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Evaluation of table and processing varieties of potato (*Solanum tuberosum* L) for North-Central India

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Abstract
A field experiment was conducted at ICAR-Central Potato Research Station, Gwalior, Madhya Pradesh during 2014-15, 2015-16 and 2016-17 to evaluate high yielding table and processing potato varieties for commercial cultivation for the North Central region under changing climatic situations. A total of 11 potato varieties *viz* Kufri Chandramukhi, Kufri Lauvkar, Kufri Khyati, Kufri Surya, Kufri Pukharaj, Kufri Jyoti, Kufri Bahar, Kufri Badshah, Kufri Garima, Kufri Pushkar, and Kufri Chipsona-1 got tested. The experiment was planted in three replications in randomized block design. Variation in growth parameters *viz*, germination%, Plant height (cm), compound leaves and stems/ plant and vigor were recorded between the three years of study and the year 2016-17 found best for these parameters. Dry matter % was recorded significantly better in the year 2015-16. WUE (Kg/hamm) was significantly higher in the crop year 2015-16 and 2016-17 for 60, 75 and 90 days of crop. Significantly higher marketable and total tuber (t/ha) yield were recorded in the crop year 2015-16 and 2016-17 over 2014-15. Among varieties, Kufri Pushkar (91.88) and Kufri Chipsona-1(92.57) recorded significantly higher germination % over Kufri Bahar (86.76). Variation among varieties was recorded for growth parameters. Dry matter was significantly highest in Kufri Chipsona -1 19.04, 19.49% and 21.77% for 60, 75 and 90 days crop respectively among all the varieties under test. WUE (Kg/hamm) was significantly highest in K. Pukhraj followed by Kufri Khyati and Kufri Pushkar for 60, 75 and 90 days crop. Similar trend for marketable and total tuber yield as well as higher net return and B: C ratio were recorded in Kufri Pukhraj, Kufri Khyati and Kufri Pushkar for 60, 75 and 90 days crop under varied climatic situations of three years. Hence, Kufri Chipsona-1 is identified for processing and Kufri Pukhraj, Kufri Khyati and Kufri Pushkar as table purpose varieties for cultivation. These varieties will sustain farmer's income in the changing climate scenario under North-Central India.

Keywords: Variety, potato, dry matter, water use efficiency, marketable tuber, tuber yield and B: C ratio

Introduction
North-central plains consists of western-central Uttar Pradesh and North-western Madhya Pradesh where potato crop of 90-100 days duration is grown during winter under milder temperatures and short days (10 h day) from Oct.–Jan./Feb. The region is free from major potato diseases. Varietal features of short-day adapted, medium maturing, moderately resistant to late blight, slow rate of degeneration are desirable for the zone (Gaur *et al.,* 1999 and Patil *et al.,* 2014) [11, 41]. In North-Central India especially Agra and Gwalior are important seed and ware potato growing regions of the country having high yield potential due to mild winters, but are constrained by high water deficit (Govindakrishnan *et al.*, 2015) [14].
Potato plant is sensitive to several climatic factors, such as temperature, rainfall, humidity and photoperiod which exert a considerable influence on its growth and tuber development. Good crop growth is observed when days are sunny and nights are cool (Ghosh *et al.*, 2000) [13]. Low temperature, high light intensity and short days are conducive for early initiation of tuberization and subsequent tuber development (Das *et al.*, 2014) [7]. Potato requires optimum soil moisture throughout its growing period and its productivity is hampered to a great extent in absence of these favorable conditions (Cabello *et al.*, 2013) [5]. Minimum of 70-90 days of favorable cool season is required to obtain an economical potato yield. The optimum planting date for potatoes in Indo-Gangetic plains is the middle of October and harvesting in February/March (Kumar *et al.*, 2007) [24]. Altering the planting and harvesting times can influence the accumulation of heat units and ultimately the potato yield (Khan *et al.*, 2011) [21].

Development of heat tolerant cultivars and adjustment in production system management has made it possible with very high productivity, even in subtropical and mild subtropical and warmer climates (Singh *et al*. 2008, Malhotra and Srivastava 2014) [52, 28].

Climate change and its variability are posing the major challenges influencing the performance of agriculture including annual and perennial horticulture crops (Malhotra, 2017) [29]. Potato is well known for its exact temperature and day length requirement for tuber formation (20 ^{0}C), so it becomes the most vulnerable crop for climate change. An increase in temperature of above 21 ^{0}C cause sharp reduction in the potato tuber yield, at 30 ^{0}C complete inhibition of tuber formation occurs (Sekhawat, 2001, Swarup *et al.*, 2012) [48 and 54]. Climate change scenario is supposed to adversely affect potato production, profitability and productivity in India (Dua *et al*., 2013) [8]. Modelling research at CPRI suggests that potato yield is estimated to fall by 9.56% and 16% by 2020 and 2050 at national level if needed steps are not taken to mitigate the effects of climate change. (Singh *et al.*, 2009, CPRI- 2015) [6, 51].

Tuberization (tuber initiation and tuber bulking) and gross photosynthetic rate are inhibited by moderately high temperatures which ultimately affects the total biomass production (reduced tuber numbers and size) and tuber yield (Peet and Wolfe, 2000, Khan *et al*. 2003,Minhas and Kumar 2005, Fleisher *et al*., 2006 and Paul and Gogoi, 2013) [43, 22, 10, 42]. As a result of climate change, it is expected that in the coming decades a greater pro-portion of potato crop area will be exposed to high temperatures (Monneveux *et al*., 2014) [35]. In the Indo-Gangetic Plains of India with a potato acreage of 1.5 Mha, the potato crop duration is heat and water sensitive and projected to decrease because of climate change (Kumar *et al*., 2005) [25].

Dry matter (DM) content is one of the most common indicators of tuber quality (Storey & Davies, 1992) [53]. Potato produces the highest dry matter per unit area compared to that of other crops (Zelalem *et al*., 2009) [59]. Early potato varieties have lower DM content than main crop potatoes (Gray & Hughes, 1982) [15]. This genetic trait is modified by many other factors like cultural practises, climate, and soil may largely affect final DM content (Simson *et al.*, 2016) [50]. The WUE is reported to either increase or decrease due to climate change. The subtropical plains of India where potato is grown in the autumn season under irrigation, increase in ET as well as decrease in WUE are important implications of climate change (Kumar *et al.*, 2007) [35].

Cultivar selection is very important for growers trying to market quality product (Mohammadi *et al.*, 2010) [34]. The farmers need varieties that show high performance for yield and other essential agronomic traits having reliable superiority over a wide range of environmental conditions and also over the years. The basic cause for difference in the performance of genotypes over environments is the occurrence of genotype-environment interaction (GEI) Gedif and Yigzaw (2014) [12]. Till today CPRI has developed 51 varieties for different agro-climatic zones of India (Kumar *et al.*, 2014). Presently 23 varieties are under cultivation and occupy nearly 95% of the total potato area in India. For North central plains a total of 21 varieties were developed by CPRI, Out of which 11 varieties were taken under study.

