'PRP 25861.1': A High Yielding, Early Maturing and Red-Skin Promising potato Clone for the Hills of Nepal

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Abstract

'PRP 25861.1' is a new high yielding, early maturing and red skinned potato clone*. It was selected at Hattiban Research Farm of National Potato Research Programme (NPRP), Nepal from a cross between 'Desiree' and 'LBr-40'. It has semi-erect growth habit, medium plant height, light green foliage, medium flowering habit and whitish-pink flowers. Tubers are medium size, red skin, white flesh, round to oval shape, medium eye depth, medium dormancy and good keeping quality. It is resistant to late blight, early blight, powdery scab and wart disease but susceptible to potato leaf roll virus. It has medium dry matter (19.5%) and specific gravity (1.073) which is higher than 'Desiree' and 'Kufri Jyoti'. Stakeholders preferred its plant character, yield, tuber and cooking qualities. 'PRP 25861.1' exhibited high yield both at on-station and on-farm experiments. Its average yield was 18.4 tha^{-1} both at on-station and on-farm which is 31.4% and 8.2% higher than 'Desiree' and 'Kufri Jyoti', respectively. High yielding, late blight resistant, early maturing and red skin characteristics of this clone were preferred by the potato growers and it is expected to be fit in the hill cropping system of Nepal.*

Keywords: *Clone, keeping quality, late blight resistant, on-farm, on-station*

Introduction

Potato (*Solanum tuberosum* L.) is one of the important cash crops for food security in the hills of Nepal cultivated mostly as rainfed crop. Potato is a major vegetable in mid-hill and staple food in high hills. Potato cultivation in hills occupies almost 60% of the total potato cultivated area of the country (NPRP, 2016). In the hills, late blight is a serious problem in potato causing significant yield loss (Sharma *et al.,* 2013).

National Potato Research Programme (NPRP) has released ten cultivars since its inception in 1991. However, the cultivars released as resistant ones have lost their resistance against new pathogens in pathogen population. But cultivar like 'Janak Dev' has durable resistance to date (Sharma *et al.,* 2013). Changes in quality demands (e.g. processing into fast food products) and increasing environmental concerns (e.g. use of disease resistant varieties) are the factors which have stimulated the change for new cultivars (Struik and Wiersema, 1999). There are different approaches to obtain new cultivars. To date, NPRP has followed the selection programme on advanced clones provided by International Potato Center (CIP), Lima, Peru. NPRP first attempted to set up the crossing program of potato since 2004 at Hattiban Research Farm, Khumaltar followed by the selection in segregating breeding population (NPRP, 2007).

In Nepal, systematic research on potato variety development started since 1991 with the establishment of National Potato Research Programme (NPRP). Progress in potato production achieved so far in Nepal is mainly due to the development and release of high yielding with disease resistant varieties. 'Kufri Jyoti' and 'Desiree' are the most popular varieties in the hills. But these varieties are susceptible to late blight (Khatri *et al*., 2015), have moderate productivity and was released in 1992. In recent years, high yielding, late blight resistant and early maturing with red-skin varieties are the interests and demand of the potato farmers in hills (Sharma *et al*., 2013; NPRP, 2014a). The breeding of a new potato variety involves long procedure. Parents are first selected for their potential to produce new and desirable genotypes. A large number of seedlings (genotypes) raised from the true seeds are evaluated

in the seedling (F_1) or first clonal generation. Certain proportions of these seedlings are further advanced in un-replicated experimental units for screening in second clonal generation (Tai and Young, 1984). In this study, we have provided report on the brief procedure of breeding a new clone 'PRP 25861.1', its varietal description, agronomic performance, tuber quality characters, diseases evaluation, production, and seed management aspect.

