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Effect of planting windows on production of Kufri Khyati: An early bulking potato cultivar for Central India

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Abstract
Field experiment was conducted to study the performance of potato CV. Kufri Khyati to aberrations of temperature and rains in relation to production and incidence of disease and pests at Central Potato Research Station, Gwalior, India. Potato cultivar Kufri Khyati was planted with four planting windows *viz* 15th September, 30th September, 15th October and 30th October for three consecutive years during 2009-10, 2010-11 and 2011-12. Data revealed that early planting of potato CV. Kufri Khyati at higher temperature delayed tuberization, reduced tuber number (259,000/ha) and finally there was a drastic reduction in tuber yields (9.5 t/ha) with net returns showed negative (Rs 14612/ha) trend. The B: C ratio was also less than 1 in 15th September planted crop along with higher incidence of mite, thrips and stem necrosis disease. The highest N uptake (92 kg/ha) was recorded with 15th October planted crop, however it was lowest with 15th September planted crop. The highest nitrogen use efficiency (182 kg tuber/kg N applied) and water use efficiency (109 kg tuber/mm water) was recorded with 15th October planted crop with low incidence of pests and diseases. Severe mite, thrips and stem necrosis disease incidence were recorded in 15 and 30th September planting window of potato. Thus, the planting window of 30th October is the most suitable planting date for potato cv. Kufri Khyati for ware crop to get maximum tuber yield, low incidence of mite and thrips and higher net profit in Central India.

Keywords: planting window, climate change, N use efficiency, N uptake, water use efficiency

Introduction
Emergence and plant development are greatly affected by environmental factors such as temperature, rainfall and sunlight, which are not controlled by growers. One of the most important grower controlled factors is the decision on when to plant. Every production region has an "optimum" planting window during which conditions are most favourable for producing the highest potential yield in a given season. Planting before this window tends to reduce yields by exposing the crop to stresses, such as unfavourable soil conditions, high temperature and humidity, which tend to reduce yield. Likewise, planting after this optimum window also reduces potential yield by reducing the days available for plant growth and tuber bulking. The changing climate (specially rise in Temperature and aberrant rains) is going to affect the crop yields through out the world. Potato (*Solanum tuberosum* L.) is one of the most important food crops in India. Extreme weather fluctuations are widely depressing agricultural yields, increasing production instability, and degrading natural resources. If the change is not managed adequately, the agricultural yields will drop by up to 20% by the year 2050 (Hijmans, 2003) [9]. Temperature, level of green house gases, rainfall, and high humidity directly affect the crops, pathogens, insects, and weeds (Savary *et al*., 2011) [16]. Several new diseases, weeds, and insect pests have started appearing with the changing climate. High day temperatures have both direct and indirect damaging effects associated with hot tissue temperatures, plant water deficits due to high transpiration, and low plant water potentials (Hall, 2001) [8]. Potato has been thermo-sensitive and was productive only under long day conditions in temperate climate. But development of heat tolerant cultivars and adjustment in production system management has made it possible to have very high productivity in subtropical and warmer climate. Temperature controls the plant growth, development and yield and day degrees are normally used to quantify its effect. The partitioning of dry matter into the different organs viz. leaves, stems and roots has been found to be a function of development stage which in turn is a function of accumulated heat units. Threats to crops from increase in temperature are i) increased risk of higher average temperature at critical stages ii) Increased risk of more

extreme temperature iii) increased risk of soil fertility management v) Increased risk of water management, Increased risk of insect/ pest/ disease management and increased risk of aberrant rains.
To address the adverse impacts of rising temperature on productivity and quality of crop we need to develop sound adaptation strategies. Minor changes in climatic parameters can often be managed reasonably well by altering date of planting.