It is necessary to evaluate table and processing varieties for the farmers which can yield higher, having good quality so that farmers can generate higher income. Hence, the present investigation was undertaken to evaluate table and processing potato varieties for commercial cultivation for the North Central region of India.

Material and methods

The experiment was conducted at ICAR-Central Potato Research Station, Gwalior during 2014-15, 2015-16 and 2016-17. Situated at 26^o 13'N latitude 78^o 14' East longitude and 206 m above sea level are the geographical coordinates of experimental field, Gwalior MP. The soil was silty clay loam with pH 7.4 and EC 0.23 dS/m, low in organic (0.37%) and available nitrogen (165kg/ha), medium in available phosphorous (20kg/ha) and high in available potassium (395 kg/ha) and 1.28g/m3, 2.56 f/m3 and 44.47% in case of bulk density, particle density and water holding capacity. Annul average rainfall in the range of 600-800mm with low water availability in the region.

11 varieties recommended for North-Central India were planted in this trail *viz* early duration: Kufri Chandramukhi, Kufri Lauvkar, Kufri Khyati, Kufri Surya and Kufri Pukharaj, medium duration: Kufri Jyoti, Kufri Bahar, Kufri Badshah, Kufri Garima, Kufri Pushkar, and Kufri Chipsona-1. Experiment was planted in Randomized Block Design in three replications with well sprouted tubers of 40-60 g in plot size 3x3m. During 2014-15 and 2015-16 planting was done in first week of November and in 2016-17 planting was done in last week of October. Row to row distance was 60 cm and plant to plant distance was 20 cm. Recommended dose of fertilizers (N: P: K) was applied in the ratio of 180:80:120. 50% of N and full dose of P and K were applied at the time of planting. Rest fifty percent of N was applied at the time of earthing up. Crop was dehaulmed at 60, 75 and 90 days after planting during the years. Data on growth parameters *viz* germination%, vigor, No. of stem, compound leaves and height were recorded at 50 days of planting. Data on tuber number and weight/ ha were recorded at 60, 75 and 90 days after planting during the years. Tubers were divided in two grades <20g (Non marketable), and >20g (marketable) at harvest. Dry matter content were determined by drying 100g of fresh tuber tissue in hot air oven at 60±2 ^{o}C till constant weight and was calculated on fresh weight basis %.Water use efficiency (WUE) was worked out with the following formula (Reddy and Reddi, 2002).

$$\text{WUE} = \frac{\text{Tuber yield kg/ha}}{\text{Water applied through irrigation (mm)}}$$

Economics of various treatments was worked out on the basis of prevailing prices of inputs and output. A net return was calculated by subtracting the cost of total inputs from the cost of total produce. Cost of produce corresponds to value of the harvested crop which is approximately taken as Rs 3000/ton for <20g tubers (non marketable) and Rs 6000/ton for marketable tubers (>20 gm). The variable component in the total cost of inputs was irrigation water and gunny bags. Economics was worked out taking mean tuber yields and B: C ratio was worked out. Benefit cost ratio (B:C) indicates the returns one gets after investing one rupee. It was calculated by dividing the total returns with total costs of cultivation. Economic study was done with data analyzed with simple RBD. Data of the three years were pooled analyzed statistically with two factor RBD and means were separated according to least significant difference (LSD) at 0.05 level of probability.

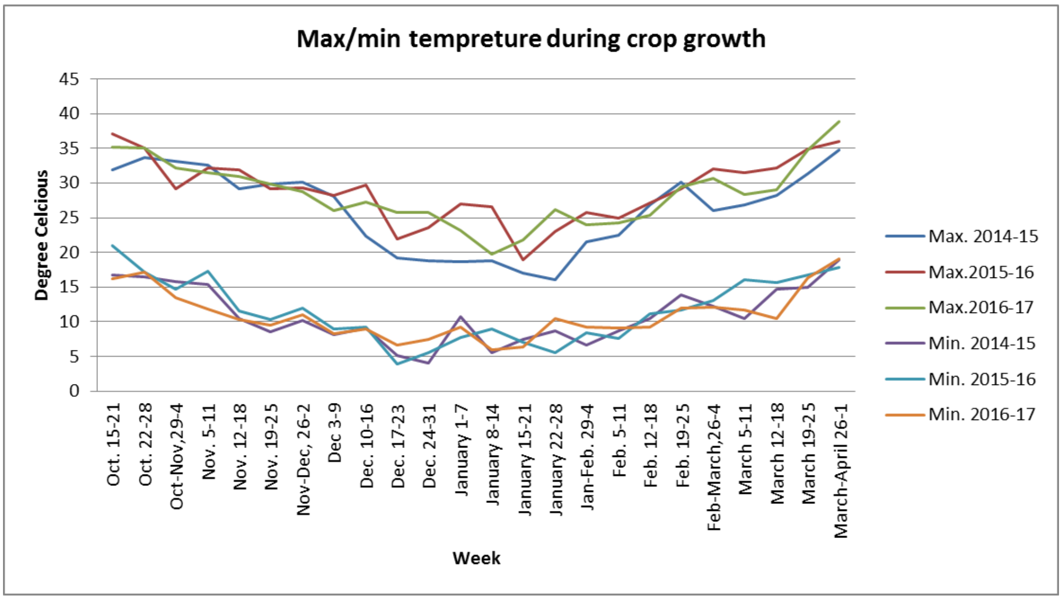

Fig 1: Max/min temperature (2014-15 to 2016-17) during crop growth.