Materials and Methods

'PRP 25861.1' is a cross of Desiree x LBr-40 made by Hattiban Research Farm (Fig. 1) of NPRP, Breeding Program, Khumalar (located at 27°40' N, 85° 20'E, 1,340 masl) during August of 2000-2016. The female parent 'Desiree' was a released cultivar of Nepal, developed in Netherlands. It has red, long shaped tubers with shallow eyes and early maturity. It is late blight susceptible both in the foliage and tubers but immune to wart and potato leaf roll virus (PLRV). The pollen was from'LBr-40' as a parent, received from International Potato Center (CIP), Peru and it is white, round tubers with medium eye depth, and white flesh. It is medium maturing cultivar and possesses the late blight resistance (Sharma *et al*., 2013) for both foliage as well as tubers. True seeds collected from this cross were stored in desiccators for two years, and about 500 seeds were sown in wooden tray in July 2004. About 450 seedlings were transplanted in the field at the spacing of 60 cm x 25 cm. The first selection cycle criteria were based on resistance to late blight and tuber appearance. The clone was at seedling stage from 2004 to 2005, five-hill plot from 2005 to 2006 and replicated yield trial during 2006-2008 at on-station (e.g. Initial Evaluation Trial and Coordinated Varietal Trial) and during 2009-2012 at on-farm (e.g. Coordinated Farmers' Field Trial). The seedlings and subsequent clonal stages were evaluated using the procedure described by Gaur *et al*. (1984) and Tai and Young (1984).

On-station experiments were conducted in NPRP, Khumalar; Agriculture Research Station, Horticulture Farm, Jumla (2,330 masl) and Agriculture Research Station, Pakhribas (1,750 masl) for three years. Based on superior performance in replicated on-station yield trials, 'PRP 25861.1' was introduced in the on-farm trials at Kavre, Kusadevi (1,250 masl); Kathmandu, Jitpurfedi (1,000 masl); Sindhupalchowk, Nigaley (2,550 masl); Dolakha, Boanch (2,850 masl); Tehrathum, Basantapur (2,650 masl); Patmara, Jumla (2,400 masl), Lumle Kaski (1,675 masl) and Nawadurga, Doti (850 masl) during 2009 - 2016. 'Desiree' and 'Kufri Jyoti', popular released varieties in the hills, were used as control both at on-station and on-farm trials.

