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PROMOTION OF DIFFUSED LIGHT STORAGE OF SEED POTATOES IN THE HILLS OF NEPAL: A REVIEW

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ABSTRACT

Diffused light storage (DLS) of seed potato, a traditional practice of storing seed potatoes in small areas of some countries has become a popular seed potato storage method in a number of developing countries after 1980. Reported benefits of DLS are production of a large number of short and robust sprouts per tuber, less storage losses, early and uniform emergence and higher tuber yield than comparable seed potatoes stored in dark. Research on, and promotion of DLS technology started from as the late 1970s. In the 1980s, the International Potato Centre (CIP) took the leading role in research and extension of DLS technology, which was introduced to more than 21 developing countries. The Philippines, Sri Lanka, Peru, Colombia, Guatemala, Thailand and Vietnam have adopted DLS but in other countries, including Nepal, adoption of this technology was not very encouraging. In Nepal, experiments on DLS made by the National Potato Development Programme (NPDP) commenced in 1977. It was further studied and promoted by Lumle Agricultural Research Centre and other institutes. The technology was tested and demonstrated in many parts of the country representing the major agro-ecological zones. Available information revealed the feasibility of DLS in the mid hills (1000 - 2000m asl) and large variations among the genotypes for their storability and subsequent field performance. However, detailed studies were lacking to develop specific technologies by utilising genotype and environment interactions. Adoption of the technology was very low despite the considerable efforts made for its promotion. This paper reviews the research and developmental work on DLS in Nepal and discusses the future research needs.

Additional Key Words: Adoption, seed tuber physiology, sprout growth, storage loss

INTRODUCTION

Post-harvest handling and storage losses of seed as well as ware potatoes have been estimated to be 20-30% (by weight), and the supply of potatoes can be increased more easily by reducing post-harvest losses than by increasing yields (CIP, 1978). Unlike the more easily stored grain crops, the potato is a highly perishable and bulky item. Whilst potato storage in the temperate zones is relatively straight forward, successful storage of potatoes is one of the major problems in the seed potato industry in the tropics and sub-tropics of the developing world. Refrigerated storage is the most effective method of storing seed potatoes and losses can be kept to a minimum and physiological ageing of seed potatoes can be prevented or slowed down (Sparenberg, 1981; Mehta and Kaul, 1989). However, since potato production in many developing countries in the tropics and sub-tropics is characterised by large numbers of small growers who cultivate in remote rural areas, usually lacking good transport connections and a reliable electricity supply (Booth, 1985), refrigerated storage is beyond their reach. In the absence of refrigerated stores, seed potatoes are stored at ambient temperature in ordinary farm-houses (Potts, 1983; Rhoades, *et al.*, 1983; Hediger, 1985) or in clamps (Potts, 1983; Rhoades, 1985; and Dhital, *et al.*, 1994). Storing potatoes (both seed and ware) in the dark was the most common storage method until recently. This provides the flexibility of using potatoes either for seed or table purposes and is a very cheap method of storage.

Diffused light storage (DLS) is a good alternative to both ambient temperature storage in the dark and refrigerated storage for seed potatoes (Potts, *et al.*, 1983; Booth, 1985; Rhoades, 1986 and Richarte *et al.*, 1986). Several papers published during the 1980s advocated development and promotion of the DLS technology in the tropics and sub-tropics. Whilst adoption of this technology is encouraging in some countries, this is not the case in Nepal despite rigorous promotional activities since its inception in 1977. This paper reviews the history of DLS technology, its global spread and current adoption situation in Nepal and constraints to the adoption of the technology. It also discusses the effect of DLS on seed tuber quality and its effect on subsequent field performance of the potato crop.

DIFFUSED LIGHT STORAGE OF SEED POTATOES

Diffused light in this context simply means indirect sunlight or daylight. DLS is a method of keeping seed tubers under indirect sunlight in a thin layer or layers that allows excellent aeration and keeps storage temperature down. Light inhibits sprout growth and promotes greening of tubers. Thus, DLS technology has proven to be advantageous in reducing storage losses and results in better quality seed due to reduced weight losses, more sprouts per tuber which are vigorous and robust and decreased susceptibility to fungal diseases (Sparenberg, 1982 and Booth, 1985). This leads to better emergence, increased stems per hill, increased ground cover and increased yields compared with dark stored seed. Fluorescent light may also be applied instead of natural light or in combination with natural light but it is not practicable in most rural areas of developing countries.

History of the Diffused Light Storage of Seed Potatoes:

Storing seed potatoes in diffused light is not a new invention. For many years farmers have traditionally stored a small amount of seed potatoes in this way in some tropical and sub-tropical highlands of Peru, Kenya and Nepal (Rhoades, 1989). The inhibitory effect of light on sprout growth has also long been known (Krijthe, 1948 as quoted by Sparenberg, 1982; Headford; 1962 Dinkel, 1963). Use of light as a pre-planting treatment was quite an old practice in Europe, started in the early twentieth century (Van der Schild, 1981). Farmers used to pre-sprout seed potatoes in those days particularly for early harvest of the crop. Investigations of the use of diffused light in seed potato storage, however, started only recently. The International Potato Centre (CIP) pioneered the development of low cost storage structures, which are applicable to subsistence farmers in developing countries. Two storage specialists - Roy Shaw and Robert Booth - designed and tested rustic storage structures using the diffused light concept at the CIP highland research facilities in Huancayo (3200m asl), Peru in the late 1970s (CIP, 1981). Table 1 shows a brief history of the initiation of DLS technology.

