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PERFORMANCE ANALYSIS, EVALUATION METHODOLOGIES OF ADVANCED CLONES OF POTATO (*Solanum tuberosum* L.) FOR YIELD AND QUALITY PARAMETERS

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ABSTRACT

An experiment was conducted at ICAR- Central Potato Research Institute Regional Station Patna, Bihar during the year 2020-21, 2021-22 & 2022-23. Seven advance clones viz. PS/17-09, PS/17-11, PS/17-12, PS/17-15, PS/17-19, PS/17-20, PS/17-22 along with four controls viz; Kufri Lohit, Kufri Manik, Kufri Lalit and Kufri Neelkanth. In the present scenario Potato is most consumed vegetable crop in India. As per the nutritional profile, potatoes are rich source of carbohydrate, proteins, vitamins (vitamin C, B6) and minerals Fe, Zn and Folate (*Robertson et al.*, 2018). Nowadays, red potato varieties are gaining people attention due to enhanced nutrient rich compounds like Anthocyanin, Carotenoids etc. The red Anthocyanin gives attractive colour to the potato clones. The important anthocyanin pigments present in nature are red, purple pink, dark, purple, blue, reddish purple etc. which are very important in our diet. The carotenoids are present in the flesh part of the potato, these may be white, light yellow, cream, dark yellow, red, pink, purple, dark purple etc. Potatoes also contain a significant amount of minerals like iron, calcium, phosphorus and Zinc (*Burgos et al.*, 2007). The objective of this study was evaluation of these advanced clones suitable for cultivation in eastern Indo Gangetic plains of India.
Keywords **:** Potato, Advanced Clones, Control varieties, Anthocyanins, Carotenoids.

Introduction

Potato (*Solanum tuberosum L.*) is one of the most widely consumed vegetable crops in India. Major potato-producing states include Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab, Assam, Haryana, Jharkhand, and Chhattisgarh. During the 2021–22 agricultural year, India produced 53.03 million tons of potatoes from 2.16 million hectares, with an average yield of 24.55 tons per hectare (FAOSTAT, 2021). Nutritionally, potatoes are a rich source of carbohydrates, proteins, vitamins (notably vitamin C and B6), and minerals such as iron, calcium, phosphorus, zinc, and folate (Lutha *et al.*, 2001 and Yadav *et al.*, 2023). In recent years, red potato varieties have gained increasing attention due to their enhanced nutrient content, particularly anthocyanins and carotenoids. Anthocyanin pigments impart attractive skin colours ranging from red, purple, pink, dark purple, blue, to reddish-purple, while carotenoids contribute to flesh coloration, varying from white, cream, and light yellow to dark yellow, red, pink, and purple (Burgos *et al*., 2007). Flesh colour and dry matter content are important determinants of taste and consumer preference. The advanced potato clones evaluated in this study were developed through hybridization in 2017 at the ICAR-Central Potato Research Institute, Kufri-Fagu Unit, Shimla, Himachal Pradesh, and ICAR CPRI regional station in Patna, Bihar. These clones were selected from seedling to advanced clonal generations and evaluated through Initial Evaluation Trials (IET), Preliminary Yield Trials (PYT), and Confirmatory Yield Trials (CYT). Field experiments were conducted in a randomized block design (RBD) with three replications at the ICAR CPRI Regional Station, Patna, during 2020–21, 2021–22, and 2022–23. The clones were assessed for total tuber yield, marketable yield, dry matter percentage, storage behaviour, and nutritional quality, and compared against control varieties. Consistently superior performers were advanced through successive generations. Since potato is a cool-season crop, trials were conducted during the Rabi season. The primary objective of this study was the breeding and selection of superior advanced potato clones suitable for cultivation in the Eastern Indo-Gangetic Plains of India

Materials and Methods

Potato is a cool season crop (Khurana *et al*., 2003). It performs best in cool seasons with sufficient moisture and in fertile lands. Its cultivation requires the well-prepared field with proper drainage facility. It performs well in soil temperature ranges between 17-19^{0}C because this temperature is favourable for crop growth as well as favours the tuber initiation and tuber development (*Luthra et al*., 2001). Potato can be grown on wide range of soils from sandy loam, silt loam and clayey soils. India ranks 2nd in potato production after China due to vast availability of favourable soil in the country. The Northern & Eastern plains of India are major growing region due to fertile soil available in these areas suitable for better cultivation of potatoes. The well drained field is prerequisite for conducting the experiment as well for planting of the crop. The soil pH ranges from 5.0-6.5 are suitable for potato crop cultivation

Planting Materials

The material in this study were seven advanced clones of potato *viz.* PS/17-09, PS/17-11, PS/17-12, PS/17-15, PS/17-19, PS/17-20, PS/17-22 along with four control varieties of potato viz; Kufri Lohit, Kufri Manik, Kufri Lalit and Kufri Neelkanth.