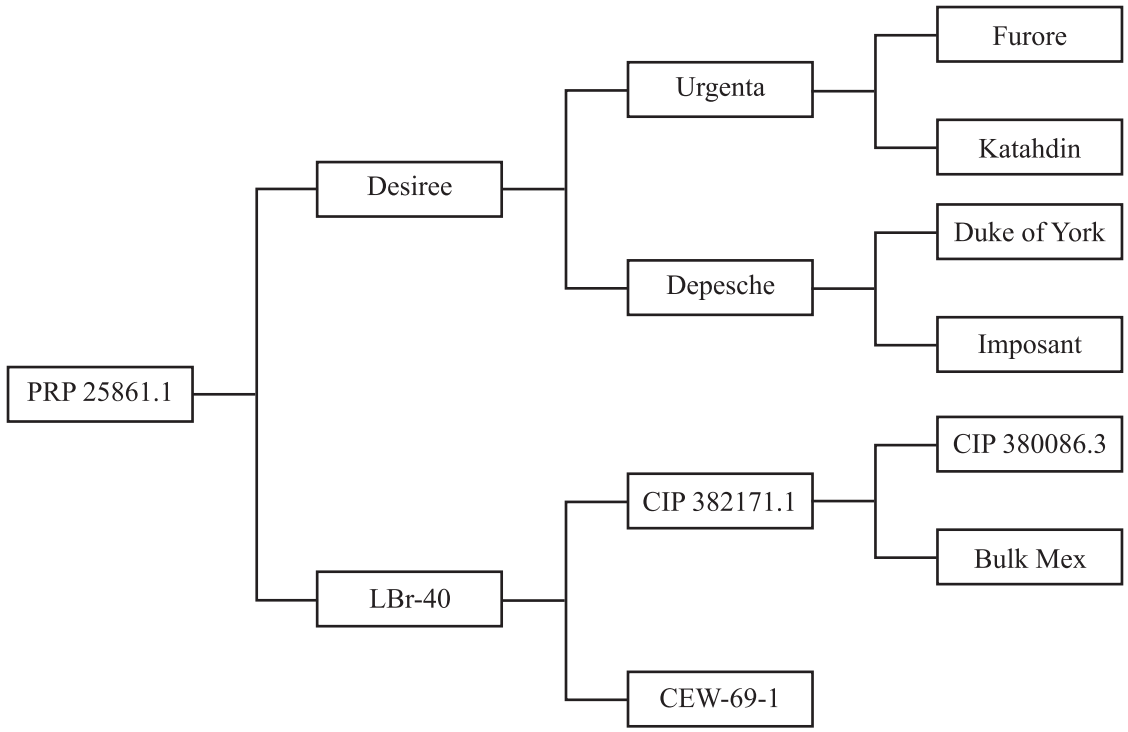

Figure 1 Pedigree diagram of the new potato clone 'PRP 25861.1'

The morphology of the plants, leaves, flowers and tubers and their descriptions were taken as descriptors developed by Mosley *et al*., 2003 and UPOV(2001). Measurements were also taken on yield, tuber quality, disease, and physiological response following the procedures described by NPRP (2014b). The diseases (late blight, early blight, powdery scab, wart and virus) and abiotic stress (frost and hailstorm) responses were taken according to procedure explained by NPRP (2014b). Stakeholders' preferences of potato cultivars were assessed for their plant, yield, tuber acceptance and cooking quality at on-farm trials by observing the plants, yield, cooking quality and tuber appearance, and they were provided their feedback in a schedule adopted by International Potato Center (CIP, 2014).

Descriptive statistic (mean) was used to analyze the agronomic data and quality characters (dry matter, specific gravity, reducing sugar and starch content) using Microsoft Excel (version 10.0; Microsoft, Redmond, WA, USA). In addition, one-way analysis of variance (ANOVA) was done by following Student-Newman-Keuls test for multiple comparisons of means among the genotypes.

Results and Discussion

Plants

*Growth habit***:** It has semi-erect growth habit and medium height with early maturity (Fig. 2A). *Plant foliage*: It is intermediate between stem and leaf type, green foliage or canopy, strong pigmentation on rachis. *Stems*: It is medium thick, dark green with anthocyanin pigmentation, presence of secondary leaflets, well-developed wings with few hairs. *Leaves:* Leaves are ovate, green, moderately pubescent, close and less glossy type. Terminal leaflet is broad ovate, cuspidate tip with wavy margin (Fig. 2B). Primary leaflets are ovate with pointed tips. Secondary and tertiary leaflets are 3 to 4 pairs with an average of four pairs.

Flowers

It is medium-flowering type and contains two to four inflorescences per plant, medium number of buds per inflorescence and inflorescence is drooping type. *Buds*: The buds contain anthocyanin pigmentation. *Calyx*: It contains medium anthocyanin pigmentation. *Corolla*: Corolla is whitish-pink and pentagonal shape (Fig. 2C). *Anthers*: The anthers are broad cone shaped with abundant pollen production. Stigma is capitate shaped with little berry production as observed in Khumaltar condition.

Tubers

Shape: Tuber varied from round to oval (Fig. 2D). *Skin*: Tuber is dark red with no secondary color and the skin is smooth texture. *Eyes*: There are medium number of eyes, medium depth and evenly distributed. *Flesh*: It is creamy-white with no secondary color. *Tuber set*: Tuber set is medium and average tuber number plant^{-1}is 6-8. *Dormancy*: It is medium ranging from 6 to 8 weeks from tuber harvest at room temperature (25°C) which is similar to 'Desiree' and 'Kufri Jyoti'. Tubers have a creamy texture when boiled. Slight darkening observed after boiling but none observed when baked. Similar observation has been reported by Knowles and Pavek (2008).