Spread of the Technology - A Global Perspective:

DLS structures have been disseminated and adopted in many parts of the tropical and sub-tropical highlands in Sri Lanka (Rhoades *et al.*, 1984 and Rhoades, 1986), the Philippines (Potts, 1983 and Rhoades *et al.*, 1983), Peru and Colombia (Booth, 1985; and Rhoades *et al.*, 1983),

Table 1 A summary of the history of diffused light storage experimentation.

Institution	Place	Year	Persons involved	Source of information
CIP, Lima, Peru	Huancayo	1977-78	Roy Shaw & Robert Booth	CIP, 1981
NPDP, Nepal	Khumaltar	1977-78	Laxmi P. Khairgoli	Khairgoli, 1978
Philippine Pot Programme	Benguet and Mount Provinces	1978	Prof. Elmo O. Sano and Felix Rutab	Potts, 1983 and Rhoa *et al.*, 1983
Dept. of Agric., Sri Lanka	Badulla and Nuw Eliya districts	1979-80	W.V.D. Albert and Rob Rhoades	Rhoades *et al.*, 1984 & Rhoades, 1986,

Guatemala (Rhoades, 1988) and Thailand (CIP, 1985 and Thongjiem, 1987). The diffused light storage principle was introduced into 21 developing countries within five years of its inception (Rhoades *et al.*, 1983). This was done through CIP's regional research and training programmes in collaboration with the respective country's potato programme. Literature revealed that the adoption of the technology is remarkable in the Philippines, Sri Lanka and Peru, and satisfactory in many other countries such as Colombia, Indonesia, Thailand, Vietnam, Burma and Kenya. The situation in China, India, Pakistan, Bangladesh and Bhutan regarding the adoption of the DLS technology is not well known because of few reports in the literature but it does not seem to be encouraging in these countries. Published documents are also almost lacking from Nepal.

DLS of Seed Potatoes in Nepal and its Promotion:

DLS experiments were started by Mr L.P. Khairgoli in 1977 where storability of four varieties, viz. Kufri Jyoti, NPI/T-0012, Rasuwa Red and Local Red Round were tested in a small rustic store at the National Potato Development Programme (NPDP), Khumaltar (1300m asl) (Khairgoli, 1978). Later on, assessment of promising varieties under DLS became almost a regular activity at NPRP (formerly NPDP) (Bhomi, 1987; NPDP, 1987 and 1990; NPRP, 1991 and 1992; Shakya 1986, 1987 and 1989, and Upraity, 1986). NPDP demonstrated various types of rustic store structures in many parts of the country from the beginning of 1980. These demonstrations were made in co-ordination with the District Agricultural Development Office (DADO) of the respective districts and other institutions interested in potato research and development. Lumle Agricultural Research Centre (LARC) constructed a rustic store of 8 tonnes capacity in 1982. Seed potatoes are kept on shelves in thin layers in diffused light conditions. This has been the only way used for storing seed potatoes at LARC since 1982.

Some rustic stores were designed to store seed potatoes in gunny-sacks or in baskets of variable sizes, whereas some others were based on the diffused light concept with seed potatoes kept on fixed shelves in thin layers. Construction of separate storage structures was found costly and they were not fully utilised by individual subsistence farmers who rarely store large amounts of seed potatoes. Consequently, various other ways of keeping seed potatoes in diffused light were demonstrated. Trays (racks) might not be costly which can be prepared from a cheap wooden frame and planks or bamboo pieces and are easily moved to desired places in a farm-house. So seed potato storage in trays were also demonstrated by NPDP in Pumdi Bhumdi (1100m asl), Kaski district, Palung (1800m asl), Makwanpur district and Naldung (1500m asl) during early to mid 1980s. Similarly, a number of shelves can be erected in a small area of farmhouse or cattle shed with a minimal cost, or seed potatoes can just be spread in up-stair floors of farmhouses or cattle sheds. LARC also preferred to promote seed potato storage in racks and shelves instead of large rustic store structures. These demonstrations were made at Tapu (1150m) in 1990 (Dhital, *et al.*, 1991), at Keware (1250m) in 1991 (Dhital and Subedi 1994), at Patlikhet in 1993 (Dhital, 1994) and at Sigana in 1995 in the Western Hills.

Rustic stores of about 5-15 tonnes capacity were also demonstrated in the Koshi Hill Districts by the Koshi Hill Development Programme in 1990. Four stores each at Shyamshills (Bhojpur), Hururu (Sankhuwasaba), Basantapur (Terhathum) and Mudhebas (Dhankuta) were constructed for community use (Cromwell *et al.*, 1992). Later, 12 other stores were demonstrated during 1993/94 (*pers. com.* Mr CB Shresthha).

Adoption Situation of DLS Technology in Nepal:

Hediger, (1985) pointed out the need to conduct studies on the extent of adoption and diffusion of DLS technology in the hills of Nepal. However, studies have not taken place until recently and information is lacking about the adoption situation. She reported that farmers in the Kathmandu valley separate seed and ware potatoes before storage and a small amount of seed potatoes are kept in small bamboo baskets. These baskets are suspended on the farm-house ceiling or outside, under the roof of the house. Cromwell *et al.*, (1992) made a preliminary study on four Koshi Hill Districts in Eastern Nepal that was undertaken as part of a mid-term evaluation of the Koshi Hill Development Programme. Their findings revealed a lack of appropriate management regulations to operate the store as a community property and the structures demonstrated were rather large and not appropriate for individual farmers. General observations in the Western Hills reveal unsatisfactory adoption and no diffusion of the technology. Farmers have continued storing potatoes on the racks or shelves, which were demonstrated, but they have neither expanded the storage capacity (number of racks or shelves) nor diffused the technology to neighbouring farmers.

