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Evaluation of advanced processing hybrids and varieties of potato (*Solanum tuberosum* L.) for chipping performance and yield for North-Central India

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Abstract
A field experiment was conducted at ICAR-Central Potato Research Institute RS, Gwalior, Madhya Pradesh during 2018-19 and 2019-20 to evaluate advanced potato hybrids and varieties for growth yield and biochemical parameters for commercial cultivation for the North Central region of India. A total of 14 potato cultivars in which 6 hybrids and 8 varieties were evaluated. The experiment was planned in three replications in randomized block design. Variation in growth parameters *viz*, seed weight, Plant height (cm), compound leaves and stems/plant and vigor were recorded in two year among hybrids and varieties tested under study. Hybrid MP/10-172 recorded higher non processing grade (<45 mm) tuber yield (t/ha) at 75 DAP and at senescence and hybrid MP/8-1900 for 90 DAP over all others hybrids/varieties. For processing chip grade (45-75 mm tuber) Kufri Lauvkar for 75 DAP, Tauras for 90 days, and MP/10-172 at senescence recorded significantly mean higher yield. Processing chip grade (>75 mm) significantly mean higher yield was recorded at 75 DAP and senescence in hybrid MP/6-39 whereas for 90 DAP high yield was in K. Frysona and hybrid MP/6-39. Significantly mean higher total tuber yield (t/ha) was recorded in MP/6-39 in all three days of potato harvesting 75, 90 and at senescence with Kufri Chipsona 4 at 75 DAP under varied climatic situations. Dry matter content was in acceptable limit in all cultivar except MP/4-816, K. Lauvkar, K. Surya, K. Jyoti and K. Chipsona-4 at 75 DAP and only in MP/4-816 at 90 DAP. Reducing sugar content was low in K. Chipsona-1 and K. Chipsona-4 sequentially at 75 DAP and 90 DAP. Low phenol content recorded in MP/10-172 in both harvesting days. K. Chipsona-1 at 75 DAP and Atlantic at 90 DAP contains mean lowest free amino acid content. These processing hybrids/ varieties can be made suitable to meet the need of the potato industry by harvesting manipulations and will sustain farmer's income in the changing climate scenario under North-Central India and hybrid MP/6-39 found to be most suitable under the present study.

Keywords: Potato, variety, hybrid, dry matter, processing grade tuber, non processing grade tuber, tuber yield, amino acids, phenols and reducing sugars

Introduction
After maize the potato is the most widely distributed crop in the world. In central India where potato crop duration is around 90-100 days where it is grown in winter under mild temperature and short days where photo period is about 10hr a day from October to February. Central region is free from major potato diseases. In India, demand for processed potato products like chips and french fries is increasing continuously mainly due to improved living standard, increased urbanization, preference to fast foods and expanding tourist trade. As a result, the farmers are finding it remunerative to grow processing varieties of potatoes. The north-western and west-central plains are ideal for providing raw material for processing industries (Pandey *et al*, 2005) [14]. The state of Madhya Pradesh in central India has emerged as retail hub of processing of potato and malwa potato has gained reputation for potato chips processing because produced potato have a quality of high dry matter & low sugar, which is a gift of nature (www.mponline.com, 2013).

Development of indigenous processing varieties like Kufri Chipsona-1, Chipsona-2, Chipsona-3, Chipsona-4 and Himsona and Frysona released by Central Potato Research Institute (CPRI), Shimla have been found fit and advantageous for potato processing. Few exotic varieties *viz*. Lady Rosatta and Atlantic for chip and Kennebec and Sanata for French fries purpose are grown in India. These varieties have >21% dry matter content in tuber, contain low reducing sugars (<0.1% on fresh weight) and are most suitable for producing chips, French fries and dehydrated products. Generally, late maturing varieties contain high dry matter, as compared to early maturing varieties. Keeping in view, the future demand of quality raw material for processing industries in India and utilization of more potato produce towards value addition, short duration varieties having good yield potential (30-35t/ha) with high dry matter (21-23%) and low reducing sugars (150mg/100g fresh weight) are required.