Sprout

Sprouts are cylindrical in shape with few lateral shoots, red color (Fig. 2E) with an open growth habit. The base of sprout exhibits more red pigmentation and few number of small root initials.

Table 1. Morphological characteristics of the new potato clone 'PRP 25861.1'

Cultivar	Plant		Leaf		Flower	Tuber			
	Height	Shape	Shape	Color	Color	Shape	Skin color	Flesh color	Eye depth
PRP 25861.1	Medium (58 cm)	Semi-erect	Ovate	Anthocyanin	Whitish-pink	Round oval	Red	Creamy-white	Medium
Desiree (Check)	Medium (35 cm)	Spreading	Ovate	Anthocyanin	Pink	Long	Red	Yellow	Shallow
Kufri Jyoti (Check)	Medium (45 cm)	Spreading	Broad ovate	Green	White	Oval	White	Creamy-white	Shallow

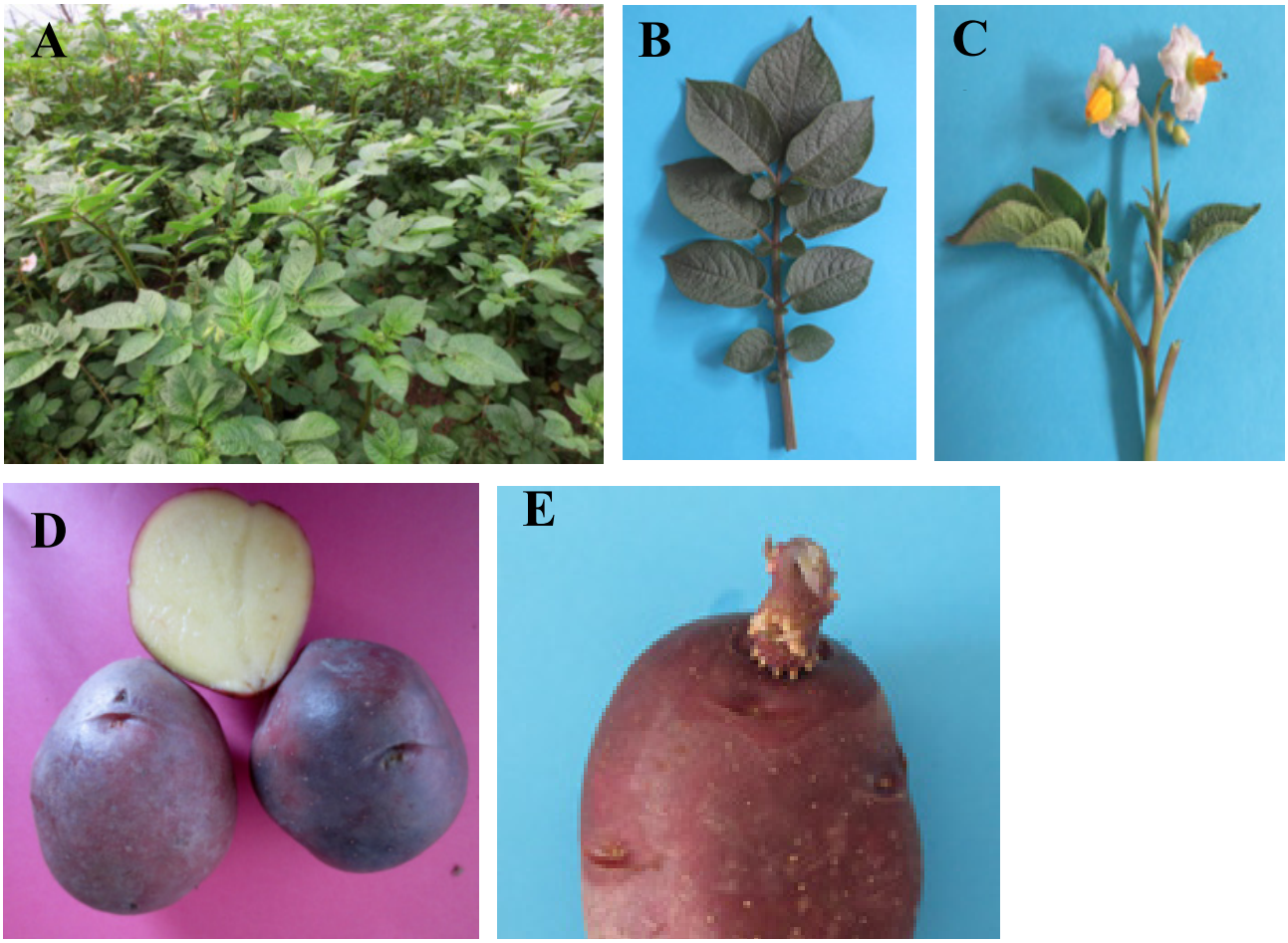

Figure 2 Canopy (A), leaf (B), inflorescence (C), tuber (D), and red sprout (E) characteristics of cultivar 'PRP 25861.1'.

Agronomic Performance

PRP 25861.1 was evaluated for agronomic performance at on-station and on-farm sites across the hill of the country. It was compared with 'Desiree' and 'Kufri Jyoti', early and medium maturing varieties of Nepal, respectively (NPRP, 2013). In the on-station trail, 'PRP 25861.1' yielded, on an average, 19.6 t ha^{-1} compared to 13.3 and 15.5 tha^{-1} by the control varieties 'Desiree' and 'Kufri Jyoti', respectively (Table 2). Its yield was 20.9% higher than that of 'Kufri Jyoti'.

Table 2. Yield (tha^{-1}) performance of the new potato clone 'PRP 25861.1' at on-station trials during 2006-2008 (means of the three years)

