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Standardization of planting date for potato (*Solanum tuberosum*) breeder seed production in Gwalior region of north central india under prevailing climatic situations

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ABSTRACT

A field experiment was conducted at the Central Potato Research Station, Gwalior, Madhya Pradesh during 2012-13, 2013-14 and 2014-15 for standardization of planting date for Potato (*Solanum tuberosum* L.) breeder seed production with five planting dates, viz. 10 October, 17 October, 24 October, 31 October and 7 November with three popular varieties namely Kufri Chandramukhi (early medium), Kufri Sindhuri (late) and Kufri Chipsona-1(medium). The experiment was planted in three replication in split plot design. Seed production was done as per standard seed plot technique. Days to emergence were significantly delayed in 2012-13 and in 10 October (10.4 days) planting. Final emergence was significantly higher in 2014-15 (93.27%) and in 7 November (91.93%) and in Kufri Sindhuri (91.19%). 2014-15 planting and Kufri Sindhuri and Kufri Chipsona 1 recorded significantly higher growth attributing parameters, viz. stem number, compound leaves and plant height. Significantly higher stem number were recorded in 24 October (4.2) and onward planting. All the other four date of planting recorded significantly higher compound leaves/plant over 31 October planting (38). Decreasing trend in case of plant height was recorded with delay in planting.Significantly higher total tuber number and yield/ha was recorded in planting year 2013-14 and from 24 October, 31 October and 7 November planting over other two earlier planting date and highest was in 7 November planting date (634 thousand/ha and 25.39 tonnes/ha). Significantly higher tuber number and weight was recorded in Kufri Sindhuri (669 thousand/ha and 23.87 tonnes/ha) and Kufri Chipsona 1 (551 thousand/ha and 23.87 tonnes/ha) over Kufri Chandramukhi. Severe mosaic, mild mosaic and off type in each date of planting and varieties were far below maximum permissible limit under Indian minimum seed certification standards. Aphid population (weekly) were below critical limit in all the planting years, date of planting and varieties and lowest was found in year 2014-15, 31 October and 7 November planting and in Kufri Chandramukhi, respectively. Breeder seed production under prevailing climatic situation can be done by planting breeder seed crop during 1 week of November in Gwalior region of north central India.

Key words: Aphid population, Breeder seed production, Date of planting, Health standard, Potato, Variety

Potato (*Solanum tuberosum* L.) planting dates for each region is one of the factors that has a significant role in the performance of this crop. Each stage of growth should coincide with desired environmental conditions. The proper planting time for different climatic conditions, characteristics of cultivars and planting should be determined (Kochki *et al*. 1995, Khajeh-poor 1991). The potato planting date should be calculated based on the length of the growing season. In areas where the growing season is limited, planting shall be selected so that tuber formation and tuber growth period do not coincide with warmer situations (Mortazavi-bak and Ramin-pour 2009). No potato crop growth is possible below 2°C and above 30°C. The minimum (0-7°C), optimum (16-25°C) and maximum (40°C) temperatures for net photosynthesis are reported. Potato requires cool night temperature to induce tuberization (Singh and Lal 2009). Since tuber initiation occurs early in the season, therefore optimum soil temperature (16-19°C) is needed. Tuber development requires temperature of 20°C. Yields are highest when average daytime temperatures are about 21°C (Khan *et al*. 2011).

Viruses are a limiting factor for producing high quality seed potato in the presence of widespread sources of infection. Potato Seed production that follows the prescribed health standards is not an easy task. Under high infection pressure, it is almost impossible to produce good quality potato seed due to a lack of adequately efficient control measures for prevention of virus infection. Only combined

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(integrated) measures, depending on virus infection pressure up to a certain level, can bring about positive effects, which are nevertheless often insufficient to reach the goal in compliance with prescribed standards (Miloševic 2012).

Aphids normally affect potato seed production in two ways: direct damage caused by the feeding on the plants and indirect damage through virus transmission (Hanifa *et al*. 1995, Carli and Baltaev 2008). Green peach aphid represents the most viruliferous aphid species as it is notoriously considered as a vector of PLRV that is transmitted in a persistent manner (Miloševic *et al*. 2012). Degeneration of potatoes seed in the country showed that the aphid, particularly *Myzus persicae* (Sulzer), is responsible for the spread of virus diseases in the fields (Lakra 2010).