Material and Methods

Field experiments were conducted during 2018-19 and 2019-20 at the Research Farm of ICAR-CPRS Maharajpura, Gwalior (M.P.) Under All India Coordinated Research Project during *rabi* season in Random Block Design with three replications. Treatment consists of 6 advanced processing potato hybrids and 8 processing control varieties. Sowing was done on 30th October in 2018-19 and 18th November in 2019-20. The experimental field was well drained with loamy soil.

Well sprouted seed tubers weighing of 35-45 gm were planted at a spacing of 66cm×25cm in the plot of 3.96 m x 3.75 m. Half of the N (112.5 kg/ha), full P (100kg/ha) and K (120 kg/ha) were applied at planting. Remaining half of Nitrogen (112.5 kg/ha) was applied at the time of earthing up (after 25 DAP). N was applied through ammonium sulphate at the time of planting and through urea at the time of earthing up. P and K was applied through single super phosphate and murate of potash. Haulm killing was done at 75, 90 and at senescence. Morphological parameters like number of stems, no. of compound leaves andplant height was observed at 45-50 DAP while canopy cover was observed at 10 days interval upto 90 days. Harvesting was done after 15 days later after skin set in both season. Total and processing grade tuber yield was recorded at harvest. Cultivars were evaluated for tuber dry matter, reducing sugars, phenols and total free amino acids by the standard procedure (CPRI Bulletin 2 bio-chemistry). Data were pooled and analyzed statistically and means were separated according to the least significant differences (LSD) at 0.05 level of probability.

Result and Discussion

Growth parameters

Seed weight / plot was ranged from 3.00 to 3.97 kg/plot, significantly lowest seed weight per plot recorded in MP/4-816 and MP/8-1900 among hybrids but variety Kufri Chipsona-3 found lowest among all treatment. Investigation revealed that germination % was significantly higher in hybrid MP/10-172 (97.78) and was at par with MP/4-816, MP/8-1900, Tauras and others. Overall germination % was > 95% in all the varieties (Table no.1).

Plant height recorded significantly higher in hybrid MP/6-39 (58.61 cm) which was at par with MP/10-172 over others. Variation in plant height was reported by Sandhu *et al*. (2014) [9] and Sadawarti *et al*. (2016) [20] who reported that differences in plant height can be attributed to the differences in the prevailing weather conditions whereas lower plant height is due to the lower temperature experienced by the plants leading to reduced allocation of assimilates (Table no.1).

There was no significant difference recorded among hybrids and varieties for number of stem per plant and mean high number of stem / plant was recorded in K Chipsona-3 (5.38). Luitel *et al*. (2015) [11] reported variation in stem/plant under Nepal conditions among 7 clones and 4 cultivars under Bangladesh conditions (Amanullah, 2010) [2] and 11 new cultivars in Iran conditions (Mohammadi *et al*., 2010) [15]. Number of stems per plant is affected by the number of eyes per seed tuber used (Iritani, 1983) [10] (Table no.1).

Significantly highest no of compound leaves / plant were recorded in Kufri Chipsona-3 (85.67) over other hybrids /controls. Variation recorded in compound leaves/plant in different years of planting by Sadawarti *et al*. (2016) [20]. Varieties with more number of stems tend to have more vegetative growth leading to higher number of leaves (Abubaker *et al*., 2011) [1]. Significantly higher vigor (scale 1-5) was recorded in hybrid MP/10-172, Tauras (4.67) among hybrids and Kufri Jyoti (5) among controls and was at par with Kufri lauvkar, K. Chipsona-1, K. Chipsona-3, K. Chipsona-4 and K. Surya. Variations in the plant vigor (1-10 scale) was recorded in Bangladesh conditions (Hasan *et al*., 2013) [8] (Table no.1).

Yield parameters

Non processing grade (<45mm) tuber yield (t/ha)

For 75 days crop, mean higher non processing grade tuber yield (t/ha) recorded in hybrid MP/10-172 (7.84 t/ha). For 90 days crop hybrid MP/8-1900 (7.21 t/ha) observed significantly mean high tuber yield which was at par with MP/10-172 and MP/6-39. For crop harvested at senescence, hybrid MP/10-172 (8.48 t/ha) recorded significantly high tuber yield over all other hybrids and varieties (Table no.2).