It may not be necessary for farmers to adopt the **storage structure** as demonstrated. Instead, the storage problem could have been solved to a greater extent if at least the concept of diffused light could have been adapted to fit the farmers' own situations. On the other hand, dark stored seed potatoes could have been de-sprouted and re-sprouted in diffused light for a short period before planting so that short, green and sturdy sprouts could be produced instead of long, etiolated and weak sprouts. Likewise, though the construction of separate storage structures is costly for individual subsistence farmers, such stores could have been developed by middlemen and operated individually on a commercial scale. This also did not happen.

It has also been found that the technology has not been adopted in some other parts of the tropics and sub-tropics. In most cases, farmers did not copy a demonstrated design precisely but modified the stores to meet their specific requirements (Rhoades, *et al.*, 1983 and Rhoades, 1989). Rhoades (1989) further states that farmers do not think in terms of adoption or non-adoption as scientists do, but select elements from technological complexes to suit their constantly changing circumstances. Nevertheless, a modified version of the DLS technology has also not been disseminated well in the hills of Nepal.

Reasons for Low Adoption in Nepal

Studies have not been conducted to the adoption situation of the DLS technology; as a result problem and constraints in the adoption of the technology are not well understood, and information is not available on these aspects. Based on the observations and experiences it is possible that the following issues might have played a major role in the non-adoption of the DLS technology in Nepal:

(i) In the high hills potato is not a new crop as it is in the Philippines and Sri Lanka; it has been grown for more than 150 years in the hills of Nepal. As a result, farmers have developed their own systems for potato production and storage and these systems are established as traditions. For an example, bringing seed potatoes from the high hills is a common practice in mid and low hills and DLS might not be necessary in the high hills.

(ii) The potato is not a major crop in many mid and low hill areas and there could be lack of concern amongst farmers about seed tuber quality: any type of potato tubers are being used as planting material. So they are not interested in storing their own seed potatoes.

(iii) Lack of location or environment specific to diffused light storage technologies might also have hindered the adoption rate. For example, local varieties are considered very important in the high hills (>2000m asl) and these varieties could have been stored well even in a dark store and there might not be any benefit in using DLS technique for local varieties. Similarly, genotypes with short dormancy and/or poor storability would not perform well even by storing in diffused light. Moreover, de-sprouting prior planting would be beneficial to minimise the effect of physiological ageing of DLS stored seed potatoes. Investigations have not been done in these aspects.

(iv) There is no well-developed seed system in the country and farmers may be unsure about the sale of their seed potatoes. DLS stored seed might go to waste if it cannot be sold as seed. On the other hand, there is a flexibility with the use of dark stored potatoes: these can be sold either for seed or ware or can be used at home according to the farmer's needs and desires.

(v) Farmers might be ignorant of the technique and its benefits in many rural areas and there could be a lack of an effective technology dissemination programme.

PERFORMANCE OF SEED POTATOES UNDER DIFFUSED LIGHT STORAGE

Effects on Storage Losses

For the first time, seed potatoes harvested on 1 June 1977 were stored under DLS from 15 June to 15 December at NPDP, Khumaltar. Total weight loss (both due to shrinkage and rotting) ranged from 42% (Kufri Jyoti) to 53% (NPI/T-0012). The higher loss of NPI/T-0012 was due to pre-mature harvest of the crop (Khairgoli, 1978). Overall storage loss was also very high which might have been due to the improper handling and bruising of tubers due to lack of experience. Another experiment was conducted in Palung valley (1800m asl) where seed potatoes of variety Kufri Jyoti were stored in wooden racks. These racks were kept on a wooden platform outside the north-facing window of a local farmhouse. A total of 27.2% loss was recorded for the storage period of 11 June 1986 to 31 January 1987 (NPDP, 1987). The same seed potatoes were tested further for their subsequent field performance comparing cold storage (CS) and dark stored (farmer practice) seed potatoes. DLS (rack) stored seed potatoes produced higher yields than CS (17.4 cf. 14.6 t/ha) and the dark stored seed potatoes produced the lowest (13.3 t/ha) tuber yield (NPDP, 1987).

An on-farm seed potato storage trial in storing seed potatoes in baskets under diffused light was conducted at Dhampus (1600m asl), Kaski in 1985. Seed potatoes of Kufri Jyoti were stored from mid July to end of March and an average of 37% weight loss was recorded (Shakya, 1986). Very high storage losses could be due to a long storage period. The seed potatoes should have been stored only until the end of January or early February. This is because usually potatoes are planted in early February in this area.

Bhomi (1987) assessed the DLS performance of seven potato genotypes in Khumaltar (1300m asl) for a period of three and half months (May to September) in 1985. Per cent weight loss for the storage period ranged from 12.5 (K-2500) to 25.0 (K-2305) with mean losses of 19.4%. He also reported that the total storage losses (shrinkage and rotting) were higher in early part of the storage than at the later part under DLS condition. In fact, seed potatoes need to be stored from late May to early January for next planting in Khumaltar conditions. So assessing the storage performance only up to the half of the season does not mean much and it might be misleading to present the findings like higher losses during the early storage period than the later.