Materials and Methods
Field experiment was conducted to study adaptation of potato to climate aberrations at Central Potato Research Station, Gwalior, India which is located in Central Plains at 26^0N and 78^0E and 207 m above mean sea level. Potato cultivar Kufri Khyati was planted with four sowing windows (planting dates) *viz* 15th September, 30th September, 15th October and 30th October and three rain fall patterns (WRP- with 50 mm rains at planting, WORP-without rain at planting and RJH-rains just after haulm cutting for three consecutive years during 2009-10, 2010-11 and 2011-12. Treatments were replicated four times. The soil of the experimental site was silty clay loam, low in organic carbon (0.33%), available N (149 kg/ha) and P (9.97 kg/ha) and medium in available K (280 kg/ha) with pH of 6.7. Well sprouted medium size seed tubers (35-40g) were planted at 60 x 20 cm spacing in the ridges at a depth of 5-7 cm so that tuber mergence start at 8-10 d days after planting (DAP). Recommended doses of N, P and K were applied @ 180:34.9:100 kg/ha, respectively. Fifty percent N through ammonium sulphate and full doses of P and K were applied through single super phosphate and muriate of potash, respectively at planting. Remaining half dose of N was applied through urea at earthing up. Metribuzin @ 0.75 kg a.i./ha was applied just after planting to control weeds.
Irrigation was applied through furrow method at an interval of 8-10 days in first two date of plantings initially and 12-15 DAP later when temperature became cool. The quantification of irrigation water applied was measured using depth – interval method. All the standard cultural and plant protection practices were followed as per recommended schedules to raise a stress free crop. Destructive plant sampling and computations of total fresh weights were done at 10 days interval starting from 25 DAP to 90 DAP. At each sampling fresh weight of leaves, stems and easily recoverable roots were recorded from 5 plants per plot. Dehaulming was done manually at 90 days after planting (DAP) as per treatments and harvesting was done two weeks later after skin suberisation. The plant stand was monitored from 12 DAP till constant emergence. Meteorological data were obtained from the meteorological observatory located at the station are presented in (Table 3). Soil samples were collected from 0-15 cm depth before planting during first year and at harvest of crop and were analysed for OC and Available N. Economics were computed using the prevailing market prices for inputs and out puts. The standard analytical method was used for determination of nutrient N by alkaline permanganate method. The nitrogen use efficiency (kg tuber/kg N applied) was calculated by dividing the tuber yield with applied N. Nitrogen content and uptake by potato were analysed through prescribed laboratory procedure. Water use efficiency was also worked out with the following formula WUE = Tuber yield (kg/ha)/ Water applied through irrigation (mm).
The observations of mite damage was recorded from 45 days old crop and converted into percent mite burn plants i.e. total healthy plants and damaged plants, while incidence of stem necrosis disease was recorded on 60 days old crop, i.e. total healthy plants and diseased plants. Thrips population was recorded from 10 randomly selected plants at 45 and 60 days old crop using standard sampling technique. Data has been transformed using angular transformation $X=\sqrt{X+0.50}$.

Results and Discussion
Growth and yield attributes: Establishment of optimum plant population was difficult in extra early planted crop due to unfavourable environmental conditions (Fig. 1, 2 & 3). Fifty mm rains at planting hastened tuber emergence. This might be due to reduced temperature after planting due to artificial rains. There was no loss due to 50 mm artificial rains which might be due to low atmospheric humidity despite artificial rains. In 15th September planted crop 50% emergence was recorded on 19th day and full emergence on 46th day. The 50% crop emergence on 15th day and full emergence at 31st day was recorded in 30th September planted crop while it was 50% emergence at 12th day while full emergence at 21st day in 30th September planted crop. Almost similar trend was recorded in 30th October planted crop. Delay in date of planting from 15th September to 30th October increased tuber emergence from 75 to 80 per cent. In 15th and 30th September planted crop growth of plants was lanky due to high ET demand due to higher temperature.