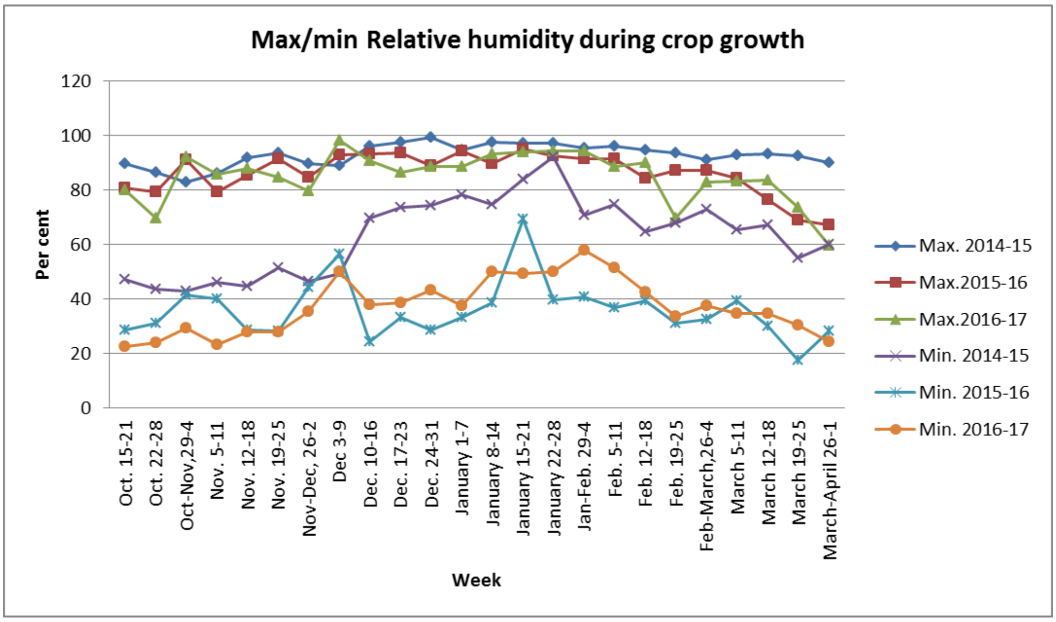

Fig 2: Max/min relative humidity (2014-15 to 2016-17) during crop growth

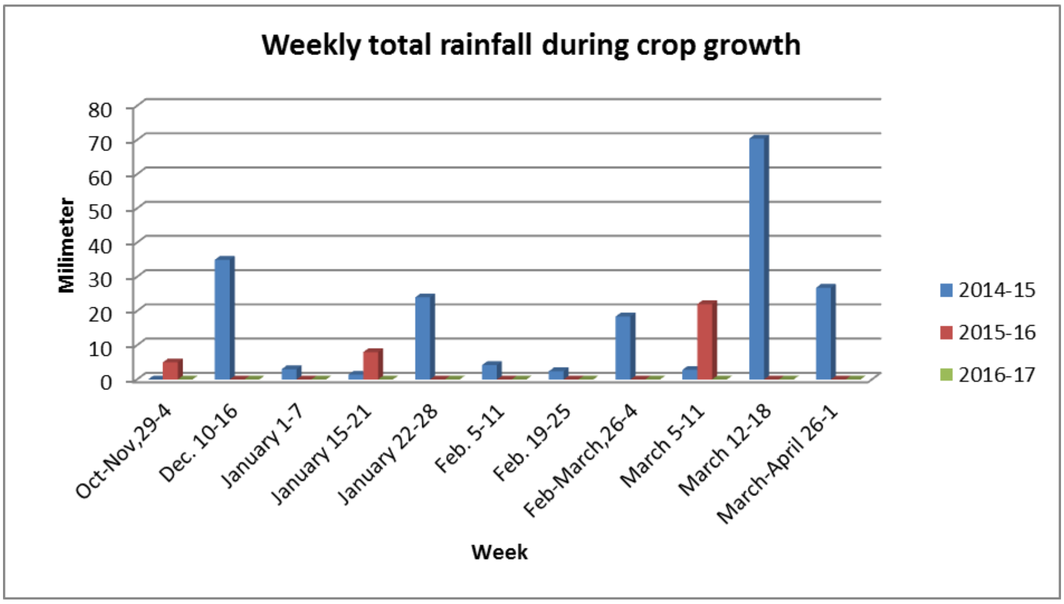

Fig 3: Weekly total rainfall during crop growth period for three year during (2014-15, 2015-16 and 2016-17).

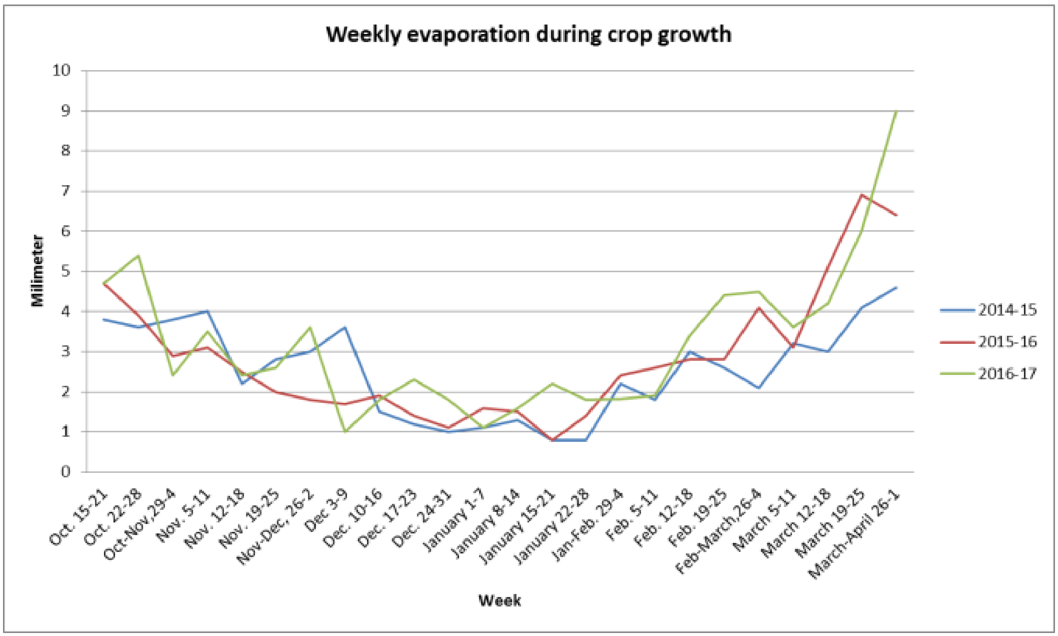

Fig 4: Average weekly evaporation (2014-15 to 2016-17) crop growth

Results and discussion

Growth attributing parameters

Three year experimentation revealed that germination % was significantly higher in year 2014-15 (92.37) and 2016-17 (88.57) over the year 2015-16 (85.66).Highest average germination % (93.27) was reported in the year 2014-15 when 4 varieties were tested under breeder seed production at Gwalior region N-C India (Sadawarti *et al.*, 2016) [47]. Most of the potato cultivars showed a considerable variation for this trait. The germination % was > 85% in all the varieties taken under trail, but Kufri Pushkar (91.88) and Kufri Chipsona-1 (92.57) recorded significantly higher germination % over Kufri Bahar (86.76). In the year x variety interaction, all the interactions recorded >81.00% germinations and significantly highest was recorded in 2014-15 K. Chipsona-1 (99.26%) table 1. Variation in the varietal emergence is due to genetic structure of variety and sprouting ability of tubers. Variation in the varietal germination were reported by Sadawarti *et al.*, 2014 where 92-95% germination was recorded in 4 varieties *viz* Kufri Lauvkar, Kufri Chandramukhi, Kufri Chipsona-1 and Kufri Sindhuri grown under Gwalior region for seed production. Significantly highest plant emergence was recorded in Kufri Chipsona-1 (93.26%) which was found at par with MP/98-172 (92.44%), MP/99-322 (91.76%), MP/-403 (88.88%) when 9 hybrids were tested under Raipur conditions of Chhatisgarh. Significantly maximum emergence in Kufri Chipsona-1 is due to inherent genetic character of that cultivars/ hybrids to more emergences (Bhuwneshari *et al.*, 2013) [4]. This confirms the present study where K. Chipsona-.1 recorded maximum germination over the years. Variation in germination percent was reported in 11 varieties tested under Hoogly conditions of W.B. (Das *et al.*, 2014) [7].