Processing chip grade (45-75 mm) tuber yield (t/ha)

For 75 days crop, significantly mean higher yield of processing grade tuber was recorded in hybrid MP/10-172 (15.30 t/ha) followed by MP/6-39 and other among hybrids but overall control Kufri Lauvkar (18.93 t/ha) recorded significantly high yield of tubers over all other hybrids and varieties. For 90 days crop, hybrid Tauras (23.11 t/ha) recorded significantly high processing grade tuber yield among all hybrids and varieties and at par with hybrid MP/10-172, MP/9-28, K. Chipsona-1, Kufri Lauvkar and K. Chipsona-4 over others. Tuber harvested at senescence significantly mean high processing grade tuber yield recorded in hybrid MP/10-172 (24.75 t/ha) over all other hybrids and varieties (Table no.2).

Processing chip grade (more than 75 mm) tuber yield (t/ha)

For 75 days crop significantly mean higher yield of processing grade tuber was recorded in MP/6-39 (12.78 t/ha) over other hybrids and varieties. For 90 days crop hybrid MP/6-39 (17.23 t/ha) recorded high yield among hybrids but K. Frysona (17.52 t/ha) recorded significantly mean high yield at par with MP/6-39 (17.23 t/ha) and K. Surya (16.72 t/ha) over other hybrids and varieties. For crop harvested at senescence, hybrid MP/6-39 (31.33 t/ha) recorded significantly mean high yield over all other hybrids and varieties and observed that tuber yield of cultivars increased significantly up to the last date of harvest (Table no.2). Similar results also reported by (Ashiv *et al.*, 2018) that varieties with high processing grade tuber yield gives higher return to farmers on supplying the tubers to the industries, therefore this kind of varieties are preferred.

Total tuber yield (t/ha)

For 75 days crop, significantly mean higher total tuber yield (t/ha) was recorded in MP/6-39 (32.59 t/ha) and K. Chipsona-4 (32.03 t/ha) over all other hybrids and varieties. For crop harvested at 90 days, MP/6-39 (43.55 t/ha) recorded significantly mean high tuber yield and it was at par with K. Chipsona-4 (41.95 t/ha) & K. Chipsona-1 (42.04 t/ha) over all other hybrids and varieties. For crop harvested at senescence MP/6-39 (54.22 t/ha) recorded mean high tuber yield which was at par with MP/10-172 (52.54 t/ha) over all hybrids and varieties. In related work there were 27 clones and 8 commercial varieties tested under modipuram conditions, total and marketable tuber yield increased linearly with the delay in harvesting from 60 to 90 days after planting. The increase, however, was faster between the 80 and 90 days after planting than between other successive days after planting intervals. The increase up to 70 days after planting was both due to increase in number of tubers and average tuber weight, whereas at 75 days planting it was mainly due to increase in average tuber weight. It maybe because of the formation of maximum number of tubers 70 days after planting, whereas average tuber weight continued to increase till the last harvest which was at 90 days after planting Pandey *et al.*, (2005) [14] (Table no.2). All cultivars produced minimum yield at early harvest (70 DAP) (Hasnut *et al*., 2015) [9]. Harvesting time can influence the biomass accumulation in potato tuber (Marwaha *et al*., 2005 and Patel *et al*., 2005) [13].

Dry matter

Dry matter content is one of the most important parameter of processing as it determines the yield and texture of the processed product. High dry matter content in potato are ideal for chipping and it has been associated with yield, crispness, mealiness and reduced oil uptake in fried products (Grewal and Uppal 1989) [7]. For 75 days crop hybrid MP/9-20 (23.59%) recorded mean high dry matter content and was at par with Tauras (22.69%) followed by MP/6-39 over other hybrids and varieties. For 90 days crop hybrid Tauras (26.14%) found significantly mean high dry matter, at par with MP/9-28 (25.76%), MP/8-1900 (25.32%) and K. Chipsona-1 (24.89%) followed by MP/6-39 over others (Table no.3).

Reducing sugar

Reducing sugar (mg/100gm) content of potato tuber is of great importance in terms of processing, especially for fried products. Potato contains high reducing sugars make chips unacceptable for consumers owing to excessive darkening and development of off-flavor (Marwaha 1999) [12]. At 75 DAP control K. Chipsona-1 (154.17) recorded mean significantly low content of reducing sugar over all other hybrids and varieties followed by MP/6-39. Potato harvested at 90 DAP control K. Chipsona-4 (156.33) found significantly mean low reducing sugar content over others (Table no.3).