Location of Experiment

The experiment was conducted at crop improvement experimental field of ICAR-CRPI RS Patna, Bihar during the year 2020-21, 2021-22 & 2022-23. The advanced clones were planted as per the standard approved Institute Research programme "Breeding trait specific varieties for productivity, quality and resistance to biotic and abiotic stresses", project entitled "Breeding medium maturing red skinned potato varieties for eastern plains" during 2020-21, 2021-22 and 2022-23 in the *Rabi* season. The cropping season starts from November and ends during last week of February with the harvesting and storage of seed tubers of the crop.

Experimental Design

The design of the experiment was Randomized Block Design with three replications in two sets of experiments varying in days of harvesting i.e. experiment harvested with 75 days after planting and 90 days after planting. All advanced clones along with control varieties were planted in 5 rows of 12 tubers each (3.0 m x 2.4 m) with the area 7.2 m^2.

Field preparation **Planting of advanced clones** **Crop stand** **Harvesting**

Plate 1 : Important Agronomic practices in potato cultivation

Field Preparation

A well-prepared field is important for good crop growth and development in potato cultivation. Potato crop can be planted as early, medium and late crop in the month early October, last week of October to mid of November and last week of November to first week of December respectively (*Rukundo et al*., 2020). This experiment was done to evaluate seven medium maturing red skinned potato advanced clones along with control varieties of potatoes. For successful experiment, field was prepared by deep ploughing (20-25 cm deep) with the help of soil turning plough during the month of June and planting of green manure crop *Dhaincha* in the month of July. The dhaincha crop 45 days after planting was ploughed in the field to incorporate the plant nutrient in the soil which are present in the green manure crop. The green manure crop incorporated in the soil takes 15-20 days for complete decomposition. As the plant material decompose it releases nutrients like nitrogen, phosphorus and potassium in the soil, act as natural fertilizer. The field can be prepared for planting of the potatoes by one deep ploughing followed by 2-3 cross harrowing and 2-3 shallow ploughing with leveling of the field. Good tuberization of the potato crop needs a well-prepared field during cultivation of the crop. Planking is very important cultural practices to retain the available moisture in the field, which plays important role at the time of planting and helps better and good germination of the crop (*Singh et al*., 2014).

Seed Size, Seed Rate and Spacing

In potato crop tubers with 30 to 50 g weight are ideal for planting of the crop (*Hirdesh et al*., 2003). In this experiment, whole tubers of seed size were planted on the ridges (15 cm). The plant-to-plant distance was 20 cm and row to row distance was 60 cm. After planting of the crop, light irrigation was given in the field in order to promote quick and even germination of the tubers (*Luthra et al*., 2001)

Manure and Fertilizers

Potato crop is considered as heavy feeder crop with respect to fertilizer doses (natural/organic/ inorganic). It requires high doses of fertilizers i.e. 180:80:100 (N: P: K). Along with these fertilizers we can apply farm yard manure (FYM) plays important role to maintain this soil health, structure and population of beneficial microflora and fauna (*Luthra et al*., 2001). In the potato crop 25-30 tones/ha well decomposed farmyard manure was applied for getting better crop growth and tuber yield. This FYM was applied during land preparation and given enough time for mixing, decomposition and release of the nutrients in the soil. Whereas chemical fertilizers like Nitrogen in the form of Urea, Phosphorous in the form of Di-Ammonium Phosphate (DAP) or Single super phosphate (SSP), Potassium in the form of Murate of Potash (MOP) were applied as basal dose (1/2 N: P: K). the remaining dose of nitrogen was applied after earthing up operation that is 25-30 days after planting (Subarta, 1997).

Method of Planting

The tubers were planted on the ridges. These ridges were made after land preparation with the help of tractor driven ridge-maker or manually with the help of spade and similar tools. For conducting the experiment bed cutting (3m x 60cm x 5 lines) was done as per the planting layout of the experiment. The planting of potato tubers were done with the help of *khurpi* at the depth of 7-8 cm followed by covering of the tubers with surrounding soil. Light irrigation was given just after planting of the experiment for better germination of the experimental material.