Number of tubers: Highest number of small size tubers (290,000/ha) were recorded with 30th October planted crop which was significantly higher over all other planting windows. Highest number of medium size tubers (187,000/ha) was recorded with 30th October planted crop which was significantly higher over all other planting windows. The suitable temperature and low ET demand favoured the faster crop growth. Highest number of large size tubers (111,000/ha) was recorded with 30th October planted crop which was significantly higher over 15th September and 30th September but at par with 15th October planting window. Highest total number of tubers (587,000/ha) was recorded with 30th October planted crop which was significantly higher over all other planting windows. Lower number of tubers in 15th and 30th September planted crop were due to high temperature stress to potato crop which resulted in decreased tuberization and tuber production. Minhas *et al.* (2011) [13] also reported high temperature results in reduction of tuber yield or even failure of tuberization. Relatively lesser availability of nutrients specially N and water are also among the reasons for production/survival of lower number of tubers as well as bulking of tubers. Fifty mm artificial rains could not exert any significant effect on tuber number.

Yield of tubers: Highest yield of small size tubers (3.9 t/ha) was recorded with 30th October planting window which was significantly higher than all other planting windows. Production of medium size tubers (12.4 t/ha) was highest with 30th October window which was significantly higher over all other planting windows. Highest production of large size tubers (16.4 t/ha) was recorded with 30th October planting window which was significantly higher over 15th and 30th September but statistically on par with 15th October planting window. Highest production (32.7 t/ha) of all size tubers was recorded with 30th October planted crop which was significantly higher over 15th September and 30th September but statistically on par with 30th October planting window. Higher night temperature above 20 ^{0}C in 15th and 30th

September planting windows increased vegetative growth without converting carbohydrates into tubers (Basu and Minhas, 1991) [4]. Plants became tall and lanky. Highest dry weight of haulms was recorded with 15th September and 30th September planted crop. High day temperatures also cause reduction in the rate of photosynthesis and carbon assimilation compared to optimum temperatures because of damage to components of photosystem II (Al-Khatib and Paulsen, 1999) [1]. In tubers, no rottage was observed at harvest due to 50 mm artificial rains at planting/haulm cutting.

Economics: Highest cost of cultivation (Rs 93,502/ha) was recorded with 30th October planted crop due to higher requirement of labourer for harvesting, transport charges and old gunny bags cost. Highest gross return of Rs 228,900/ha was obtained with 30th October planted crop which was higher over all other treatments. Highest gross return was on account of higher tuber yield. Ahmadi, (2008) [2] also reported increase in income by planting at suitable dates. Net return was highest (Rs 135,398/ha) with same treatment. The lower returns with 15th and 30th September were on account of lower yields due to higher temperature. Higher cost of planting material (Azimuddin *et al.* 2009) [3] and increased cost of cultural practices were main cause of high cost of potato cultivation. Similar trend was observed with B:C ratio though it was same with 15th October and 30th October planting windows. Rana *et al.* (2011) [4] also reported increasing temperature as potential threat to potato.

Fertility status of soil: Significantly higher organic carbon (0.43%) was recorded with 30th September planted crop which was significantly higher over all other treatments. Higher organic carbon in 30th September treatment might be due to lower removal of nutrients from soil and longer period for lying soil vacant.

Highest available N (408 kg/ha) was estimated with 30th October planted crop which might be due to coverage of land by crop canopy for longer time which is known to maintain N availability for longer time by reducing N losses from soil.

Nutrient uptake and use efficiency: Comparatively higher P and K uptake (14 and 114 kg/ha, respectively) was recorded with 30th October planted crop which was significantly higher over all other planting windows. Higher uptake of N was recorded with 15th October planted crop. Higher uptake of Nutrients was attributed to favourable climatic condition resulting in higher tuber yield. Highest N use efficiency (182 kg tuber/kg N applied) was recorded with 30th October planted crop which was higher than all other planting windows. Results are in conformity with Singh *et al.* 2012 [17].

Water use efficiency: Highest water use efficiency (109 kg tuber/mm of applied water) was recorded with 30th October planted crop which was higher than all other planting windows. This was due to optimum temperature, lesser sunshine hours, lower ET demand and increased atmospheric humidity. A considerable increase in water application without significant increase in yield is known to reduce the water use efficiency (Kumar *et al*., 2006) [12].