Cultivars	Khumaltar	Jumla	Pakhribas	Mean
PRP25861.1	16.8 a[y]	23.1 a	19.1 a	19.6
Desiree (Check)	14.2 b	20.1 c	5.6 c	13.3
Kufri Jyoti (Check)	13.5 b	22.0 b	11.1 b	15.5

[y]Means in the column followed by different letter are significantly different at $P<0.05$.

In the on-farm experiments, 'PRP 25861.1' produced higher yield (average 17.2 tha^{-1}) than 'Desiree' and but lower than 'Kufri Jyoti' (Table 3). 'PRP 25861.1' produced about 17.0 % higher than 'Desiree' but 7.5% lower than 'Kufri Jyoti'. The continuous use of seed tuber of PRP 25861.1 since 2009 (its clonal generations) might have degenerated the seed tuber due to virus eventually reducing yield potentiality of the clone . In contrast, 'Desiree' and 'Kufri Jyoti' were normally used as Basic-4 (improved seed) which was produced from pre-basic seed (PBS). This might be one of the reasons for being lower yield of PRP25861.1 in some on-farms. All tested cultivars in the on-farm sites showed difference in mean yield than on-station. Yield gaps noticed between the on-station and the on-farm might have been due to differences in the local environment, set of biological and socioeconomic conditions (Crissman *et al*., 1991). In the on-farm condition, 'PRP 25861.1' outperformed 'Desiree' but exhibited inferior performance than 'Kufri Jyoti'. But both at on-station and on-farm condition, 'PRP 25861.1' gave higher yield (average, 18.4 tha^{-1}) than 'Desiree' (average, 14.0 tha^{-1}) and 'Kufri Jyoti' (average, 17.0 tha^{-1}) (data not shown).