Phenols and total free amino acids

Phenolic compound (mg/100gm) has been associated with enzymatic discoloration of product which is undesirable trait and decrease cooking quality of tubers. Some of the constituents like tyrosine and ortho-dihydric phenols present in tuber react with oxygen in the presence of polyphenol oxidase enzyme and flesh of tuber turn brown (Schaller and Amberger, 1974). Hybrid MP/10-172 (90.33) found significantly mean low phenol content over all other hybrids and varieties when tuber harvested at 75 DAP. Potato harvested at 90 DAP hybrid MP/10-172 (94.50) recorded significantly mean low phenol content and it was at par with Tauras (97.83) and K. Chipsona-3 (99.17) over all others (Table no.3).

Free amino acids (mg/100gm) react with reducing sugars at frying temperature to cause non-enzymatic browning or dark coloration of chips (Roe *et al*. 1990) [18]. Free amino acid content of the cultivars increased up to last date of harvest. Potato harvested at 75 DAP found that K. Chipsona-1 (94.33) contains mean lowest free amino acid content and it was at par with MP/10-172 (100.33) and Atlantic (95.50) followed by MP/6-39 over other treatments. Potato harvested at 90 DAP significantly low amount of amino acid observed in control Atlantic (91.67), which was at par with hybrid MP/10-172 (92.00), MP/9-28 (93.00), MP/6-39 (96.83) and control K. Frysona (96.83) over others (Table no.3).

Table 1: Mean value of seed weight per plot, germination %, No. of stem/plant, No. of compound leaves/plant, plant height and plant vigor after 50 days of planting for different varieties of potato.

Treatment	Seed weight / Plot	Germination %	No. of stem/Plant	No. of compound leaves/plants	Plant height (cm)	Plant Vigor (visual scale 1-5)
MP/4-816	3.07	97.59	4.93	65.05	43.94	4
MP/6-39	3.52	94.58	4.27	72.91	58.61	4.33
MP/8-1900	3.07	97.55	5.22	53.17	47.89	3.5
MP/9-28	3.39	92.13	4.93	53.67	50.61	4.17
MP/10-172	3.09	97.78	3.98	55.17	55	4.67
Tauras	3.12	97.08	4.27	55.17	46.94	4.67
K. Chipsona-3	3.04	96.16	5.38	85.67	51.44	4.5
K. Chipsona-1	3.1	95.33	4.55	72.94	52.33	4.67
Atlantic	3.23	96.71	5.17	76.28	53.67	4.5
K. Chipsona-4	3.29	96.57	4.77	69.44	44.67	4.83
K. Frysona	3.9	93.24	4.55	64.5	50.39	3.67
K. Lauvkar	3.51	97.36	4.43	54.89	48.44	4.83
K Jyoti	3.19	96.75	4.88	56.11	46.81	5
K. Surya	3.26	97.36	4.87	54.56	48.67	4.5
SE(m)	0.06	0.84	0.28	1.37	1.34	0.23
C.D.	0.16	2.45	N/A	3.99	3.93	0.66

Table 2: Mean total yield (t/ha) and yield of processing and non processing chip grade of tubers at 75, 90 and at senescence.