Inter Culture Operations

Inter culture operation plays important role in the expression of qualitative and quantitative traits in plants. In potato crop weeds are major problems in the crop during early stages. The important weeds are Moth grass, Gajar grass, Palak grass, *Trifolium spp.* etc. The weeds can be controlled by spraying of pre-emergence weedicide Oxflurofen 23.5% EC (500 ml/ha). This weedicide controls prolific growth of weeds in the field during germination of the crop. All the inter culture operations like weeding, hoeing, earthing up etc. were done manually as per requirement of the crop. After hoeing remaining half dose of Nitrogen in the form of Urea was applied in side furrows and then earthing up was done in order to get better nutrition to support tuberization in the crop. In potato crop 4-5 irrigations at an interval of 10-15 days were given to meet the moisture requirement of the crop. Irrigation interval may vary as per requirement and level of moisture present in the field. In potato crop Late blight of potato is very harmful and devastating disease as it affects leaves, stems, tubers etc. and even complete plant (*Singh et al*., 2014). This disease spreads very fast under disease favourable environment (cloudy weather, high humidity) and if not controlled timely then it may destroy whole crop. The disease was controlled by one prophylactic spray of Mancozeb 75WP followed by 2 sprays of Cymoxanil 8% + Mancozeb 64% WP at an interval of 15 days. In potato crop insect & pests are serious problem, for control of aphids and potato leaf cutters, cutworms etc. Imidacloprid 17.8% SL was sprayed in 45 days crop.

$$\text{Plant Emergence}\,(\%) = \frac{\text{No. of emerged plants}}{\text{No. of total tubers planted per plot}} \times 100$$

$$\text{Total Tuber yield (t/ha)} = \frac{\text{Weight of the total tubers per plot (kg)}}{\text{Area of the plot (m}^2)} \times 10000$$

$$\text{Marketable Tuber yield (t/ha)} = \frac{\text{Total wt. of harvested tubers (kg) - wt. of very small tubers per plot (kg)}}{\text{Area of the plot (m2)}} \times 10000$$

$$\text{Dry matter}(\%) = \frac{\text{Weight of the cut oven, dried potato}}{\text{Fresh weight of the potato}} \times 100$$

Result and Discussion

Plant Emergence

Data were recorded for plant emergence, 25 days after planting (Table-1). The plant emergence ranged from 86.39% (K. Lohit) to 97.78% (PS/17-19) in 75 days crop. In the experiment planted for evaluation in 90 days crop the range was 90.00% (K. Manik) to 98.89% (PS/17-19).

Table 1: Plant Emergence of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23)

Advanced clones /Varieties	Emergence (%)	
	At 75 days	At 90 days
PS/17-09	95.00	97.23
PS/17-11	95.00	97.23
PS/17-12	94.52	97.50
PS/17-15	95.93	95.28
PS/17-19	97.78	98.89
PS/17-20	96.67	96.95
PS/17-22	97.04	97.78
K. Kesar	96.11	97.23
K. Lalit	88.70	92.50
K. Lohit	86.39	92.78
K. Manik	89.78	90.00
K. Neelkanth	96.85	96.67
CD (0.05)	3.92	4.28
CV (%)	2.47	2.66

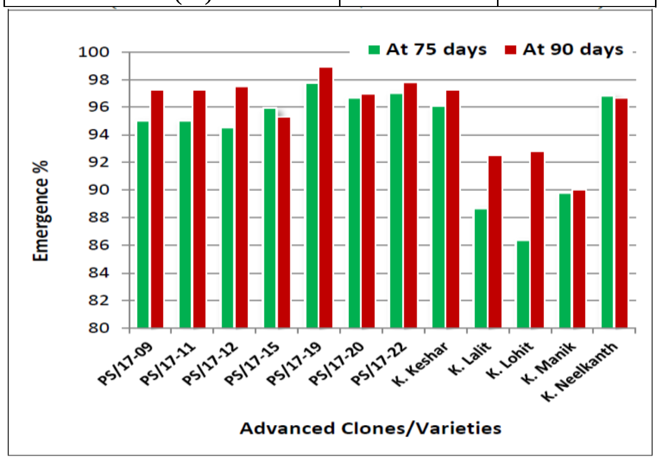

Fig. 1: Plant Emergence of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23)

Total tuber yield

The total tuber yield was recorded maximum in PS/17-09 (30.64 t/ha) followed by PS/17-12 (30.42 t/ha) in 75 days crop experiment. In the 90 days crop experiment the total tuber yield was highest in PS/17-09 (36.88 t/ha) performed better than the controls followed by PS/17-20 (32.75 t/ha), PS/17-12 (31.82), PS/17-11 (30.61) performed significantly at par with the controls. (Table-2).