Plant height recorded significantly higher in the year 2015-16 (54.3 cm) and 2016-17 (54.3 cm) over the year 2014-15 (43.1 cm). Variation in plant height was reported by Sandhu *et al.* (2014) [45] and Sadawarti *et al.* (2016) [47] 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. This confirms the result of present study where maximum temperature was low (16-20 ^{0}C) for about one month (December). All the other 7 varieties except KCM, K. Surya and K. Lauvkar recorded significantly higher over K. Garima (42.9 cm). In interaction year x variety, all the interactions recorded significantly higher plant height (cm) except K. Pukharaj and K. Lauvkar of 2014-15 over K. Garima of 2014-15 (table 1). Variation in plant height of 4 varieties at 60 days of planting has been reported in varieties *viz* K Jyoti (43.27 cm), K. Chipsona-1 (49.52 cm), K. Pushkar (46.16 cm) K. Chipsona-1 (54.97) under Mandsaur conditions of M.P. (Jatav *et al.* 2017) [20]. Kumar *et al.* (2005) [20] reported variation in plant height (cm) *viz* K. Pukhraj (62.1), K. Chipsona-1 (63.6) and K. Lauvkar (54.8) under Modipuram conditions of UP. Bhuwneshari *et al.*, 2013 [4] reported average plant heights at 60 DAP ranged from 48.50 - 62.66 cm, with the mean of 56.84 cm among 9 hybrids where tallest plant was measured in Kufri Chipsona-1 (62.66 cm.) and MP/99-403 (62.66 cm.) which were at par with MP/ 99-322 (61.93 cm), MP/98-172 (61.83 cm), Kufri Surya (61.76 cm) and MP/98-71 (56.90 cm). The variation in plant height among different potato cultivars may be due to genetic and inherent character of cultivars/ hybrids of potato which is in accordance with the finding of Kumar *et al.*, 2008, Bhuwneshari *et al.*, 2013 [4] and Enujeke., 2013 [9]. Variation in plant height were reported under Hoogly conditions of W.B. (Das *et al.*, 2014) and other countries Iran (Mohammadi *et al.*, 2010) [34], Bangladesh (Amanullah, 2010) [2] and Nepal (Luitel *et al.* 2015) [27] in different genotypes.

Non significantly higher compound leaves/plant were recorded in the year 2016-17 (62) over both the year (55). Variation in compound leaves/plant in different years of planting were recorded by Sadawarti *et al.* (2016) [47]. Varieties except KCM, K Garima and K. Pukhraj recorded significantly higher compound leaves/plant over K Lauvkar (41). In year x variety interaction, K. Jyoti in 2016-17, K. Bahar, K. Badshah and K. Chipsona-1 in 2014-15 and 2016-17, K. Garima in 2015-16 and K. Pushkar in all the 3 years recorded significantly higher compound leaves/plant (table 1). Jatav *et al.* 2017 [20] reported that number of leaves was maximum in Kufri Pushkar (71.68) followed by Kufri Chipsona-1 (70.75) and Kufri Jyoti (67.53). This confirms the present findings. Varieties with more number of stems tend to have more vegetative growth leading to higher number of leaves (Abubaker *et al*., 2011) [1].

Year 2016-17 (6.0) recorded significantly higher number of stem/plant over year 2014-15(3.9) and 2015-16 (4.3). Average stem/plant was significantly higher in 2012-13 (4.0) and 2014-15 (4.2) over the year 2013-14 (3.7) when 4 varieties were tested for seed production under Gwalior region of N-C India (Sadawarti *et al.*, 2016) [47]. Non-significant differences were recorded among the varieties for number of stem/plant, but highest was recorded in K. Pushkar (5.7) and lowest in K. Lauvkar (3.7). In year x variety interaction, all the varieties planted in 2016-17, K. Badshah in 2014-15 and K. Garima and K. Pushkar of 2015-16 recorded significantly higher number of stem/plant (table 1). The maximum number of shoot/ plant were found in Kufri Chipsona-1 (5.36), which was at par with Kufri Surya (5.27), Kufri Chipsona- 2 (4.90) and MP/98-172 (4.83) (Bhuwneshari *et al.*, 2013) [4]. Luitel *et al.* (2015) [27] reported variation in stem/plant among 7 clones under Nepal conditions and 4 cultivars under Bangladesh conditions (Amanullah, 2010) [2] and eleven new in Iran conditions (Mohammadi *et al.*, 2010) [34]. Stem number per plant is affected by the number of eyes per seed tuber used (Iritani, 2002) [18].

Both the year 2015-16 and 2016-17 (4.7) recorded significantly higher vigour (scale 1-5) over the year 2014-15 (4.1). All the other 8 varieties recorded significantly higher vigor (scale 1-5) over K. Bahar (3.9) except KCM and K. Lauvkar (4.0). In year x variety interaction, K. Jyoti, K. Badshah, K. Pushkar, K. Khyati, K. Pukharj and K. Chipsona -1 recorded significantly higher vigour (scale 1-5) in all the three years. K. Bahar, K. Garima and K. Surya recorded significantly higher vigour (scale 1-5) in 2015-16 and 2016-17. KCM and K. Lavkar recorded significantly higher vigour (scale 1-5) in 2014-15 and 2016-17 respectively (table 1). Similar variations in the plant vigor (1-10 scale) was recorded in Bangladesh conditions (Hasan *et al.*, 2013) [16].

Table 1: Growth and quality parameters during crop growth period, in variety and their interaction