Treatment	less than 45 mm at 75 DAP	less than 45 mm at 90 DAP	less than 45 mm at Senescence	Tuber 45-75 mm 75 DAP	Tuber 45-75 mm90 DAP	Tuber 45-75 mm Senescence	More than 75 mm at 75 DAP	more than 75 mm at 90 DAP	more than 75 mm at senescence	Total yield 75 DAP	Total yield 90 DAP	Total yield Senescence
MP/4-816	4.27	5.04	4.76	11.32	17.73	19.36	4.78	10.07	24.05	20.36	32.84	48.17
MP/6-39	4.89	6.93	4.38	14.92	19.39	18.5	12.78	17.23	31.33	32.59	43.55	54.22
MP/8-1900	7	7.21	6.72	14.87	19.95	22.35	5.56	9.19	16.71	27.43	36.34	45.77
MP/9-28	6.56	5.98	5.1	14.63	22.54	20.11	4.83	9.7	20.6	26.02	38.23	45.81
MP/10-172	7.84	7.08	8.48	15.3	22.51	24.75	3.74	8.78	19.3	26.87	38.37	52.54
Tauras	4.53	5.07	4	13.49	23.11	19.01	2.76	5.19	8.08	20.78	33.37	31.1
K. Chipsona-3	4.39	6.53	6.43	15.68	17.87	16.77	6.41	12.56	17.68	26.48	36.97	40.87
K. Chipsona-1	5.36	6.42	6.1	16.33	21.92	19.84	7.11	13.71	20.5	28.79	42.04	46.45
Atlantic	4.04	4.82	4.74	13.92	18.79	17.68	4.15	10.58	15.81	22.11	34.19	38.23
K. Chipsona-4	5.29	7.17	6.03	17.24	22.67	20.12	9.5	12.12	24.2	32.03	41.95	50.35
K. Frysona	3.87	5.7	4.86	12.65	16.19	20.18	7.51	17.52	23.31	24.04	39.41	48.35
K. Lauvkar	5.19	4.43	5.06	18.93	22.17	16.43	6.33	6.11	14.34	30.45	32.71	35.83
K Jyoti	4.51	3.43	4.1	15.3	16.77	16.19	6.53	7.23	10.2	26.34	27.43	30.48
K. Surya	3.05	5.23	4.21	14.06	17.17	16.19	11.48	16.72	24.46	28.59	39.12	44.86
SE(m)	0.23	0.33	0.32	0.48	0.6	0.41	0.33	0.61	0.6	0.61	1.01	0.72
C.D.	0.67	0.96	0.93	1.4	1.76	1.21	0.96	1.78	1.75	1.79	2.95	2.1

Table 3: Mean value of Dry matter %, Reducing sugar, Phenols and total free Amino acids (mg/100gm) at 75 and 90 DAS.

Treatment	Reducing Sugar (75 DAP)	Reducing Sugar (90 DAP)	Dry matter (75 DAP)	Dry matter (90 DAP)	Phenols (75 DAP)	Phenols (90 DAP)	Amino acids (75 DAP)	Amino acids (90 DAP)
	pooled	Pooled	pooled	pooled	pooled	pooled	pooled	pooled
MP/4-816	184.15	181.83	18.69	19.21	123.5	116.7	103.29	109.83
MP/6-39	162.33	187	21.03	23.33	120.33	123.17	102.5	96.83
MP/8-1900	193.5	192.67	21.85	25.32	98	101.81	102.83	99.17
MP/9-28	190.58	183	23.59	25.76	96.17	102.83	102.03	93
MP/10-172	182.46	189.83	22.19	23.8	90.33	94.5	100.33	92
Tauras	190	227	22.69	26.14	96.02	97.83	101.17	100.67
K. Chipsona-3	185.17	180.33	21.9	22.84	94.67	99.17	104	97.83
K. Chipsona-1	154.17	184.83	21.21	24.89	112.17	113	94.33	99.5
Atlantic	164.5	189	20.45	24.07	107.67	104.67	95.5	91.67
K. Chipsona-4	192.67	156.33	19.8	21.82	108.67	105.33	108.17	97.5
K. Frysona	199.65	175.67	21.98	23.86	139.5	108.5	110.17	96.83
K. Lauvkar	216.5	181.83	18.62	20.62	110.33	106	101.33	105.83
K Jyoti	222.83	188.17	19.72	20.76	119.83	111.67	104.67	101
K. Surya	230.83	187.33	19.1	21.59	127	119.83	104.33	100.17
SE(m)	1.11	0.97	0.36	0.53	1.23	2.31	2.27	1.94
C.D.	3.24	2.83	1.06	1.55	3.59	6.74	6.64	5.68

Conclusion

The result clearly indicate that MP/6-39 were most suitable for chipping and gives high yield in all three days of potato harvesting 75, 90 and at senescence. Yield of processing grade tuber was high in MP/6-39. Most of these hybrids/varieties contain dry matter, phenols and reducing sugars in acceptable limit which is required for processing. The cultivation of these varieties will meet the requirements of potato processing industries located in this region which will not only benefit the industry but will bring remunerative return to the farmers.

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