Table 2 : Total tuber Yield (t/ha) of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23).

Advanced clones /Varieties	Total tuber Yield (t/ha)	
	At 75 days	At 90 days
PS/17-09	30.64	36.88
PS/17-11	27.23	30.61
PS/17-12	30.42	31.82
PS/17-15	26.13	26.44
PS/17-19	27.83	26.65
PS/17-20	26.68	32.75
PS/17-22	28.19	30.85
K. Kesar	27.35	27.72
K. Lalit	23.76	28.15
K. Lohit	26.23	35.14
K. Manik	22.68	16.87
K. Neelkanth	24.94	29.03
CD (0.05)	3.28	5.68
CV (%)	8.26	12.59

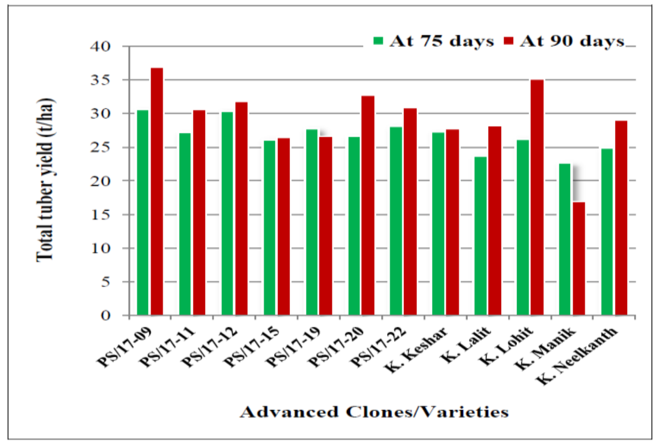

Fig. 2 : Total tuber Yield (t/ha) of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23)

Marketable tuber yield

The marketable tuber yield was recorded after subtraction of weight of very small tubers from the total tuber yield. In 75 days crop marketable tuber yield was maximum in PS/17-09 (29.56 t/ha) significantly superior over planted control varieties. In the 90 days crop highest marketable tuber yield was recorded in PS/17-09 (34.96 t/ha) followed by PS/17-20 (30.21 t/ha) significantly at par with the most of the control varieties (Table-3).

Table 3 : Marketable tuber Yield (t/ha) of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23)

Advanced clones /Varieties	Mkt. tuber Yield (t/ha)	
	At 75 days	At 90 days
PS/17-09	29.56	34.96
PS/17-11	26.32	28.05
PS/17-12	27.85	30.07
PS/17-15	24.74	25.13
PS/17-19	24.41	24.70
PS/17-20	23.28	30.21
PS/17-22	24.32	28.59
K. Kesar	26.21	26.28
K. Lalit	23.41	26.86
K. Lohit	24.88	33.78
K. Manik	21.72	16.04
K. Neelkanth	24.26	27.17
CD (0.05)	3.13	5.29
CV (%)	8.29	12.31

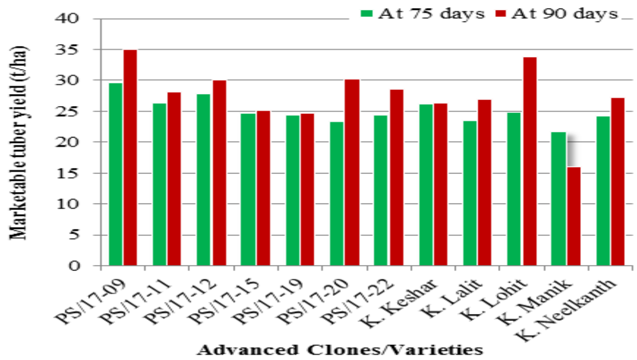

Fig. 3: Marketable tuber Yield (t/ha) of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23)

Dry Matter

The dry matter content plays very important role in selection of clones. The range varies from 17.42% (PS/17-11) to 15.42% (PS/17-09). The advanced clones PS/17-11 performed better than the controls except K.Lalit during 75 days crop. In 90 days crop it varies from 19.50 (PS/17-19) to 16.50% (PS/17-12). The dry matter performance of PS/17-19 & PS/17-11 were significantly superior over the planted control varieties (Table 4).

