed, the health standard of varieties can be appreciably improved. Added precautions of not allowing any green parts of the plants appearing above ground after mid-January is bound to improve the situation further.

It will be seen that the degenerative effect on the varieties even when grown without vigorous field inspection during low aphid period is indeed very low and reliance could be placed on the productive potential of this seed, if multiplied from healthy foundations in the plains during this period.

Yield performance of seed raised through 'Seed Plot Technique': For October-November planting in the plains it is a common practice to utilize the hill-seed grown once in the plains in spring season between January and April. When this seed is compared with the seed raised through 'Seed Plot Technique', the superiority of the latter is revealed not only in the significantly higher yields obtained but also in earliness and better seed size. Table 5 presents results of field trials carried out with the two grades of seed between 1960 and 1963 with the varieties Up-to-Date and Kufri Red. On an average, seed developed through 'Seed Plot Technique' yielded 37% more than once grown hill-seed.

TABLE 5.—*Average yield (q/ha) with two sources of seed in trials at Jullundur (Average of three crop seasons)*

Variety	Maturity group	Average yield (q/ha) with source: Hill seed once grown in the plains Source: 'A'	Seed developed through 'Seed Plot Technique' Source: 'B'	Percentage increase of Source 'B' over Source 'A'
Up-to-Date	Mid-early	170.2	238.7	40.2
Kufri Red	Mid-late	170.9	229.6	34.3
			Average	37.25

These conclusions are further confirmed indirectly by the behavior, in yield tests, of seven hybrids under conditions of Jullundur. All these hybrids were developed under Jullundur conditions and yield trials carried out with the seed raised through 'seed plot technique'. In Table 6 yields

TABLE 6.—*Yield performance of hybrids over four years in plains at Jullundur.*

Hybrid	Yield in quintals per hectare* during 1961	1962	1963	1964	Average
A.2708	340.0	262.7	311.5	324.5	309.7
A.3649	297.5	267.0	311.5	421.6	299.4
A.3773	269.2	239.2	313.0	341.2	290.7
A.3803	250.0	258.2	279.5	301.2	272.2
A.5176	299.7	256.7	284.7	291.6	283.2
B.2190	332.7	264.2	298.0	316.4	302.8
C. 156	249.2	213.2	308.5	282.5	262.9
Mean yield	290.9	251.6	301.0	311.3	

*Crop affected by early frost. Multiply yields by .892 to obtain pounds per acre.

over a period of four years are shown. It appears from individual and mean yields that there have been very few reductions in productivity of seed during this period.

Plains grown seeds are free from soil-borne diseases: Seed stocks developed in sub-tropical plains offer some advantages over the stocks developed in temperate hill regions. Thus, the soil borne diseases, Brown rot (*Psudomonas solanacearum* E.F. Smith), Wart (*Synchytrium endobioticum* (Schilb.) Perc.) and even root-knot nematode (*Meloidogyne incognita* (Kofoid and White) chitwood) would, unlike the hill produce, seldom be carried with seed tubers since these diseases do not thrive in the plains. An indirect benefit from the use of plains-grown seed would be in the elimination of late blight affected tubers from the seed material, since blight rarely appears in the sub-tropical plains between October and January when seed stocks are raised in the plains.

Summary

The complex problem of degeneration of seed stocks caused by several virus diseases has hitherto limited the production of potatoes in sub-tropical India. The reduction in yield by over 50% through the use of degenerated seed stocks necessitated development of seed areas in temperate climate in the hills of northern India, 2,000 meters above sea level.

This system of 'hill-plain culture' posed problems connected mainly with photosensitivity and dormancy. Limited areas available in the temperate hills for development of the seed potato industry simultaneously restricted culture of potatoes in the sub-tropics where, to maintain productive levels of crops, hill-seed found increasing demands. The evolution of a new system of production of healthy seed in the sub-tropical plains is described which promises to overcome these problems of trade and technology.

Extensive areas of the country, it is expected, will now be available for seed potato production in sub-tropical India. Diversification of varietal pattern can now be brought about, for the country no longer will need varieties suited to hill-plain culture. Seed stocks developed in hot subtropical plains also hold promise for overcoming the incidence of soil-borne diseases like bacterial wilt.

Resumen

El complejo problema de degeneración de semilla causada por varias enfermedades de virus ha limitado hasta la fecha la producción de papas en India subtropical. Como ocurría una reducción de más de 50% en rendimiento cuando se usaba semilla degenerada, ha sido necesario establecer áreas de producción de semilla en el clima templado de las colinas del norte de India, 2000 metros sobre el nivel del mar.

Este sistema de cultivo de "colina-llanura" presentó problemas que se referían principalmente a la fotosensitividad y letargo de la semilla. Reducidas áreas disponibles para el desarrollo de la producción de la semilla en las colinas a suvvez restringían el cultivo de papa en el subtrópico donde se demandaban cantidades de semilla cada vez mayores. Se describe la evolución de un nuevo sistema de producción de semilla sana en los llanos subtropicales que promete de evitar estos problemas de comercio y tecno-

logía. Se espera que grandes áreas del país serén ahora disponibles para la producción de la semilla de papa en la India subtropical. Esto hará posible una diversificación de las variedades establecidas, ya que el país ya no necesitará més variedades adaptadas a la región de las colinas. Semilla producida en los calientes llanos subtropicales promete también de superar la ocurrencia de las enfermedades presentes en el suelo, tales como la marchitez bacterial.

Acknowledgment

The disease ratings both in the field and laboratory were taken by the Virus Pathologists, Dr. S. B. Lal and Dr. B. B. Nagaich. I am particularly grateful to Dr. Nagaich for the deep interest he has shown in preparing virus disease-free foundation seed and subsequent work connected with testing and assessment of virus infection in the stocks.

Mr. L. C. Sikka and Mr. A. K. Singh of Jullundur station willingly cooperated in obtaining yields of the seed stocks of several varieties.

Several growers in the Punjab and Uttar Pradesh have helped in extension of 'seed plot technique' in the commercial channels. Without the help of these several friends the technique may not have created such consciousness and impact among those interested in the promotion of the potato crop in the country.

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