NPDP/SDC in co-ordination with Farming Systems Research and Development Division conducted on-farm seed potato storage trials at Pumdi Bhumdi (1100m asl), Kaski district and Naldung (1500m asl), Kavre district during 1985/86 and 86/87 (Shakya, 1987 and Upraiti, 1986). A total of five genotypes were evaluated for their storage performance under basket and standard trays at Pumdi Bhumdi and Naldung respectively. Storage losses reported from these sites were quite high in both structures. Moreover, subsequent field performance of the seed potatoes stored under trays and baskets was remarkably poor compared with the performance of seed potatoes stored in refrigerated store (Shakya, 1987). The seed crops were harvested before their full maturity, and one of the reasons for a very poor performance of basket and tray stored seed could be due to pre-mature harvest of the seed crop.

NPDP/SDC also investigated the possibility of using DLS technology in *terai* (<100m asl) in 1988 (Shakya, 1989). This was carried out in two sites where seed potatoes of Kufri Sindhuri were stored in trays in a farm-house in one site and they were stored in shelves as well as in trays in a small rustic store in the next site. Total storage losses for a storage period of eight months were 60.6% and 63.9% for rustic store storage and tray storage respectively. A large proportion of the losses were due to excessive shrinkage of tubers. However, losses due to tuber rotting were also quite large. Subsequent field performance of these seed potatoes was evaluated comparing with the seed potatoes stored in refrigerated store. The tuber yield given by the tray and rustic store storage were not satisfactory and were less than half of the tuber yield given by seed potatoes stored in refrigerated store (Shakya, 1989).

Hediger (1985) conducted comprehensive studies of the storage methods and their effect on subsequent field performance. Experiments were conducted in the Central region of Nepal at three major agro-ecological zones representing plains (100m asl), mid hills (1300m asl) and high hills (2500m asl). The following conclusions may be drawn from Hediger's findings:

(i) The plains (70-300m asl): Potatoes were stored perfectly well under DLS for four to five months (February/March to June) after harvest, but could not be stored until the next planting (8½ months) in October or November. A very high storage loss (50-80%) due to rotting of tubers at the beginning of the monsoon (July) was recorded.

(ii) Mid hills (1300m asl.): Total storage losses were significantly reduced in the diffused light store compared with the farmhouse store (storage period of June to January): storage losses due to respiration and evaporation decreased on average by 10-20%. Moreover, the total storage losses (including rotten tubers) decreased by 50%. Kufri Jyoti had higher storage losses than NPI-106. Unlike in the high hills, NPI-106 showed a strong apical dominance whereas Kufri Jyoti had multiple sprouts at mid hill conditions (Kathmandu valley). Apical sprouts in the case of NPI-106 however were broken or desprouted and produced similar numbers of main stems to Kufri Jyoti.

(iii) High hills (2500m asl): Storage losses in DLS and stone-wall stores was not different for variety Kufri Jyoti and CFJ, nor for all storage methods in case of variety I-1095. However, physiological conditions of DLS stored seed potatoes seemed to be slightly superior to those kept in the farmhouse. The low ambient temperatures in the high hills also permitted storage of seed potatoes in jute bags in stonewall stores (SWS) with natural ventilation. The storage losses were lower in the SWS than in the farmhouse store. The low temperatures at the beginning of the storage period and the appropriate pre-sprouting of the tubers before planting positively influenced the seed quality (short and sturdy sprouts) of the tubers in the SWS. In DLS, sprouting initiated after three months of storage, thus apical dominance had been broken and multiple, strong and short sprouts were observed at planting time. Apical dominance was not a problem in the high hills in all types of stores and varieties tested.

The combination of smoke and fire in farmhouses increased the temperature leading to quicker physiological ageing of seed tubers. Relatively high air temperature and a low RH% encouraged water loss from the tubers, and shrivelling to a greater extent than in other stores. Very early sprouting of tubers was observed in farmhouse stores. Long, white and weak sprouts were produced in farmhouse stores and most had broken off at planting time. Seed potatoes stored in SWS were pre-sprouted before planting but seed tubers from farmhouses were planted without pre-sprouting. Storage loss was attributed more to respiration and evaporation than tuber rotting which was minimal.

Experimental results from Lumle Centre (1675m asl) reveal a marked difference in the DLS performance of the varieties tested (Dhital 1995 & 1994). The difference in the storage performance was attributed to the differences in shrinkage, rotting, dormancy and sprouting behaviour of the seed potatoes (Dhital, 1995). Weight loss due to shrinkage was found to be quite high compared with the weight loss resulting from rotting of the tubers. This result agrees with the findings of Hediger (1985). Varieties such as GPGAD, NPI/T-0012, Kufri Jyoti, Mex-750838, Mineira and CIP-380584.3 had less storage loss but it was higher in case of LT-9, Timate, Amapola and MS 42-3 (Dhital, 1995). Overall, a total storage loss of 19.2% was observed for the storage period of six and half months (August to February) at Lumle conditions.

From 1978 to 1980 Booth (1985) intensively investigated the storage behaviour of seed potatoes in DLS and their subsequent field performance. Experiments were first conducted at Huancayo (3200m asl) CIP's highland research facilities and on-farm experiments were carried-out simultaneously during 1978 to 1980. At Huancayo, the storage loss in the dark store was 105% higher than the DLS stored seed potatoes (storage loss of 20.3% cf. 9.9%). There were large differences in the length and number of sprouts per tuber, and total storage losses between DLS and dark stored seed potatoes (Table 2). Similar results were obtained while the technology was tested under a large number of on-farm experiments (Booth, 1985). Experimental results from the highlands of the Philippines (Potts, 1983 and Potts *et al.*, 1983) and Sri Lanka (Rhoades, 1986) fully agree with the findings of Booth (1985).