Plate 3 : Tubers of introduced advanced clones in AICRP

Table 4 : Dry Matter (%) of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23)

Advanced clones /Varieties	Mkt. tuber Yield (t/ha)	
	At 75 days	At 90 days
PS/17-09	15.42	17.50
PS/17-11	17.42	19.34
PS/17-12	15.50	16.50
PS/17-15	15.92	17.41
PS/17-19	16.42	19.50
PS/17-20	16.09	17.92
PS/17-22	16.59	18.25
K. Keshar	17.33	18.34
K. Lalit	18.21	19.92
K. Lohit	15.25	17.25
K. Manik	17.11	18.33
K. Neelkanth	16.71	18.17
CD (0.05)	0.63	1.01
CV (%)	2.16	3.22

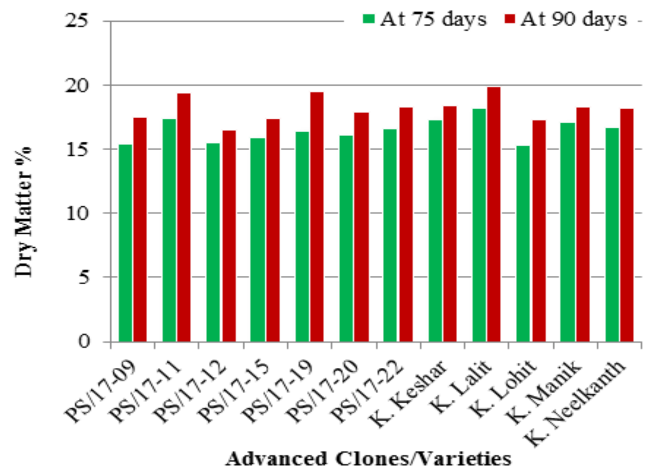

Fig. 4: Dry Matter (%) of advanced clones (Pooled data 2020-21, 2021-22 & 2022-23)

Plate 2: Sprouted tubers of advanced clones

Data collection and recording

The important observations were recorded for range of plant emergence (%), Total Tuber Yield (t/ha), Marketable tuber yield (t/ha), bio-chemical components and dry matter (%). The other important observations like Plant Emergence (%), total tuber yield (t/ha), marketable tuber yield (t/ha), dry matter (%) and Dry matter (%) were recorded at different physiological stages of the crop. Plant emergence was recorded at 30 days after planting by counting and calculation of percentage with germinated tubers over total planted tubers per plot, Total Marketable yield was calculated by weighing of the whole produce harvested from a plot (total tuber yield) & designated as total tuber yield per plot. The marketable tuber yield (kg/plot) was recorded by eliminating very small grade tubers from the total tuber yield of the plot and designated as marketable yield per plot. Dry matter (%) was calculated by keeping 200g fresh tubers during the harvesting from each replication. These tubers were cut into small pieces followed by 72 hours drying in hot air oven. After drying of the cut potatoes these were weights on the electronic balance. The measured cut tuber weight of the dry matter (%) of the respective advanced clones and varieties. The biochemical parameters were evaluated and estimated at ICAR CPRI Shimla laboratory by using standard procedures of estimation for each nutritional component.

Table 5: Nutritional Status of selected advanced clones and control varieties.

Advanced clones /Varieties	Zn (ppm)	Fe (ppm)	Carotenoid (µg/100-gram fresh weight)	Anthocyanin (mg/100-gram fresh weight)	Vitamin C (mg/100 -gram fresh weight)
PS/17-9	21.33	26.40	37.60	5.35	37.05
PS/17-11	24.20	28.19	139.70	13.57	41.57
PS/17-12	28.34	34.66	113.90	4.58	34.56
PS/17-15	19.52	25.23	178.90	2.68	41.85
PS/17-20	29.62	28.98	189.60	2.89	19.35
PS/17-22	19.61	26.32	20.90	1.93	30.59
K. Lalit	27.48	49.53	136.90	0.94	24.12
K. Lohit	26.15	32.54	124.00	0.84	28.89
K. Manik	26.55	42.70	79.05	0.93	31.54
K. Neelkanth	25.25	47.26	85.30	1.00	30.81