The purpose of determining cultivation timing is to achieve planting time figure or group of similar figures, in a way that sets of the environment for the emergence and seedling establishment is appropriate. And every stage of plant growth that is faced with appropriate conditions, not to be faced with inappropriate condition (Dehdar *et al*. 2003). Gwalior region in north central India is considered as one of the most effective region for potato seed production due to congenial climatic conditions during October to January. Generally seed production of potato starts in third week of October (CPRS 2014). As potato seed production is highly temperature sensitive, it is necessary to standardize the planting time for potato seed production under changing climatic scenario, hence the present study was undertaken.

MATERIALS AND METHODS

A field experiment was conducted at the Central Potato Research Station, Gwalior (Madhya Pradesh) during 2012-13, 2013-14 and 2014-15 for standardization of planting date for potato breeder seed production with five planting dates, viz. 10 October, 17 October, 24 October, 31 October and 7 November with three popular varieties namely Kufri Chandramukhi (early) and Kufri Sindhuri (late) and Kufri Chipsona 1(medium). The seed crop was planted according to date of plantings. Well sprouted 40-50 g tubers were planted in plot size 4.2 × 4.0 cm with spacing 60 cm (row to row) and 20 cm (plant to plant). The experiment was planted in split-plot design as year and date of planting as main plot and variety as sub plot. Nitrogen, phosphorus and potassium were applied @150 kg, 80 kg and 100 kg/ha, respectively. Full doses of P through single super phosphate, K through muriate of potash and half dose of N (75 kg/ha) through ammonium sulphate were applied at the time of planting. Remaining half dose of N (75 kg/ha) was applied through urea at the time of earthing up. Standard seed production practice was followed during crop season as per seed plot technique during crop growth.Thimet 10 G was also applied @ 10 kg/ha at the time of earthing up to control insects. Crop was sprayed with mancozeb @ 2 kg/ha as a preventive measures for late blight and other foliar diseases and leaf spot of potato. Besides, alternate spray of imidacloprid @ 0.002%, triazophos @ 1.6 l/ha and thiomethoxam @ 130 g/ha was done to protect seed crop from insects after emergence at 15-20 days interval was done. To control weeds, metribuzine was applied @ 0.75 kg *a.i*. /ha mixing in 1 000 litre of water on per hectare basis.

The growth and yield parameters were recorded time to time. Visually virus infections were recorded three times, first before hoeing (before 21-25 days), 2nd during 50-55 days and third before haulm killing. Haulm was killed after 80 days of planting for each date of planting. Weekly data on aphid infestation was recorded after 20 days of planting for each planting date on 15 randomly selected plants from upper, middle and lower leaves. Weekly weather data on max/min temperature, relative humidity and rainfall was recorded during crop growth in all the three year of experimentation and average max/min temperature and relative humidity is presented in Fig 1 and 2. Year wise rainfall data is presented in Fig 3.The average sunshine data presented in Fig 4. The data of three year was pooled and analysis was done accordingly.

RESULTS AND DISCUSSION

Growth attributing parameters

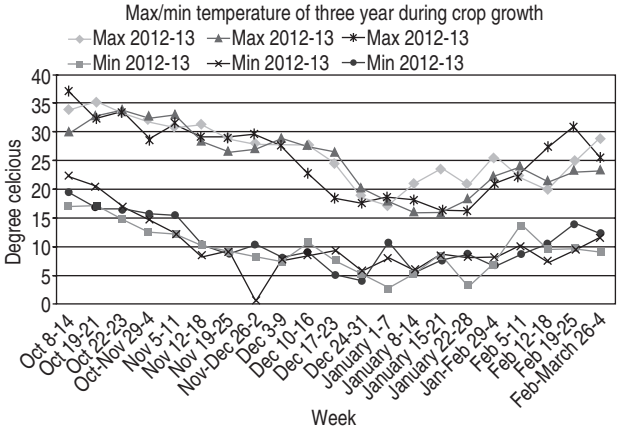

Fig 1 Max/min temperature (2012-13 to 2014-15) during crop growth.

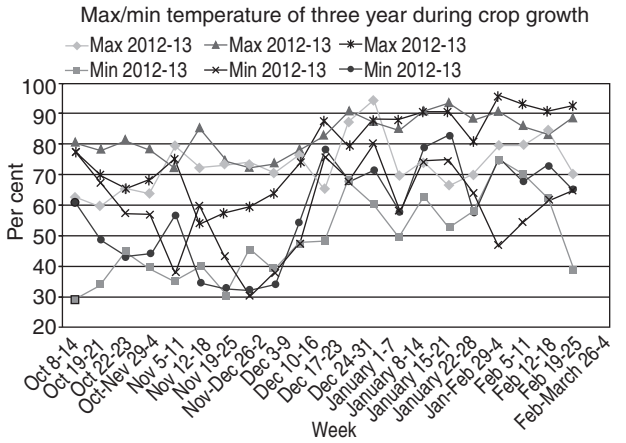

Fig 2 Max/min relative humidity (2012-13 to 2014-15) during crop growth.