Table 2. Effect of natural diffused light on storage behaviour and field performance of seed tubers stored at CIP, Huancayo (3200m asl) (mean of three years with eight cultivars stored for 180 days)

Characteristic	DLS stored	Dark stored
Sprout length (cm)	1.8	21.7
No. of sprouts/tuber	3.4	1.4
Total storage losses (%)	9.9	20.3
Days to full emergence	30.6	38.1
Total yield (t/ha)	28.8	24.6

(Source: Booth, 1985)

Marutani and Cruz, (1990) compared the storage performance of seed potatoes under DLS and refrigerated storage. They found a large variation in total storage losses among the three varieties and two storage methods tested (Table 3). The storage method had a significant effect on the subsequent field performance and cold stored seed potatoes gave 98% higher yield than DLS stored seed potatoes (Table 3).

Table 3 Diffused light storage & subsequent field performance of selected varieties of potato in Guam, Micronesian Islands, 1985-86

Variety and storage method	Tubers retained (%) (% of tubers stored)	Tuber wt. loss (%)	Yield (g/plant)
Kennebec			
CS	100	2.3	300
DLS	84	31.0	184
Sequoia			
CS	100	2.3	378
DLS	93	38.2	130
LT-2			
CS	100	2.8	112
DLS	53	44.0	85
Storage	***	***	***
Cultivar	***	**	ns
Storage x cultivar	***	ns	ns

(Source: Marutani and Cruz (1990) CS = Cold store, DLS = Diffused light store

Suitability of DLS technology has been tested in a wide range of environments. For example, it has been tested in the North Indian Plains (Mehta and Kaul, 1989) where maximum temperatures during potato storage range from 29 to 44°C and the Himalayan Mountains where maximum temperatures range from 5 to 18°C (Shakya, 1989; Hediger, 1985). The results from extremely hot environments such as the Northern Indian Plains where seed potatoes need to be stored during the hottest period (March to October), are not satisfactory. The same is true for the Southern Plains of Nepal (Hediger, 1985). Mehta and Kaul (1989) compared the DLS storage of seven potato cultivars with the refrigerated storage in a very hot environment. They found (i) 34-82% and 6-8% losses of weight under DLS and refrigerated stores respectively, (ii) a large variation on the DLS performance of varieties where Kufri Lalima (46.0%) and Phulwa (48.4%) had the lowest losses and Kufri Jyoti (75.5%) and Kufri Lauvkar (74.1%) had the highest storage losses, (iii) DLS seed gave reduced germination and plant height, and tuber yield compared with the seed tubers stored in the refrigerated store. However, the tuber yield given by Phulwa and Kufri Lalima was not statistically different between the two storage methods. It is interesting to observe a good tuber yield from these two varieties even after a long storage period in such hot conditions. The findings of Mehta and Kaul (1989) do not agree with most others such as Booth (1985), Potts *et al.*, (1983) and Rhoades (1986). However, they do agree with the findings of Boucaron *et al.* (1990) from New Caledonia and Shakya (1989) and Hediger (1985) from Nepal.

Effect of Light on Seed Tuber Physiology:

In general, seed tuber physiology is the state of functioning of the seed tuber, which depends mainly on the temperature and duration of storage prior to planting, genotype and the growing environments of the seed crop. McGee *et al.*, (1987) studied the effect of light on dormancy and subsequent sprout growth, they found that light affect the rate of sprout elongation but not dormancy. Sprout growth virtually ceased when tubers with growing sprouts were transferred from darkness to fluorescent light. Transfer from light to darkness resulted in immediate sprout growth at a rate comparable with tubers stored continuously in the dark, and total light energy falling on the tubers was the dominant factor controlling sprout growth. Colour and duration of light for pre-sprouting potatoes was studied by Ogilvy and Roberts (1992). Their results revealed that white light is more effective than blue light for inhibiting sprout growth. Regarding the duration of light, there was no benefit of increasing the light exposure from 6 to 24 hours. However, there was a marked increase in sprout length when light exposure was reduced to less than three hours per day. An interaction between variety and lighting treatment was also observed by Ogilvy and Roberts (1992).

Effect of Light on Bio-Chemical Composition and Disease Tolerance of Seed Tubers

Much work has been done on the bio-chemical and compositional changes in potato tubers during storage (Talley, *et al.*, 1970; Burton, 1973; Van der Plas, 1981). However, information on biochemical changes of seed potatoes under DLS, which could influence subsequent field performance, is not available. So it may be necessary to study the effect of bio-chemical composition particularly, sugars and protein content, and various growth hormones during the storage period under DLS. Similarly, the role of glycoalkaloids, particularly solanin and chaconin, on the seed tuber quality may need to be determined.

Light promotes greening of the tubers, which usually increases the glycoalkaloids. Glycoalkaloids are toxic to human beings and animals and the same may apply to pathogens as well. Hence, greening of tubers reduces the susceptibility to diseases particularly the fungal diseases (Sparenberg, 1982; Booth, 1985).

Effects on Subsequent Field Performance

Lama, (1987) found no difference in crop performance between pre-sprouted and non-pre-sprouted seed tubers (tuber yield of 17.0 cf. 16.0 t/ha) at Nigale Farm (2500m asl). The variety was Kufri Jyoti, and seed potatoes were stored under diffused light for the pre-sprouting treatment, and in the dark for the non-presprouting treatment. Long sprouts produced in the dark were de-sprouted at planting. The results of Hediger, (1985) at Nigale (2500m asl) also agree with Lama's findings. However, experimental results from many other places do not agree to these findings (NPDP, 1987; Rhoades, 1986; Booth, 1985; Potts, 1983 and Potts, *et al.*, 1983). They found that the DLS stored seed potatoes had more sprouts per tuber (3.4 cf. 1.4) and earlier emergence (31 cf. 38 days) (Table 2). Subsequently, higher tuber yields were produced by the DLS stored seed compared with dark stored seed.