Incidence of pest and disease

Mite damage: Mite feeding on leaves causes withering and waxy lower surface. The maximum mite damage (6.30%) was recorded when crop was planted on 15th September with rains at planting and 10 days before halum cutting followed by 5.50% mite damage in 30th September planted crop with no rains at planting and rains 10 days before halum cutting. In general, it has been observed that early planted crop was severely damaged by mite due to favourable climatic condition (higher temperature and humidity) while late planted crop was least effected by this pest. It is concluded that early planting is one of the important factor which is harbour the incidence of this pest on potato crop (Table-3, Fig.1, 2 & 3).

Thrips population: Among insect vectors T. palmi is one of the most important emerging vectors and transmit stem necrosis disease in early potato crop (higher temperature and humidity). This disease has assumed significant status especially in parts of Madhya Pradesh, Rajasthan, and Gujrat a decade earlier (Khurana *et al*, 2001) [10]. The maximum incidence of thrips population (5.80/plant) was recorded in 15th September planted crop with rains at planting and 10 days after halum cutting. However, the population of thrips remained active on early and late planted crop but its viruliferus nature restricted to early crop, as early crop showed the incidence of stem necrosis disease (Table-3, Fig.1, 2 & 3).

Stem Necrosis disease incidence: Early planted crop was damaged by this disease with maximum incidence of 5.19% while late planted crop was almost free from this disease. Rains at the time of planting had increased the incidence of this disease on potato crop. There is a direct relation between the early planting and activity of viruliferus thrips resulting high % incidence of stem necrosis disease in early potato crop. The high temperature (30-35 ^{0}C) and dry weather during September /early October is favourable for the development of stem necrosis disease (Table-3, Fig.1, 2 & 3).

Several species of insects, non-insect pests and diseases infest this crop due to comparatively higher temperature at early crop growth. The most important pest are thrips (*Thrips palmi* Kerny), aphids (*Myzus persicae* Sulzer), whitefly (*Bemisia tabacii* Gennadus) and mite (*Polyphagotarsonemus latus* Banks). These pests can cause 20-60 % damage to potato crop (Raj, 2001; Bhatnagar, *et al* 2014) [6] depending upon climatic conditions. With the increasing temperature due to global climate change, the incidence of insects including mite is expected to increase. These pests can either appear individually or simultaneously in quick succession on potato crop. The yield losses by thrips are mainly due to transmission of stem necrosis disease (Bhatnagar, 2007) [5], while mite is responsible for direct yield losses in early crop. Mean temperature, total SSH and total rainfall were almost similar during 2009-10 and 2011-12. However, no rains was recorded in the months of October, November, December and February, resulting dry spell and higher mean temperature during 2011-12. These climatic conditions triggered the activity of thrips and viral diseases during 2011-12 as compared to slightly low incidence of insect vectors and viral diseases during 2009-10 and 2011-12.

Table 1: Yield attributes and yield of potato as influenced by planting windows (mean data of three years).

Planting windows	Number of tubers ('000/ha)				Yield of tubers (t/ha)				
	Small (< 25 g)	Medium (25-75 g)	large (> 75g)	Total (all size)	Small size tubers	Medium size tubers	large size tubers	Total	Emergence count/140 hill
15th September	141	75	42	259	1.6	3.6	4.3	9.5	75
30th September	214	115	56	385	2.4	5.6	5.8	13.9	80
15th October	205	144	108	457	3.1	8.6	16.3	28.0	86
30th October	290	187	111	587	3.9	12.4	16.4	32.7	90
SEm±	25	14	10	37	0.3	0.9	1.1	2.0	
CD (P=0.05)	61	35	24	89	0.8	2.2	2.6	4.9	10
wrp	223	132	72	427	3.1	7.3	9.1	19.4	87
worp	195	135	79	409	2.6	8.0	11.3	21.9	80
rjh	220	124	87	431	2.6	7.4	11.7	21.8	72
SEm±	21	13	5	29	0.2	0.5	0.6	0.8	
CD (P=0.05)	44	27	11	62	0.4	1.2	1.4	1.6	15

Wrp= with 50 mm rains at planting, worp= without rain at planting, rjh= 50 mm rain just after haulm cut

Table 2: Growth and yield attributes of potato as influenced by planting windows (mean data for three years).