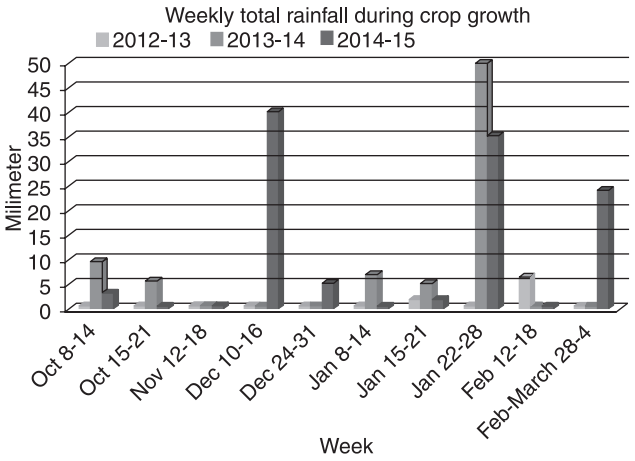

Fig 3 Rainfall during seed crop growth for three year (2012-13, 2013-14 and 2014-15).

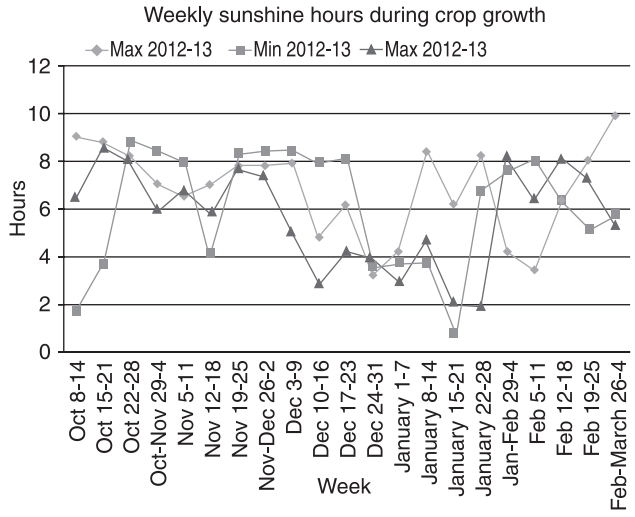

Fig 4 Weekly sunshine hours during crop growth (2012-13 to 2014-15).

Three year experimentation revealed that, the days to emergence was significantly delayed in the year 2012-13 and 10 October planting (10.4 days) and in Kufri Sindhuri (9.9 days) over other years of planting, date of planting and varieties. In year × DOP interaction, 10 October planting of 2012-13 (12.2 days) significantly delayed over all other year of study and DOP. In year × variety interaction, Kufri Chipsona 1 in 2012-13 showed delayed emergence (10.8 days). In DOP × variety interaction, Kufri Chipsona 1 in 10 October DOP showed significantly delayed emergence (10.5 days). In year × DOP × variety interaction, Kufri Chipsona1 of 10 October planting in 2012-13 showed delayed emergence (13.3 days) [Table 1]. Days to emergence was 13 days in 5 October planting over 8 days in 20 October planting under climatic situation in Gwalior region in 2011-12 where maximum temperature ranges from 35-36°C during first week of October in early planting study. (Sadawarti *et al*. 2014). Similar trend of maximum temperature (30-35°C) was noficed during 10 October planting in all the three years.

The 50% emergence was significantly delayed in 2012-13 (16.5 days) over other two years of study. Among DOP, variety and in all the interaction, there was no significant difference (Table 1). Final emergence was significantly higher in 2014-15 (93.27%), 7 November (91.93%) and in Kufri Sindhuri (91.19%) over other years of planting, date of planting and varieties (Table 1). In year × DOP interaction, 17 October planting of 2014-15 recorded significantly higher (94.05%) germination, in other interactions, viz. year × variety, variety × DOP and year × DOP × variety, there was no significant difference.