A series of field experiments conducted at NPRP, Khumaltar, revealed a large variation in tuber yield and interactions between variety and storage method for their subsequent field performance (NPDP, 1990; NPRP, 1991 & 1992). Varieties such as Kufri Jyoti, Hybrid-14 and Kathmandu Local, produced similar tuber yields with both storage methods but there was a drastic yield reduction for CIP-800947 when the seed potatoes were stored under DLS. Sarkari Seto produced better yields when seed potatoes were stored under DLS compared with CS. It was interesting to note the better field performance of DLS stored seed potatoes of local varieties such as Sarkari Seto, where DLS stored seed gave 26% higher tuber yield than cold stored ones.

Similarly, higher or comparable yield of DLS stored seed potatoes was obtained in the case of NPI-106, Hybrid-14 and Kufri Jyoti. Contrary to this, very low tuber yield was produced by DLS stored seed potatoes of CIP-800947 and it was also quite low in case of Achirana Enta. The reasons for this were not known.

The results of the subsequent field performance of seed potatoes stored in various methods by Hediger (1985) are summarised as below:

Plains: It was not possible to evaluate the subsequent field performance of DLS and farmhouse stored seed potatoes in the plains due to extremely high losses of seed potatoes in store.

Mid hills: Irrespective of variety, cold stored seed potatoes produced significantly higher yields than farmhouse and diffused light stored seed potatoes, which were 23.4% and 18.3% higher respectively. Yields of farmhouse and diffused light stored seed were not different statistically. This might have been due to good storage environment even in farmhouse in the Kathmandu valley. However, this may not necessarily be representative of rural farmhouses in the mid hills of Nepal. Interaction between variety and storage method was found in the second year revealing variable effects of storage method on variety. Effects of high storage temperature were less pronounced in the medium maturing variety (NPI-106) than in an early maturing one (Kufri Jyoti). Similar yields were given by DLS and CS seed in case of variety NPI-106 whilst cold stored seed produced significantly higher tuber yield than all other storage methods in variety Kufri Jyoti.

High hills: There were no yield differences between storage methods in 1981/82 despite marked differences in sprouting. Long and weak sprouts were produced in the farmhouse store, shorter and less vigorous sprouts in the stone wall store and the shortest and most vigorous sprouts in the diffused light stored seed. Farmhouse-stored seed produced the highest tuber yield in 1980/81 seasons. The long and weak sprouts of farm-house stored seed tubers could have been detached at or before planting and reversed the physiological age compared to the seed potatoes planted with old sprouts from the other storage methods. On the other hand, the long growing conditions available in the high hills might have favoured a higher tuber yield from the seed potatoes de-sprouted at planting. Interaction between variety and storage method in 1980/81 season revealed a different response to the storage methods and varieties as in the case of the mid hill site.

DISCUSSION

Hediger (1985) conducted comprehensive studies to understand the influence of storage methods on the quality of seed potatoes and their subsequent field performance in a range of climatic conditions in Nepal. Her findings and experiences in the hills of Nepal show that the diffused light storage of seed potatoes is not possible in the plains (*terai*) and it is not advantageous compared to the traditional method (keeping potatoes in the dark in bulk) in the high hills (2500m asl). The DLS technique may be appropriate around the altitude of 1500-2000m asl. Further investigations need to be concentrated within this region for a more specific technology generation. Except Hediger (1985), studies conducted by most of the researchers were unsystematic and underlying mechanisms of the technology were not taken care. Studies were conducted in bits and pieces and a detailed and systematic studies were lacking. Every sets of experiment were conducted for only one season in most of the cases and results of such single season experiment would not be reliable particularly in the fragile environment such as in the hills of Nepal.

Physiological behaviour of seed potatoes under DLS conditions in different agro-ecological environments was never studied where storage and subsequent field performance were undertaken. Seed potatoes used in the storage experiments were often below standard; sometimes prematurely harvested and sometimes differences in seed quality among varieties used. Often seed potatoes of different sources were used for the comparison of DLS and cold store stored seed potatoes for their subsequent field performance. Sometimes seed potatoes were stored for a longer period than required whereas stored for a very short period than required in other occasion. For example, seed potatoes at Dhampus (1600m asl) were stored until end of March (Shakya, 1986) where seed potatoes had to be planted before mid February. A high storage loss is common when seed potatoes are stored for a longer period. On the other hand, Bhomi (1987) assessed the DLS performance of potato genotypes for a very short period (three and half months) in Khumaltar where seed potatoes need to be stored for eight months (late May to early January). It is not surprising to have just minimum storage losses for such a short storage period.

Almost all researchers in Nepal evaluated exotic varieties and local varieties were not included in the testing programme despite their popularity in the mid and high hills. The local varieties might stored better than the improved ones, and low or non-adoption of the improved varieties in the hills could also be due to their poor storage performance under farm-house conditions. It is important to focus these studies on local as well as improved varieties as the former are widely grown and considered the most important in the hills of Nepal.

It is possible to produce the desired number and types of sprouts by manipulating storage temperature and light. However, since the manipulation of storage temperature is not practical in Nepalese hill conditions sprouts must be manipulated physically, i.e. de-sprouting followed by re-sprouting. When the apically dominant sprout is damaged or removed, all inhibited sprouts resume growth until another becomes dominant. In many cases, seed potatoes, even those stored under DLS might be physiologically old particularly in the mid hills (<1600m asl) and yield of such seed tubers may be reduced substantially. De-sprouting may reduce the physiological age of seed potatoes and overcome the problem to some extent (Allen *et al.*, 1992). For this reason, dark stored seed potatoes might also give considerably better yields when weak and etiolated sprouts are removed and re-sprouted before planting. However, these issues were not considered in the research and promotion of the DLS technology in Nepal.