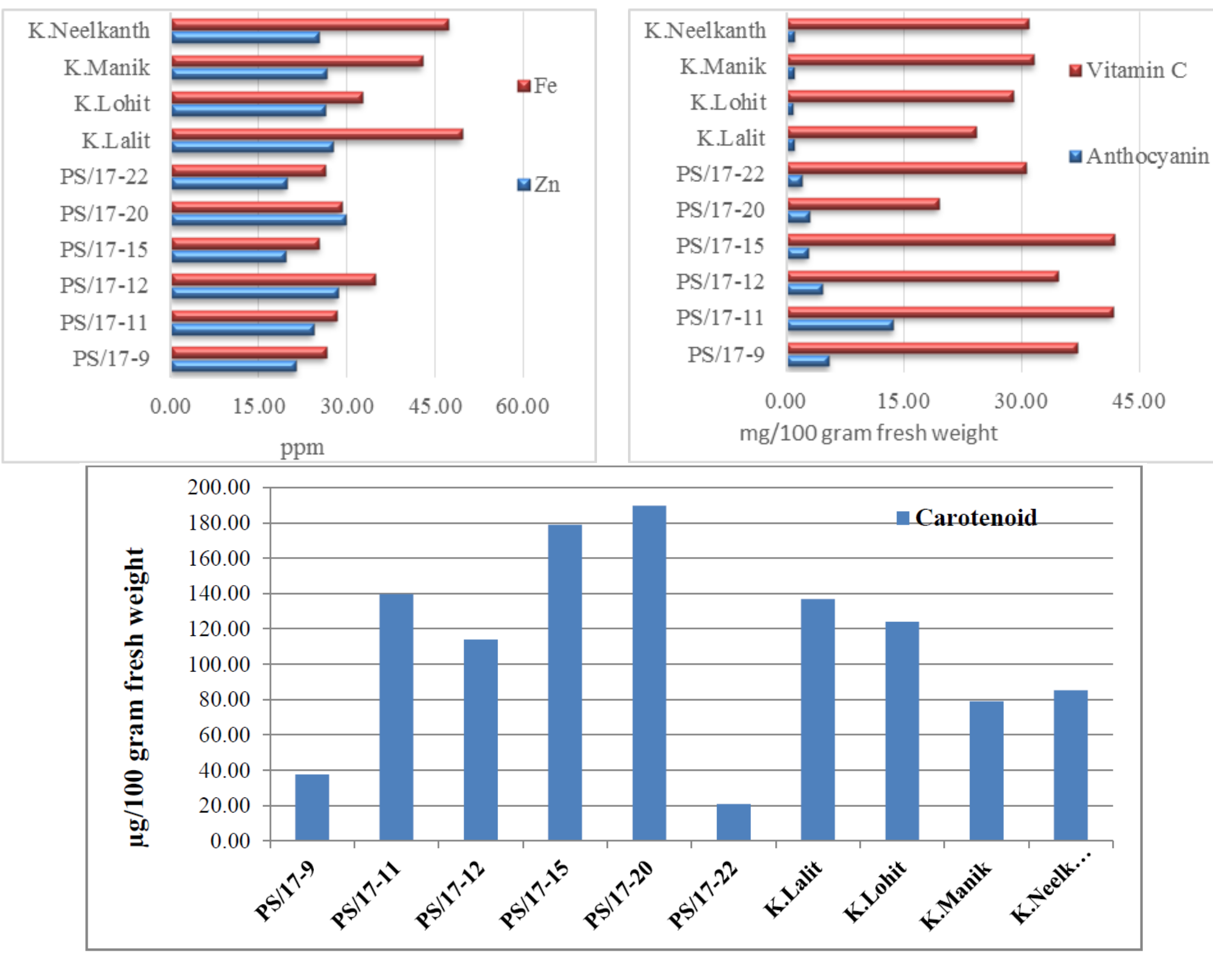

Fig. 5: The important nutritional components in Advanced clones and varieties of potato.

The nutritional components of different advanced clones showed variation in terms of Zn content, was highest in PS/17-20 (29.62 ppm), followed by PS/17-12 (28.32). The Fe content was highest in Kufri Lalit (49.93 ppm) followed by Kufri Neelkanth (47.26 ppm), Kufri Manik (42.70 ppm) and PS/17-12 (34.66 ppm). The carotenoids were highest in PS/17-20 (189.6 µg) followed by PS/17-15 (178.9 µg). The other important components of quality parameters were vitamin C and Anthocyanins were highest in PS/17-15 (41.85 mg), PS/17-11 (41.57 mg) and PS/17-11 (13.57 mg) respectively (table5).