Stem/plant was significantly higher in 2012-13 (4.0) and 2014-15 (4.2) over the year 2013-14. The 24 October planting onward there was significant increase in the stem number over earlier planting. Kufri Sindhuri (4.0) and Kufri Chipsona 1 (4.2) recorded significantly higher stem number over Kufri Chandramukhi (Table 1). In year × DOP interaction, 31 October planting of 2014-15 (4.7) recorded significantly higher stem number. In year × variety interaction, Kufri Sindhuri of 2014-15 recorded significantly higher stem number (4.9). In DOP × variety interaction, 17 October Kufri Sindhuri recorded higher stem number (4.5). In year × DOP × variety interaction, Kufri Sindhuri of 31 October recorded significantly higher stem number (6.0) Table 1. Khan *et al.* (2011) reported that earliest sowing on 24 September resulted in 3.42 stems/plant and 1 October and 7 October, 2004 resulted in 3.38 and 3.97 stems/plant, respectively, whereas highest number of stems/plant (4.16) were recorded in the last sowing of 15 October, 2004. Sowing time significantly affected the number of stems/hill, where the maximum number of stems/hill (2.72) was observed for 8 October sowing, while the minimum (1.68) stems/hill was recorded for 15 September sowing time in tuberlet, minituber and seed tuber study in Peshawar, Pakistan (Rab *et al*. 2013). Similar results the delay in planting time there is increase in stem number found in present study.

Planting year 2014-15 recorded significantly higher compound leaves (49) over the year 2012-13 and 2013-14. This may be due to higher intermittent rainfall during 2014-15. All the other four date of planting (10 October, 17 October, 24 October and 7 November) recorded significantly higher leaves/plant over 31st October planting (38). Among varieties, Kufri Sindhuri (52) and Kufri Chipsona 1 (45) recorded significantly higher compound leaves/plant over Kufri Chandramukhi. In year × DOP interaction, 17 October planting of 2014-15 recorded significantly higher compound leaves (63). In year × DOP × variety interaction, Kufri Sindhuri of 10 October recorded significantly higher compound leaves (78.0) (Table 1). Sowing time also had significant effect on the number of leaves/hill with the maximum number of leaves/hill (29.12) recorded with 22 September sowing which was non-significant with 27.92 leaves/hill of 15 September sowing. The 8 October sowing resulted in the minimum number of leaves (25.08)/hill (Rab *et al*. 2013). Kufri Sindhuri recorded significantly higher number of stems, compound leaves and plant height/plant over Kufri Chandramukhi in 5 and 20 October planting of

Table 1 Growth parameters during crop growth period, planting date and in variety and their interaction

Planting year/Date of planting/Varieties	Days to emergence	50% emergence	Final emergence (%)	Stem/plant	Leaves/ plant	Plant height (cm)
Planting year (Main factor)						
2012-13	10.4	16.5	85.84	4.0	43	39
2013-14	8.9	12.1	89.03	3.7	44	53
2014-15	9.4	14.5	93.27	4.2	49	53
SEm±	0.11	0.44	0.63	0.09	1.76	0.62
CD (P=0.05)	0.33	1.28	1.82	0.26	5.10	1.79
Date of planting (Main factor)						
10th Oct	10.4	14.6	88.73	3.7	49	57
17th Oct	9.1	15.6	86.77	3.6	46	52
24th Oct	9.3	13.8	90.29	4.2	48	46
31st Oct	8.9	13.4	89.18	4.0	38	42
7th Nov	10.0	14.4	91.93	4.2	46	45
SEm±	0.15	0.57	0.81	0.12	2.27	0.80
CD (P=0.05)	0.43	NS	2.34	0.34	5.59	2.31
Varieties						
K. Chandramukhi	9.2	14.5	87.59	3.7	39	43
K. Sindhuri	9.9	14.2	91.19	4.2	52	54
K. Chipsona-1	9.6	14.4	89.36	4.0	45	48
SEm±	0.13	0.44	0.49	0.09	1.17	0.73
CD (P=0.05)	0.37	NS	1.38	0.27	3.30	2.08
SEm±	0.26	0.99	1.42	0.20	3.93	1.38
Interaction (Year × DOP) CD (P=0.05)	0.75	NS	4.06	0.59	11.41	4.0
SEm±	0.23	0.77	0.84	0.16	2.02	1.27
Interaction (Year × Variety) CD (P=0.05)	0.64	NS	NS	0.46	NS	3.60
SEm±	0.23	0.99	1.09	0.21	2.63	1.64
Interaction (DOP × Variety) CD (P=0.05)	0.83	NS	NS	0.60	NS	4.65
SEm±	0.51	1.71	1.883	0.36	4.52	2.84
Interaction (Year × DOP × Variety) CD (P=0.05)	1.44	NS	NS	1.03	12.81	8.05

NS, Non-singnificant

seed crop under Gwalior condition (Sadawarti *et al.* 2014).