Planting windows	Economics				OC (%)	Available Soil N (kg/ha)	N Uptake (Kg/ha)	P uptake (Kg/ha)	K uptake (Kg/ha)	NUE (kg tuber/kg N)	WUE (kg tuber/mm water)
	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio							
15th September	90612	76000	(-) 14612	0.8	0.33	326	50	5	41	53	24
30th September	91020	111200	20180	1.2	0.43	295	79	7	79	77	35
15th October	91938	196000	104062	2.1	0.31	351	107	14	92	156	80
30th October	93502	228900	135398	2.4	0.37	408	103	14	114	182	109
SE m±	-				0.02	17	6				
CD (p=0.05)	-				0.04	36	14				

Sale rate of potato: 15th September –Rs 8/kg; 30th September –Rs 8/kg; 15th October –Rs7/kg; 30th October –Rs 7/kg; seed cost–Rs 15/kg

Table 3: Effects of different treatments on incidence of pest and disease on potato crop (mean data for three years).

Treatments	Mite Damage (%)	Stem Necrosis Incidence (%)	Thrips Population /plant
Planting 15th September	4.10	4.13	2.78
Planting 30th September	4.20	3.47	2.72
Planting 15th October	1.87	0.94	2.25
Planting 30th October	0.45	0.77	2.70
SEm±1	0.13	0.14	0.11
CD (p=0.05)	0.28	0.42	0.31
Inter action with rains at planting			
R1 -20mm rains	2.58	2.57	2.74
R1 –with out rains	2.40	2.17	2.44
SEm±1	0.09	0.10	0.07
CD (p=0.05)	0.27	0.30	0.22
Rains at halum cutting			
C1: Rain 10 d before halum cutting	2.79	2.29	2.60
C1: Rain just after halum cutting	2.38	2.54	2.61
C1: No Rain at halum cutting	2.42	2.33	2.48
SEm±1	0.11	0.12	0.09
CD (p=0.05)	0.33	0.36	0.27
Inter action with planting date X Rains at planting X Rains at halum cutting			
D1R1C1(WRP,RBH)	6.30	5.19	5.80
D1R1C1(WRP,RJH)	3.45	4.36	2.74
D1R1C1(WRP,NRH)	3.70	3.66	2.47
D2R1C2(WRP,RBH)	3.65	2.71	2.68
D2R1C3(WRP,RJH)	4.43	4.79	2.38
D2R1C1(WRP,NRH)	4.36	4.47	3.12
D3R1C1(WRP,RBH)	0.88	0.71	1.97
D3R1C2(WRP,RJH)	1.10	1.47	2.64
D3R1C3(WRP,NRH)	1.17	1.00	2.70
D4R1C1(WRP,RBH)	1.00	0.71	2.96
D4R1C2(WRP,RJH)	0.71	0.71	2.85
D4R1C3(WRP,NRH)	0.71	1.10	2.73
D1R2C1(WOR,RBH)	4.01	3.97	2.09
D1R2C2(WOR,RJH)	3.82	3.91	2.27
D1R2C3(WOR,NRH)	3.69	3.13	2.82
D2R2C1(WOR,RBH)	5.50	3.30	2.90

D2R2C2(WOR,RJH)	4.20	3.62	2.58
D2R2C3(WOR,NRH)	4.35	3.51	2.79
D3R2C1(WOR,RBH)	0.71	0.71	2.51
D3R2C2(WOR,RJH)	0.71	0.71	3.01
D3R2C3(WOR,NRH)	0.71	1.10	0.71
D4R2C1(WOR,RBH)	0.71	0.71	2.62
D4R2C2(WOR,RJH)	0.71	0.71	2.53
D4R2C3(WOR,NRH)	0.71	0.71	2.54
SEm±1	0.33	0.36	0.27
CD (p=0.05)	0.95	1.04	0.76