Weightage score-card of selected advanced clones

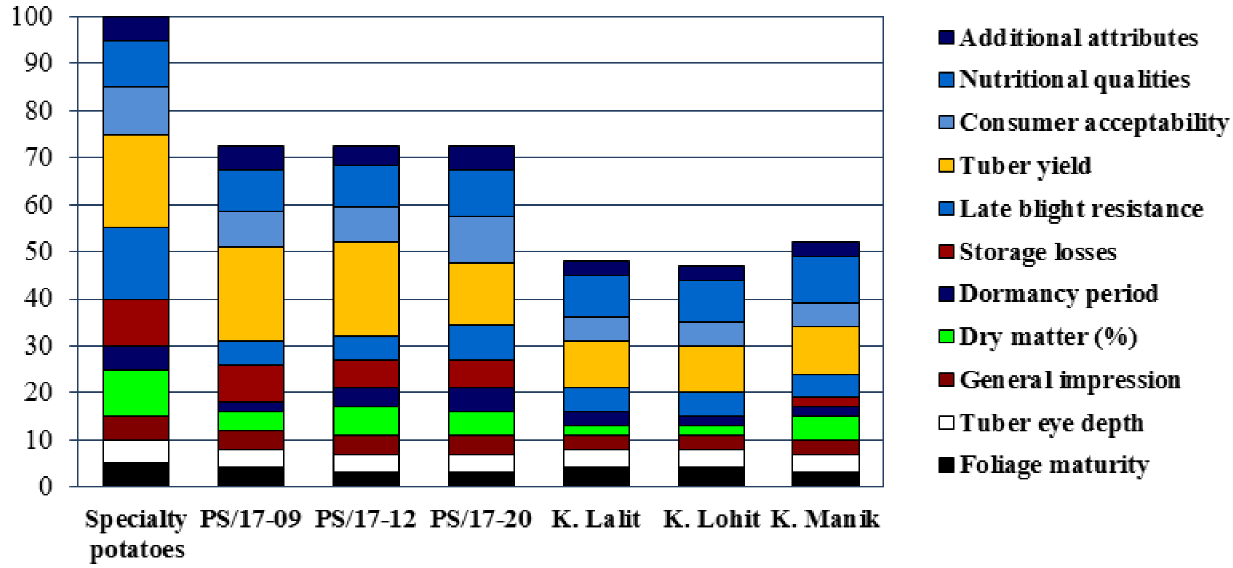

Fig-6: Weightage Score Card of advanced clones and potato varieties

The weightage scorecard indicated the outstanding performance of advanced clones, PS/17-09, PS/17-12, and PS/17-20 compared to popular varieties across multiple parameters. These included additional agronomic attributes, nutritional qualities, consumer acceptability assessed through organoleptic values, tuber shape, tuber yield, and cooking time. Among all traits, the most critical parameters for successful cultivation were disease resistance, storage life, dormancy period, and dry matter content.

Discussion

The medium maturing red skin and purple skinned advanced clones viz., PS/17-09 and P S/17–12 were suitable for table potatoes. The total tuber yield was maximum in PS/17-09 (36.88 t/ha) followed by PS/17-20 (32.75 t/ha) and PS/17-12 (31.82 t/ha). The colour of PS/17-09 and PS/17-12 is deep red skin colour with round tubers, shallow eyed and yellow fresh colour. The dry matter content plays important role in processing varieties as it is positively correlated with the quality of products like chips, French fries etc. As per organoleptic test these advanced clones bear Mealy texture with pleasant flavour. The tubers of these advanced clones cook easily (15-18 minutes) and cooked and boiled tubes were free from any discolouration after cooking. These clones do not have any internal or external defect during harvesting and after storage of the tubers.

Conclusion

The yield, yield attributing and quality traits like plant emergence (%), total tuber yield (t/ha), marketable tuber yield (t/ha), nutritional components and dry matter (%) of advanced clones were significantly superior or at par with control varieties. and do not have any internal or external defect during harvesting and after storage of the tubers. On the basis of consistent performance over the three consecutive years, the advanced clones PS/17-09 and PS/17-12 are promising for multilocation testing and competent variety release proposal.

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