Table 3. Yield performance of the new potato clone 'PRP 25861.1' at on-farm trials during 2009-2016 (means of eight years)

Cultivars	Kusadevi (tha^{-1})	Jitpurfedi (tha^{-1})	Nigaley (tha^{-1})	Bonch (tha^{-1})	Basantapur (tha^{-1})	Patmara (tha^{-1})	Lumle (tha^{-1})	Doti (tha^{-1})	Mean
PRP 25861.1	34.2a	12.4c	22.6a	23.8a	11.9b	12.3c	8.2b	12.1a	17.2
Desiree (Check)	-	17.1b	13.5c	14.8c	17.5a	20.0a	9.1a	11.1b	14.7
Kufri Jyoti (Check)	34.2a	24.4a	18.1b	21.6b	11.1b	14.2b	7.0b	-	18.6

'-' means variety is not tested in on-farms. [y]Means in the column followed by different letter are significantly different at $P<0.05$.

Tuber Quality Characters and Usage

The dry matter is significantly higher (19.5%) in 'PRP 25861.1' than 'Desiree' and 'Kufri Jyoti' (Table 4). 'PRP 25861.1' recorded the highest specific gravity (1.073) but it was statistically similar to 'Desiree' and 'Kufri Jyoti', Reducing sugar was significantly higher (35.8 mg) in clone PRP 25861.1 but starch content was significantly higher (14.6%) in 'Kufri Jyoti' than in 'PRP 25861.1'. 'PRP 25861.1' was suitable for table potatoes for preparation of almost all dishes expected from table potato variety.

Table 4. Tuber dry matter, specific gravity, and reducing sugar of the new potato clone 'PRP 25861.1' in Khumaltar during 2011-2012.

Cultivars	Dry matter content (%)	Specific gravity[z]	Reducing sugar (mg100 g^{-1} fresh weight)	Starch content (%)
PRP 25861.1	19.5 a	1.073 a	35.8 a	13.8b
Desiree	17.5 c	1.062 a	34.2 b	13.6b
Kufri Jyoti	18.3 b	1.062 a	29.0 c	14.6 a

[z] Specific gravity was determined using the weight-in-air and weight-in-water method. [y]Means in the column followed by different letter are significantly different at $P<0.05$.

Disease and Abiotic Stress Response

Late blight [(*Phytophthora infestans* (Mont.) de Bary] is one of the major biotic constraints in potato production in Nepal (Sharma *et al*., 2013). In addition, early blight, powdery scab, wart and viruses are the major potato disease in the hills of Nepal (NPRP, 2014a). 'PRP 25861.1'exhibits resistance to late blight, early blight, powdery mildew, and wart but it is susceptible to potato leaf roll virus (Table 5). 'PRP 25861.1' is wart resistant (Sharma *et al*., 2009) and susceptible to frost but moderately resistant to hailstorm under high hill conditions.

Table 5. Diseases and abiotic stresses (frost and hailstorm) response of the new potato clone ''PRP 25861.1' during 2009-2016.

Cultivars	Late blight (1-9)	Early blight (1-6)	Powdery scab (0-6)	Wart (%)	Virus (PLRV)	Frost (1-5)	Hailstorm (1-5)
PRP 25861.1	1	1	0	0.0	Susceptible	4	3
Desiree (Check)	8	5	6	0.0	Susceptible	5	5
Kufri Jyoti (Check)	9	5	6	0.0	Susceptible	4	5

Late blight score was rated on a scale of 1-9, where 1 = highly resistant, 2-3 = resistant, 4-5 = moderately resistant, 6-7 susceptible, 8-9 = highly susceptible. Early blight was rated on a scale of 1-6 where, 0 = highly resistant, 1 = resistant, 2-4 = moderately resistant, 5 = susceptible and 6 = highly susceptible. Powdery scab; 0= highly resistant, and 6 = susceptible. PLRV = Potato leaf roll virus. Other abiotic stresses were rated on a scale of 1-5, where 1 = highly resistant, 2-3 = moderately resistant and 4-5 = susceptible.