Year / Variety	Growth parameters					Dry matter content %		
Year of planting	**Germination %**	**Plant height (cm)**	**Compound leaves (No)**	**No. of stems**	**Vigor (Scale 1-5)**	**60 days**	**75 days**	**90 days**
2014-15	92.39	43.1	55	3.9	4.1	15.59	16.04	16.86
2015-16	85.66	54.3	55	4.3	4.7	17.19	17.20	18.12
2016-17	88.57	57.5	62	6.0	4.7	16.19	16.61	18.45
SE(m)±	0.80	1.27	3.0	0.3	0.07	0.269	0.25	0.28
C.D P= (0.05)	2.28	3.60	NS	0.7	0.21	0.76	0.70	0.79
Varieties								
Kufri Jyoti	89.75	52.6	59	4.7	4.6	16.27	16.71	17.59
K. Bahar	86.76	58.1	63	4.4	3.9	16.11	16.47	17.59
K. Badshah	87.00	59.6	71	5.5	5.0	15.81	16.47	16.99
KCM	87.68	49.0	43	4.5	4.0	16.80	16.61	17.23
K. Garima	87.10	42.9	58	5.6	4.3	16.56	16.44	18.58
K Pushkar	91.88	52.2	72	5.7	4.8	15.64	15.94	17.25
K. Surya	86.99	47.6	42	4.4	4.3	16.87	16.74	18.40
K. khyati	90.72	54.9	75	5.0	4.7	13.93	14.54	16.20
K. Pukhraj	90.37	51.7	46	4.2	4.9	14.91	15.63	16.35
K. lauvkar	86.99	47.6	41	3.7	4.0	17.62	17.75	17.97
K. Chipsona1	92.35	51.8	61	4.5	5.0	19.04	19.49	21.77
SE(m)±	1.539	2.43	5.7	0.5	0.14	0.52	0.47	0.53
C.D P= (0.05)	4.36	6.89	16.3	N/A	0.39	1.46	1.34	1.51
SE (m) ±	2.67	4.21	9.9	0.9	0.24	0.89	0.82	0.92
Interaction Year x Variety CD P= (0.05)	7.55	11.93	28.2	2.5	0.68	N/A	N/A	N/A

Quality parameter (Dry matter %)

Dry matter % was significantly higher in year 2015-16 for both 60 days (17.19) and 75 days (17.20) over the year 2014-15 for respective days. All the varieties except K. Pukharaj recorded significantly higher dry matter % over K. Khyati (13.93 and 14.54 for 60 and 75 days crop respectively) table 1. Dry matter at 90 days crop planting year 2015-16 (18.12) and 2016-17(18.45) recorded significantly higher % over the year 2014-15 (16.86). Among varieties, K. Garima, K. Surya, K. Lauvkar and K. Chipsona-1 recorded significantly higher dry matter % over K. Khyati (16.20%). Results are in agreement with Burton (1966) who also reported lower dry matter content in early maturing cultivars. Dry matter content is subjected to the influence of both the environment and genotypes (Tai and Coleman, 1999) [55].

In present study, in all the durations of crop K. Chipsona-1 recorded significantly highest tuber dry matter % (19.04 for 60 days, 19.49 for 75 days and 21.77 for 90 days) over other varieties. In year x variety interaction, no significant differences were recorded among interactions for the 60, 75 and 90 days crop (table 1). Dry matter content indicated significant influence of varieties where variety Kufri Chipsona-2 (22.15%) recorded highest dry matter content followed by Kufri Chipsona-1 (21.59%) and Kufri Jyoti (20.15%) with non-significant difference with significantly lower in Kufri Pushkar (18.42) (Jatav *et al*., 2017) [19]. The dry matter in potato varieties ranged from 18.57% in cv. Kufri Sutlej to K. Badshah 19.59% and 21.93% in cv. Kufri Chipsona-1 (Patel *et al*., 2005). Pandey *et al.* (2005) [36] and Marwaha, 2009[32] also reported highest dry matter in Kufri Chipsona-1 (25.5%) followed by Kufri Frysona (24.1%), Atlantic (22.1%.) and Kufri Jyoti (17.3%). DM content gradually increased from 16.94% at 80 DAP to 21.72% at 110 DAP irrespective of variety (Hasnut *et al.* 2015) [17]. Hence from present study K. Chipsona-1 is identified as suitable processing variety as it recorded highest dry matter in 60, 75 and 90 days crop for the N-C region of India.

Yield attributing parameters

Non marketable tuber yield (<20gm)

For 60 days crop, significantly higher non marketable tuber yield (t/ha) was recorded in planting year 2014-15 (2.18 t/ha) over 2015-16 (1.75). Among varieties, K, Jyoti, K. Badshah, K. Pushkar, K. Surya, K. Khyati, K. Pukhraj and K. Chipsona-1 recorded significantly higher non marketable tuber yield (t/ha) over K. Lauvkar (1.29). In year x variety interaction, Kufri Pushakr recorded significantly higher non marketable tuber yield (t/ha) in all the three years. Kufri Surya and K. Khyati recorded significantly higher non marketable tuber yield (t/ha) in the year 2014-15 and 2016-17 and K. Jyoti recorded for 2015-16 and K. Badshah, KCM, K. Pukhraj, K. Chipsona-1 for the year 2014-15 (table 2).

For 75 days crop, significantly higher non marketable tuber yield (t/ha) was recorded in year 2014-15 (2.21) and 2016-17 (2.92) over 2015-16 (1.27). All the varieties except K. Jyoti and K. Garima recorded significantly higher non marketable tuber yield (t/ha) over K. Lauvkar (1.05). In year x variety interaction, only K. Surya recorded significantly higher non marketable tuber yield (t/ha) in all the three years. K. Bahar, K. Badshah, KCM, K. Surya, K. Pukhraj and K. Chipsona-1 recorded significantly higher non marketable tuber yield (t/ha) for the year 2014-15 and 2016-17 and K. Jyoti for the year 2014-15 and K. Khyati for 2015-16 and 2016-17(table 2).

For 90 days crop, significantly higher non marketable tuber yield (t/ha) was recorded in planting year 2014-15 (3.20) and 2016-17 (2.95) over 2015-16 (1.53). All the varieties recorded significantly higher non marketable tuber yield (t/ha) over K. Lauvkar (1.60). In year x variety interaction, only K. Jyoti and K. Pushkar recorded significantly higher non marketable tuber yield (t/ha) in all the three years. All the other varieties recorded significantly higher non marketable tuber yield (t/ha) except K. Pukharaj (in 2014-15 only) in the year 2014-15 and 2016-17(table 2). The highest unmarketable yield (57.50 g/ plant) was noted in Kufri Chipsona-1, which was at par with MP/98-71 (52.16 g/ plant), Kufri Chipsona-2 (47.96 g/ plant) and Atlantic (44.76 g/ plant) at 90 days (Bhuwneshwri *et al.*, 2013) [4]. Similarly in the present study K. Chipsona-1 (3.61 t/ha) recorded highest non marketable yield at 90 DAP. Khan *et al.* (2013) [23] reported that varieties differed significantly for non-marketable yield percentage. The variation in non-marketable yield percentage of the genotypes may be due to crop vigor / maturity, inherent ability of potato genotypes (Patel *et al.*, 2008) [37]. Stem number and plant height may strongly influence the non marketable yield of potato cultivars (Arsenault and Christie, 2004) [3]. This confirms the present findings where varieties having higher growth attributes produced higher non-marketable yield.