RECOMMENDATIONS AND CONCLUSIONS

Despite a long history of diffused light storage of seed potatoes in Nepal a little is known to us about the suitability of the technology to different altitudes, physiological behaviour of seed tubers of different genotypes under DLS, possibility of manipulating of physiological age of DLS stored seed under different environments etc. Similarly, status of the farmers acceptance of the technology in Nepal has not been investigated and information is almost lacking in this regard. Available information and experiences revealed a very minimum adoption of DLS technology. However reasons for the low adoption are not known due to the lack of studies and documentation. Regarding the storage performance, a large variation has been reported in the diffused light storage and subsequent field performance of the potato genotypes. Interactions between variety and storage methods on the subsequent tuber yield have also been reported. Both of these show a good possibility of selecting appropriate genotype(s) to suit the specific storage method of a locality or individual farmers.

On the basis of available literature and experiences, the following would be the priority research areas in relation to DLS of seed potatoes in the hills of Nepal: (i) seed tuber physiology and storage performance of important potato varieties under diffused light storage and their subsequent field performance. For this, there should be a provision of assessing all promising varieties for their physiological characteristics and storage performance under diffused light and their subsequent field performance. This means, it should an important part of variety improvement programme particularly for 1000-2000m asl. (ii) the effect of sprout manipulation of diffused light and dark stored seed potatoes on their subsequent field performance, and (iii) studies on the adoption situation of the DLS of seed potatoes in the hills. Other research areas equally important for other parts of the world would be, (i) the effects of light intensity on various genotypes and determination of appropriate light intensity regimes under different temperatures, (ii) the effects of light in bio-chemical composition during the storage period and their role on seed tuber quality, (iii) use of sprouts as planting material, and (iv) effects of fluctuating temperatures on the physiological age under various sprout management practises.

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REFERENCES CITED

Allen, E. J.; P.J. O`Brien and D. Firman. 1992. Seed Tuber Production and Management. **In:** Harris, P. M (Ed.). The Potato Crop: The Scientific Basis for Improvement. Chapman and Hall, London.

Bhomi, B.K. 1987. Post-harvest study of potato varieties in the rustic store. A paper resented in South Asian Association for Regional Co-operation (SAARC) multiplicational trials conference in December 1987, Kathmandu, Nepal.

Booth, R.H. 1985. Natural diffused light, a practical alternative to controlled atmosphere storage of potato seed tubers. Paper No. 85-4029. American Society of Agricultural Engineers. 1985.

Boucaron, C., L. Collett and P. Vander Zaag. 1990. Influence of growing and storage conditions on the subsequent performance of *Solanum* seed potatoes. Tropical Agriculture 67 (1): 85-89.

Burton, W.G. 1973. Physiological and biochemical changes in the tubers as affected by storage conditions. Proceedings of 5th Triennial Conference. EAPR, Norwich (1972). pp63-81.

CIP. 1985. CIP Circular. Vol. 13 (3). The International Potato Centre, Lima Peru. September, 1985.

CIP. 1981. CIP Circular. Vol. IX (9). The International Potato Centre, Lima Peru. September, 1981.

CIP. 1978. CIP Circular. Vol. VI (11). The International Potato Centre, Lima Peru. November 1978.

Cromwell, E.; S. Gurung and R. Urben. 1992. The Koshi Hills Agricultural Project: An Impact Assessment of the Seed Programme. First and unofficial report. Koshi Hills Development Programme, Dhankuta, Nepal.

Dhital, B.K. 1995. Report on Potato Variety Improvement Research, 1995. Working Paper No. 95/67. LARC, Kaski, Nepal.

Dhital, B.K. 1994. Report on Potato Variety Improvement Research, 1994. Working Paper No. 94/46. Lumle Agricultural Research Centre, Kaski, Nepal.

Dhital, B.K. and K.D. Subedi. 1994. Report on Potato Variety Improvement Research, Summer 1993. Working Paper No. 94/4. LARC, Kaski, Nepal.

Dhital, B.K., P.M. Pradhanang and T.B. Gurung. 1994. Potato Production Systems in Inner Himalayas of Manang and Mustang Districts. Working Paper No. 94/23. LARC, P.O. Box 1, Pokhara, Kaski, Nepal.

Dhital, B.K. et al., 1991. LARC Report on Potato Research (1988-90). Seminar Paper No. 11/91. LRARC, P. O. Box No.1 Pokhara, Nepal.

Dinkel, D.H. 1963. Light-induced inhibition of potato tuber sprouting. Science, 141:1047-1048.

Headford, D.W.R. 1962. Sprout development and subsequent plant growth. European Potato Journal. 5:14-22.

Hediger, E.P. 1985. Influence of Storage Methods on the Quality of Seed Tubers in Nepal. A Dissertation submitted to the Swiss Federal Institute of Technology, Zurich for the Degree of Doctor of Technical Science.

Khairgoli, L.P. 1978. Studies on Storage Loss of Potatoes at Khumaltar. Proceedings of Horticulture Workshop held on 12-17 November 1978. National Potato Development Programme, Khumaltar, Nepal.

Lama, T.L. 1987. Pre-sprouting Trial. Nigale, 1986. Report on Potato Research, 1986/87. National Potato Development Programme, Khumaltar, Nepal.