'PRP 25861.1' is an early maturing cultivar and it is similar to 'Desiree' (Table 6) in maturity period. Plant appearance of 'PRP 25861.1' in the field is excellent, and it is good in terms of yield, tuber appearance and cooking qualities as per stakeholders' preference. Stake holders preferred this cione due to its red skin, round to oval tuber, and good cooking qualities. It possesses pleasant flavor, mealy texture and good palatability.

Table 6. Maturity and farmers' preference of the new potato clone 'PRP 25861.1' in the trials of Khumaltar during 2009-2016.

Cultivars	Maturity[z]	Stakeholders' Preferences (1-5)			
		Appearance (1-5)	Yield (1-5)	Tuber (1-5)	Cooking quality (1-5)
PRP25861.1	Early	5	4	4	5
Desiree (Check)	Early	4	3	5	4
Kufri Jyoti (Check)	Medium	5	4	5	4

[z]Maturity, early = 90-100 and medium 100-110 days. Stakeholders 'preferences were rated on a scale of 1-5 scale, where 1 = very poor, 2 = poor, 3 = fair, 4 = good and 5 = excellent.

Production Management

'Desiree' and 'Kufri Jyoti' are released varieties and regularly grown at Hattiban Research Farm, Khumaltar which represents mid-hill condition of the country. The agronomic management practices recommended for the released potato varieties are applicable to this clone 'PRP 25861.1'. Optimal commercial spacing for seed pieces of 'PRP 25861.1' is 25 cm on rows spaced 60 cm apart for seed while it is 75 cm apart for ware potato production. Optimal seed size ranges from 25 to 50 g and optimal planting depth is 10 to 12 cm. Seed tuber should be checked for fungal disease before planting and seed should be treated with an effective fungicide, if necessary.

Fertilizer recommendation of released potato varieties consists of 100 kg nitrogen, 100 kg phosphorous and 60 kg potassium and 20 tha^{-1} farmyard manure (Khatri *et al*., 2010). Half of the nitrogen should be applied as a pre-planting application along with full amount of phosphorous, potassium and farmyard manure and 50% of the total nitrogen should be applied prior to tuber initiation. No information is yet available regarding micronutrient requirements for

'PRP 25861.1'. Soil moisture within the root zone (0 to 40 cm soil depth) should be maintained between 65 to 80% of available soil moisture during tuber development and bulking. Careful handling during harvest, transport and packaging is must to prevent bruising. The management practices adopted in Khumaltar can be recommended to other potato growing regions having similar cropping patterns, climatic situation and soil fertility status.

Storage and Seed Availability

'PRP 25861.1' has good storability. It can be kept at room temperature for 60 days after harvesting without sprouting and weight loss but it showed the highest sprout number and weight tuber^{-1} after 120 days of storage (Gautam *et al*., 2012) in mid hill condition. It has good keeping quality in high hill. Disease-free in-vitro plantlets are produced in Tissue Culture Laboratory of NPRP and subsequently produced pre-basic seed tuber (PBS) or mini tuber in glasshouse. PBS undergoes at least four multiplication cycle i.e. Basic-1, Basic-2 as foundation seed, and Basic-3 as certified seed tuber and Basic-4 as improved seed. PBS of new clone is available exclusively from NPRP and small amounts of Basic seed can be obtained for the research by contacting NPRP.

Conclusion

'PRP 25861.1' is a high yielding, early maturing and late blight resistant clone having acceptable tuber characters with red skin, good dry matter content, and same keeping quality as of 'Desiree' and 'Kufri Jyoti'. Use of improved seed of 'PRP 25861.1' can impart higher yield or similar yield to 'Kufri Jyoti' in the on-farm condition. Growers have a good response to this clone due to its early maturity, late blight resistance and red skin. It fits well in rice-potato cropping system in mid-hills due to its early bulking nature. Growers prefer this clone to grow for early harvest and fetch lucrative price for fresh produce. Hence, it can be recommended for the commercial cultivation in the hills of Nepal.

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