Marketable tuber yield (>20gm)

For 60 days crop, significantly higher marketable tuber yield (t/ha) was recorded in planting year 2015-16 (16.00) and 2016-17 (17.95) over 2014-15 (11.19). Among varieties, K, Jyoti (15.20), KCM (15.34), K. Pushkar (17.69), K. Khyati (19.65) and K. Pukhraj (18.78) recorded significantly higher marketable tuber yield (t/ha) over K. Surya (11.71). In year x variety interaction, all the varieties except K. Surya and K. Chipsona-1 recorded significantly higher marketable tuber yield (t/ha) for the year 2016-17. K. Jyoti, KCM and K. Pukhraj recorded significantly higher marketable tuber yield (t/ha) in the year 2015-16 (table 2).

For 75 days crop, significantly higher marketable tuber yield (t/ha) was recorded in planting year 2015-16 (27.40) and 2016-17 (26.14) over 2014-15 (19.24). Among varieties, K, Jyoti (23.22), K. Bahar (23.15), K. Garima (27.61), K. Pushkar (27.88), K. Khyati (30.10) and K. Pukhraj (30.27) recorded significantly higher marketable tuber yield (t/ha) over K. Surya (18.72). In year x variety interaction, only K. Pukharaj recorded significantly higher marketable tuber yield (t/ha) in all the three years. Kufri Jyoti, K. Bahar, K. Garima, K Pushkar, K. Khyati and K. Lauvkar recorded significantly higher marketable tuber yield (t/ha) for two years 2015-16 and 2016-17. K. Chipsona-1, K. Badshah and KCM recorded significantly higher marketable tuber yield for the year 2014-15, 2015-16 and 2016-17, respectively (table 2).

For 90 days crop, significantly higher marketable tuber yield (t/ha) was recorded in planting year 2015-16 (32.02) and 2016-17 (30.25) over 2014-15 (24.45) table 2. Gedif and Yigzaw (2014) [12] reported among testing environments, the minimum mean marketable tuber yield (t/ha) at Injibara (2010 season) while the maximum yield was at Debretabor (2010 season). The mean performance of tested genotypes across all environments ranged from 18.78 to 25.66 t/ha with an average mean yield of 21.72 t/ha. Similar seasonal variation recorded in present study. Among varieties, K. Garima (29.01), K. Pushkar (34.65), K. Khyati (35.72) and K. Pukhraj (37.07) recorded significantly higher marketable tuber yield (t/ha) over K. Surya (24.50). In year x variety interaction, K. Pushkar and K. Pukharaj recorded significantly higher marketable tuber yield (t/ha) in all the three years. Kufri Jyoti, K. Badshah, KCM, K. Garima and K. Lauvkar recorded significantly higher marketable tuber yield (t/ha) for the year 2015-16 and 2016-17. K. Chipsona-1 recorded for the year 2014-15 and 2016-17 and K. Bahar and K. Surya for the year 2016-17 (table 2). Kumar *et al.* (2005) [25] reported significant varietal variations in marketable and total tuber yield under Modipuram condtions. The variation in the marketable yield of potato genotypes may be due to genotypic/varietal factor. Similar results were reported by Marwaha *et al.* (2007) [31], Kumar *et al.* (2005) [25], Khan *et al.* (2013) [23] and Luitel *et al.* (2015) [27] that different varieties had significant influence on marketable yield.

Total tuber yield

For 60 days crop, significantly higher total tuber yield (t/ha) was recorded in planting year 2015-16 (17.75) and 2016-17 (19.94) over 2014-15 (14.04). Among varieties, K, Jyoti (17.05), K. Chandramukhi (17.04), K. Pushkar (20.95), K. Khyati (21.89) and K. Pukhraj (20.95) recorded significantly higher total tuber yield (t/ha) over K. Surya (13.87). In year x variety interaction, Kufri Jyoti, K. Badshah, KCM, K Pushkar, K. Khyati and K. Pukhraj recorded significantly higher total tuber yield (t/ha) in the year 2015-16 and 2016-17, K. Lauvkar recorded for the year 2014-15 and 2016-17 and K. Bahar, K. Garima, K. Surya and K. Chipsona-1 for the year 2016-17 only. Harvesting time can influence the biomass accumulation in potato tuber (Marwaha *et al.* 2005 and Patel *et al.*, 2005) [30, 40]. All cultivars produced minimum yield at early harvest (70 DAP) (Hasnut *et al.*, 2015) [17].

For 75 days crop, significantly higher total tuber yield (t/ha) was recorded in planting year 2015-16 (28.67) and 2016-17 (29.06) over 2014-15 (24.45). Among varieties, K. Garima (29.27), K. Pushkar (30.59), K. Khyati (32.53) and K. Pukhraj (32.59) recorded significantly higher total tuber yield (t/ha) over KCM (21.81). In year x variety interaction, only K. Pukharaj recorded significantly higher marketable tuber yield (t/ha) in all the three years. Kufri Jyoti, K Pushkar, K. Khyati and K. Lauvkar recorded significantly higher marketable tuber yield (t/ha) for two years 2015-16 and 2016-17. K. Chipsona-1for the year 2014-15, K. Badshah and K. Surya recorded significantly higher marketable tuber yield for the year 2015-16 and K. Lauvkar for the year 2016-17 (table 2). Genotypes showed variation in total and marketable tuber yield and were non-significant at 60 DAS and showed significant differences in 75 days crop for Zone-I of Bihar (Yadav *et al*., 2005) [57].

For 90 days crop, significantly higher total tuber yield (t/ha) was recorded in planting year 2015-16 (33.55) and 2016-17 (33.20) over 2014-15 (27.65). Among varieties, K. Garima (31.41), K. Pushkar (37.98), K. Khyati (37.94) and K. Pukhraj (39.42) recorded significantly higher total tuber yield (t/ha) over K. Surya (27.31). In year x variety interaction, K. Badshah, K. Pushkar and K. Pukhraj recorded significantly higher total tuber yield (t/ha) in all the three years. Kufri Jyoti, KCM, K. Garima and K. Khyati registered significantly higher total tuber yield (t/ha) for the year 2015-16 and 2016-17. K. Chipsona-1 for the year 2014-15 and 2016-17. K. Bahar, K. Surya and K. Lauvkar for the year 2016-17 only. When 27 clones and 8 commercial varieties were 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 may be because of the formation of maximum number of tubers 70 days after planting, whereas average tuber weight continued to increase till the last harvest (90 days after planting) Pandey *et al.* (2005) [36].