Marutani, M. and J.A. Cruz. 1990. Evaluation of Storage Methods on Storability and Subsequent Field Performance of Potatoes in Guam. Asian Potato Journal 1:29-32

McGee, E., R.H. Booth, M.C. Jarvis and H.J. Ducan. 1987. The inhibition of potato sprout growth by light. I. Effect of light on dormancy and subsequent sprout growth. Annals of Applied Biology 110:339-404.

Mehta, A. and H.N. Kaul. 1989. Differences among potato *Solanum tuberosum* L. Cultivars in Northern India in performance of diffused light stored seed potatoes. Potato Research 32 (2): 197-202.

NPRP. 1992. Annual Report, 1991/92. National Potato Research Programme, Khumaltar, Nepal.

NPRP. 1991. Annual Report, 1990/91. National Potato Research Programme, Khumaltar, Nepal.

NPDP. 1990. Annual Potato Research Report, 1989/90. National Potato Development Programme, Khumaltar, Nepal.

NPDP. 1987. Annual Potato Research Report, 1986/87. National Potato Development Programme, Khumaltar, Nepal.

Ogilvy, S.E. and A.J. Roberts. 1992. Colour and duration of light for chitting potatoes. Aspects of Applied Biology 33:51-58.

Potts, M.J. 1983 . Diffused light potato seed storage as an example of technology transfer: a case study. American Potato Journal 60(4): 217-226.

Potts, M.J., W.V.D. Albert, F.R. Rutab, E.O. Sano, P.P. Mariano and R.H. Booth. 1983. An agro-economic assessment of seed-potato storage technologies in the Philippines. American Potato Journal 60(3): 199-211.

Potato Abstract. 1994. Potato Abstract vol. 19 No. 2.

Rhoades, R. E. 1989. The Role of Farmers in the Creation of Agricultural Technology. In: Chambers, R.; Pacey, A. and Thrupp, L.A. (Eds.). Farmers First: Farmer innovation and agricultural research. Intermediate Technology Publications, UK.

Rhoades, R. 1988. Post-harvest technology development: Lessons from farms and villages. In: Proceedings of a workshop on potato post-harvest technology held at Kunming China on 25-26 June 1988. CIP and APA, pp114-126.

Rhoades, R. E. 1986. Changing a post harvest system: impact of diffused light potato stores in Sri Lanka. Agricultural Systems 19(1):1-19.

Rhoades, R. E 1985. Traditional Potato Production and Farmers' Selection of Varieties in Eastern Nepal. International Potato Centre. Research Series Report No. 2

Rhoades, R.E., W.V.D. Albert and R.H. Booth. 1984. Improving a farming system through post-harvest technology: Diffused light potato stores in Sri Lanka. Farming systems Support Project Newsletter, 2, 4-8.

Rhoades, R.E., R.H. Booth and M.J. Potts. 1983. Farmers acceptance of improved potato storage practices in developing countries. Outlook on Agriculture 12 (1): 12-15.

Richate, F.A., A. De Los Santos and P. Van der Zaag. 1986. Acceptance of diffused light storage technology by potato farmers in the Benguet and Mountain Province of Philippines. American Potato Journal. 63: 162-170.

Shakya, B.R. 1989. Cursory survey on potato storage in Nepal. National Potato Development Programme and Swiss Development Co-operation (SDC), Khumaltar, Nepal.

Shakya, B.R. 1987. On-farm Potato Storage Observation, Pumdi Bhumdi, 1986/87. National Potato Development Programme Khumaltar.

Shakya, B.R. 1986. On-farm trial 'Potato Storage in Baskets'. National Potato Development Programme Khumaltar.

Sparenberg, H. and A. Rastovski. 1987. Storage of potatoes at high temperatures. In: Rastovski, A. and van Es, A. *et al.* (Eds.). Storage of potatoes: Post-harvest behaviour, storage design, storage practice and handling. pp 429-440. PUDOC, Wageningen, the Netherlands.

Sparenberg, H. 1982. Storage of seed potatoes. In: FAO Plant Production and Protection Paper, 1982. No. 39, pp350-360. FAO, Roam.

Sparenberg, H. 1981. Storage of potatoes at high temperatures. In: Rastovski, A. and van Es, A. *et al.* (Eds.). Storage of potatoes: Post-harvest behaviour, storage design, storage practice and handling. Centre for Agricultural Publishing and Documentation PUDOC, Wageningen. pp 451-462.

Talley, E.A., T.J. Fitzpatrick and W.L. Porter. 1970. Chemical composition of potatoes. VIII. Effect of variety, location and year of growth on the content of nitrogen compounds. American Potato Journal. 47: 231-244.

Thongjiem, M. 1987. Development in potato storage and utilisation in Asia. Acta Horticulturae 213: 177-181.

Upraiti, V.N. 1986. On-farm Potato Storage and Potato Varietal Trials in Farming Systems Research Sites, Pumdi Bhumdi and Naldung, 1985/87. Paper presented at the Potato Working Group Meeting held in Kathmandu, 18-20 November 1986.

Van der Plas, L.H.W. 1981. Potato tuber storage: Biochemical and physiological; changes in potato. Ed. Y.P.S. Bajaj, Biotechnology in agriculture and forestry, 3:109-135. Springer Verlag, Heidelberg, Berlin.

Van der Schild, J.H.W. 1981. History of potato storage: Biochemical and physiological; changes in potato. Ed. Y.P.S. Bajaj , Biotechnology in agriculture and forestry, 3: 3-13. Springer Verlag, Heidelberg, Berlin.