Data has been transformed using angular transformation X=√X+0.50

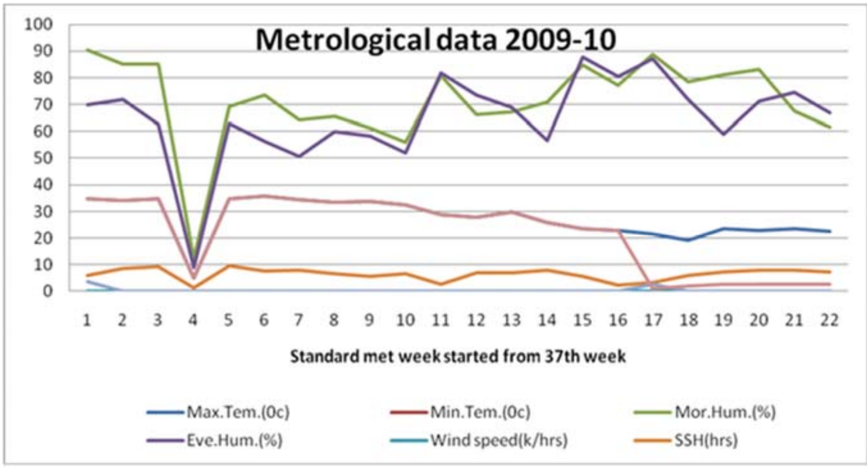

Fig 1

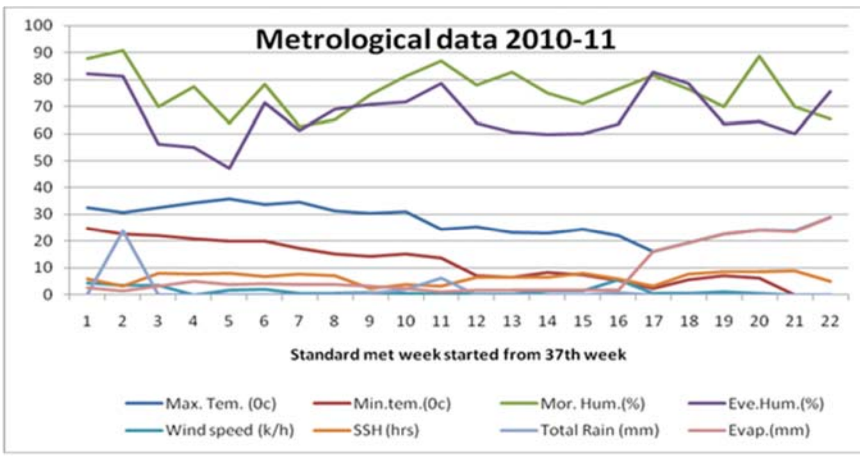

Fig 2

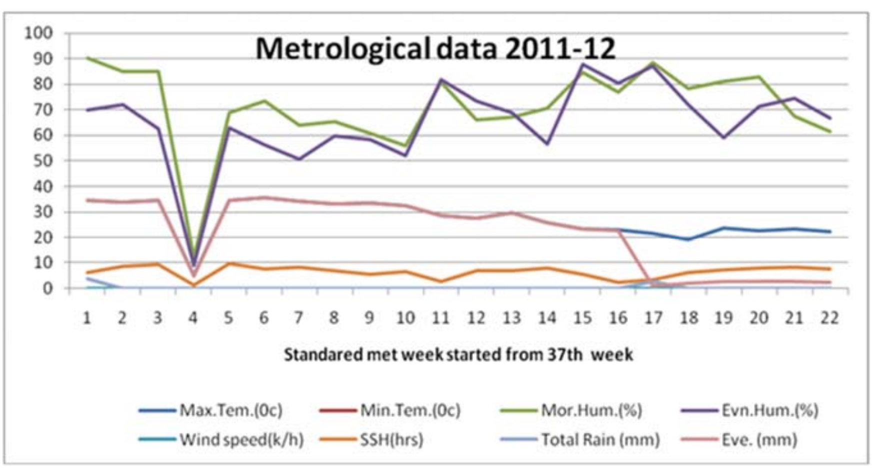

Fig 3

Conclusion
Most suitable date for planting of potato cultivar Kufri Khyati was 30th October as ware crop to get maximum tuber yield, low incidence of mite and thrips and higher net profit in Central India.

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