Genotypic differences for yield were not significant for 75 days harvest, but were significant for 90 days harvest. At 90 days harvest hybrid MS/94-899 was the highest yielder (Patel, 2006) [39]. Maximum tuber yield was from Kufri Gaurav (44.1 t/ ha) which was significantly higher over other varieties under Jalandhar conditions of Punjab (Jatav *et al.*, 2013) [20]. Various reports confirm present study where the variations in total tuber yield was reported in different genotypes/ varieties under different locations and climatic conditions (Sharma *et al.*, 2005, Patel *et al.*, 2005, Vashisht, 2005, Patel *et al.*, 2008, Amanullah, 2010, Bhuwneshari *et al.*, 2013, Khan *et al.*, 2013) [49, 40, 56, 38, 2, 4, 23]. The location, cultivar, date of harvest and tuber curing influences the, physical and biochemical changes in the structural components of potato tissue (Marwaha *et al*. 2005) [30]. This confirms the variation in tuber yield in 11 varieties in three years of study. Yield of ‘BARI TPS-1’ was highest compared to those of other local cultivars irrespective of harvesting time may be due to its varietal characteristics (Hasnut *et al.*, 2015) [17]. This confirms the results of present study where K. Pushkar, K, Khyati and K. Pukhraj recorded highest marketable and tuber yield over other varieties in different climatic situations of three planting years. Hence cultivar K. Pushkar, K, Khyati and K. Pukhraj has been identified as best promising varieties for N-C region of India.

Table 2: Yield parameters during crop growth period, in variety and their interaction

Year / Variety	**Non marketable Yield (t/ha)**			**Marketable Yield (t/ha)**			**Total Yield (t/ha)**		
Year of planting	60 days	75 days	90 days	60 days	75 days	90 days	60 days	75 days	90 days
2014-15	2.18	2.21	3.20	11.19	19.24	24.45	14.04	21.45	27.65
2015-16	1.75	1.27	1.53	16.00	27.40	32.02	17.75	28.67	33.55
2016-17	1.99	2.92	2.95	17.95	26.14	30.25	19.94	29.06	33.20
SE(m)±	0.10	0.15	0.11	0.62	0.76	0.76	0.56	0.81	0.79
C.D P= (0.05)	0.29	0.43	0.32	1.76	2.15	2.16	1.59	2.31	2.22
Varieties									
Kufri Jyoti	1.85	1.51	2.50	15.20	23.22	26.79	17.05	24.73	29.29
K. Bahar	1.44	2.13	2.46	13.23	23.15	25.20	14.67	25.27	27.66
K. Badshah	2.02	2.25	2.58	14.13	21.97	26.49	16.15	24.22	29.07
KCM	1.69	1.92	2.31	15.34	19.89	26.19	17.04	21.81	28.50
K. Garima	1.47	1.65	2.40	15.06	27.61	29.01	16.53	29.27	31.41
K Pushkar	3.26	2.71	3.33	17.69	27.88	34.65	20.95	30.59	37.98
K. Surya	2.16	3.19	2.82	11.71	18.72	24.50	13.87	21.91	27.31
K. Khyati	2.23	2.43	2.22	19.65	30.10	35.72	21.89	32.53	37.94
K. Pukhraj	2.17	2.32	2.34	18.78	30.27	37.07	20.95	32.59	39.42
K. Lauvkar	1.29	1.05	1.60	12.28	22.30	24.82	14.81	23.35	26.42
K. Chipsona1	2.09	2.33	3.61	12.43	21.73	27.54	15.76	24.06	31.15
SE(m)±	0.20	0.29	0.22	1.19	1.45	1.46	1.08	1.56	1.50
C.D P= (0.05)	0.56	0.83	0.62	3.38	4.12	4.14	3.05	4.42	4.26
SE (m) ±	0.34	0.51	0.38	2.07	2.52	2.53	1.86	2.70	2.60
Interaction Year x Variety CD P= (0.05)	0.97	1.44	1.07	5.85	7.13	7.17	5.27	7.65	7.37

Water use efficiency (WUE)

For 60 days crop, significantly higher WUE (kg/ha mm) was recorded in planting year 2015-16 (89) and 2016-17 (100) over 2014-15 (70) (Fig 5). Among varieties, K, Jyoti (85), KCM (85), K. Pushkar (105), K. Khyati (110) and K. Pukhraj (105) recorded significantly higher WUE (kg/ha mm) over K. Surya (69) (Fig 6). In year x variety interaction, similar pattern like total tuber yield was observed. For 75 days crop, significantly higher WUE (kg/ha mm) was recorded in planting year 2015-16 (115) and 2016-17 (116) over 2014-15 (86). Among varieties, K. Garima (117), K. Pushkar (122), K. Khyati (130) and K. Pukhraj (130) recorded significantly higher total tuber yield (t/ha) over KCM (87). In year x variety interaction, similar pattern like total tuber yield was observed. For 90 days crop, significantly higher WUE (kg/ha mm) was recorded in planting year 2015-16 (112) and 2016-17 (111) over 2014-15 (92). Among varieties, K. Garima (105), K. Pushkar (126), K. Khyati (127), K. Pukhraj (131) and K. Chipsona-1 (104) recorded significantly higher WUE (kg/ha mm) over K. Lauvkar (88). In year x variety interaction, similar pattern like total tuber yield was observed. Kufri Chipsona-1 (116.4 kg tubers ha-mm-1) had higher WUE than Kufri Chipsona-2 (101.7 kg tubers ha-mm-1). The lower efficiency of water use for Kufri Chipsona-2 may be attributed to maximum water was used in the development of vegetative parts at the expense of tuber development (Kumar *et al.*, 2007) [24]. This confirms the variation in WUE of different varieties of present study. Lesser yield in the all the above mentioned three harvesting dates in the year 2014-15 is due to higher precipitation (188.3mm) during crop season (Fig 3). This confirms from study of Yang *et al.*, (2007) [58] who reported a negative correlation between WUE of plants and precipitation and also in simulation study of 50 years in China on rainfall and its correlation with WUE of potato wherein, it was found that when the rain fall was 450.0 mm, the potato water use efficiency was 7.8 kg/ha, and when rainfall was <450.0 mm, the efficiency distinctly increased.

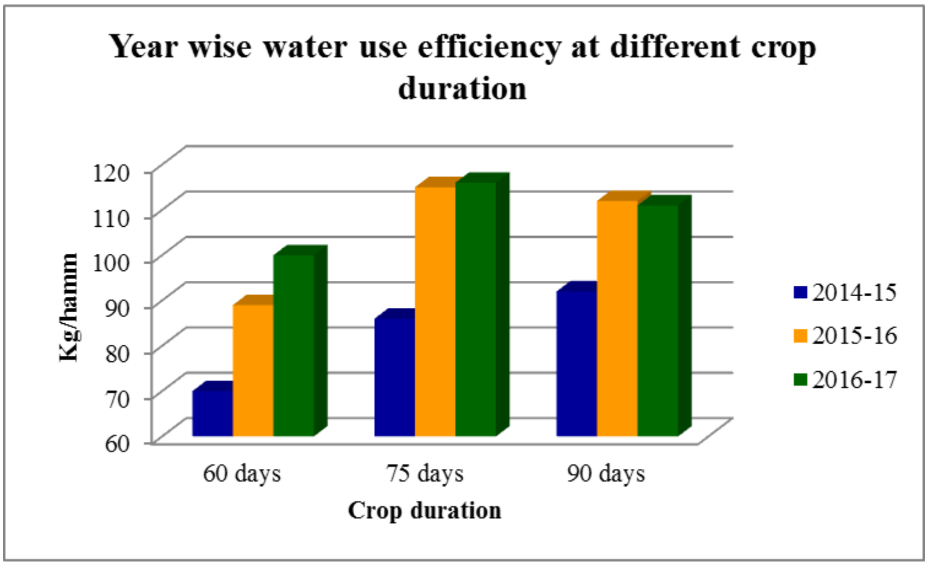

Fig 5: Water Use Efficiency during 2014-15 to 2016-17

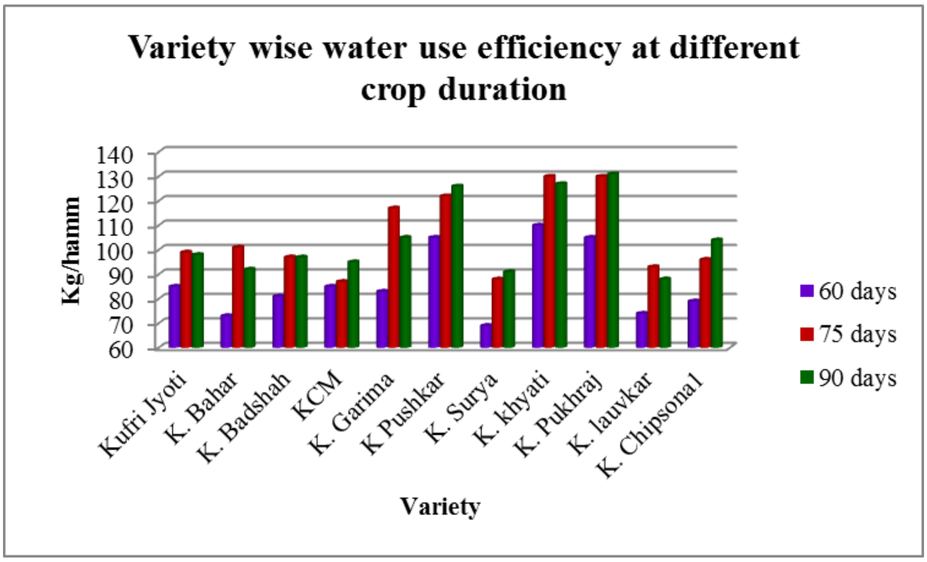

Fig 6: Water Use Efficiency of varieties at different crop duration

Economics

For 60 days crop, among all varieties gross return, net returns and B:C ratio was significantly higher in K. Khyati (Rs 124,619, Rs 54,353 and 1.77) followed by K. Pukhraj (Rs 119,182, Rs 48,915 and 1.70) and K. Pushkar (Rs 115,937, Rs 45,671 and 1.65) over (Rs 76,722, Rs 6,456 and 1.09). For 75 days crop, among all varieties gross return, net returns and B: C ratio was significantly higher in K. Pukhraj (Rs 188,582, Rs 116,516 and 2.62) followed byK. Khyati (Rs 187,900, Rs 115,834 and 2.61), K. Pushkar (Rs 175,378, Rs 103,312 and 2.43) and K. Garima (Rs 170,648, Rs 98,582 and 2.37), over K. Surya (Rs 121,900, Rs 49,834 and 1.69).For 90 days crop, among all varieties gross return, net returns and B: C ratio was significantly higher in K. Pukhraj (Rs 229,474, Rs 156,608 and 3.15) followed by K. Khyati (Rs 220,959, Rs 148,093and 3.03), K. Pushkar (Rs 217,889, Rs 145,023and 2.99) and K. Garima (Rs 181,237, 108371 and 2.50) over K. Surya (Rs 153,733, Rs 80,867and 2.11).(Table 3).

Based on three years of experimentation it was concluded that, prevailing climatic conditions during crop growth has profound effect on growth and yield parameters as well as on WUE. Varietal variation in growth and yield parameters were recorded during the study. Significantly highest WUE (Kg/hamm), marketable and total tuber yield (t/ha) as well as higher net return and B: C ratio was recorded in K. Pukhraj, K. Khyati and K. Pushkar for 60, 75 and 90 days crop under varied climatic situations of three years. Hence, K. Chipsona-1 is identified for processing and K. Pukhraj, K. Khyati and K. Pushkar as table purpose varieties for cultivation in the changing climate scenario under North-Central India

Table 3: Economics and B: C ratio during crop growth period and in variety

Growth period	60 days crop					75 days crop					90 days crop				
Varieties	**Total yield (t/ha)**	**Cost of cultivation**	**Gross returns**	**Net returns**	**B:C ratio**	**Total yield (t/ha)**	**Cost of cultivation**	**Gross returns**	**Net returns**	**B:C ratio**	**Total yield (t/ha)**	**Cost of cultivation**	**Gross returns**	**Net returns**	**B:C ratio**
Kufri Jyoti	17.05	70266	96,752	26,486	1.4	24.73	72066	143,867	71,801	2.0	29.29	72866	168,244	95,378	2.3
K. Bahar	14.67	70266	83,689	13,423	1.2	25.27	72066	145,256	73,190	2.0	27.66	72866	158,567	85,701	2.2
K. Badshah	16.15	70266	90,807	20,541	1.3	24.22	72066	138,578	66,512	1.9	29.07	72866	166,663	93,797	2.3
KCM	17.04	70266	97,137	26,871	1.4	21.81	72066	125,104	53,038	1.7	28.50	72866	164,059	91,193	2.3
K. Garima	16.53	70266	94,756	24,490	1.4	29.27	72066	170,648	98,582	2.4	31.41	72866	181,237	108,371	2.5
K Pushkar	20.95	70266	115,937	45,671	1.6	30.59	72066	175,378	103,312	2.4	37.98	72866	217,889	145,023	3.0
K. Surya	13.87	70266	76,722	6,456	1.1	21.91	72066	121,900	49,834	1.7	27.31	72866	155,433	82,567	2.1
K. Khyati	21.89	70266	124,619	54,353	1.8	32.53	72066	187,900	115,834	2.6	37.94	72866	220,959	148,093	3.0
K. Pukhraj	20.95	70266	119,182	48,915	1.7	32.59	72066	188,582	116,516	2.6	39.42	72866	229,474	156,608	3.2
K. Lauvkar	14.81	70266	77,567	7,301	1.1	23.35	72066	136,933	64,867	1.9	26.42	72866	153,733	80,867	2.1
K. Chipsona-1	15.76	70266	80,889	10,623	1.2	24.06	72066	137,393	65,327	1.9	31.15	72866	176,089	103,223	2.4
SE(m)±	1.09		7698.8	7698.9	0.1	1.48		8693.7	8693.9	0.1	1.58		9409.9	9410.0	0.1
C.D P= (0.05)	3.22		22871.5	22871.5	0.3	4.39		25827.0	25827.5	0.4	4.69		27954.8	27955.0	0.4

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