Planting year 2013-14 and 2014-15 recorded significantly highest plant height (53 cm) over the year 2012-13. Decreasing trend in case of plant height was recorded with delay in planting and highest was recorded in 10 October planting (57 cm). Kufri Sindhuri and Kufri Chipsona 1 recorded significantly higher plant height over Kufri Chandramukhi (Table 1). In year × DOP interaction, 10 October planting of 2014-15 recorded significantly higher plant height (64 cm). In year × variety interaction, Kufri Sindhuri of 2014-15 recorded significantly higher plant height (64 cm). In DOP × variety interaction, Kufri Sindhuri of 17 October recorded significantly higher plant height (66 cm). In year × DOP × variety interaction, Kufri Sindhuri of 2014-15 and 17 October planting recorded significantly higher plant height (75 cm). Sowing time also significantly affected the plant height, with the maximum (55.11 cm) with 22 September sowing, which was non-significant with 15 September (55.07) or 1 October (52.03) but 8 October sowing resulted in the least (41.84 cm) hill height (Rab *et al*. 2013). Sandhu *et al.* (2014) reported that 1 November planting recorded the highest plant height at 60, 80 and 100 days after planting as compared to 22 October, 11 November and 22 November planting dates during both the years in normal potato crop. These differences in plant height can be attributed to the differences in the prevailing weather conditions. The highest plant height recorded at 1 November, can be attributed to the most favorable environment for plant growth during the cropping season. The lowest plant height recorded at 22 November can be due to the lower temperature experienced by the plants after emergence compared to other planting dates, thus lower temperature might have reduced allocation of assimilates for growth than the remaining three planting dates. This confirms the present study and climatic data indicates that minimum temperature falls below 10 °C after 7 November planting.

Yield attributing parameters

Quantification of the total tuber yield in three different sizes is important for further seed multiplication and accordinglyseed tubers were graded in three sizes, viz. <25 g, 25-125 g and >125 g. In case of <25 g seed tubers, planting year 2013-14 recorded significantly higher <25 g tubers number and weight (277 thousand/ha and 3.79 tonnes/ ha) over other two years. The 24 October (245 thousand/ha)

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

Planting Year/ Date of planting/Varieties	Yield parameters							
	Tuber number (000/ha)				Tuber yield (tonnes/ha)			
	<25 g	25-125 g	>125 g	Total	<25 g	25-125 g	>125 g	Total
Planting year (Main factor)								
2012-13	228	284	21	532	3.31	16.52	3.15	23.51
2013-14	277	288	15	581	3.79	17.35	2.33	23.12
2014-15	208	319	11	538	2.40	16.08	1.68	20.16
SEm±	7.4	7.3	1.0	11.0	0.13	0.35	0.15	0.35
CD (P=0.05)	21.5	21.2	3.0	31.7	0.37	NS	0.43	1.03
Date of planting (Main factor)								
10th Oct	210	263	19	492	2.81	14.72	2.95	20.51
17th Oct	234	263	14	512	3.04	15.48	2.09	20.47
24th Oct	245	306	17	568	3.13	16.91	2.59	22.55
31st Oct	236	291	18	546	3.21	16.20	2.75	22.40
7th Nov	263	362	10	634	3.65	19.94	1.55	25.39
SEm±	9.6	9.4	1.3	14.1	0.16	0.46	0.19	0.46
CD (P=0.05)	27.8	27.4	3.8	40.1	0.47	1.32	0.55	1.32
Varieties								
K. Chandramukhi	172	239	20	431	2.43	15.53	3.24	20.96
K. Sindhuri	308	346	15	669	3.79	17.82	2.04	23.87
K. Chipsona-1	233	306	12	551	3.28	16.60	1.87	21.97
SEm±	11.8	7.5	0.6	12.8	0.13	0.39	0.11	0.38
CD (P=0.05)	23.6	21.3	1.9	36.2	0.36	1.10	0.30	1.08
SEm±	16.6	16.4	2.3	24.5	0.28	0.79	0.33	0.79
Interaction (Year × DOP) CD (P=0.05)	48.1	47.5	6.6	71.0	0.82	2.29	0.96	2.29
SEm±	14.50	13.0	1.1	22.2	0.22	0.67	0.18	0.66
Interaction (Year × Variety) CD (P=0.05)	41.02	36.8	NS	62.8	0.62	1.90	0.52	1.86
SEm±	18.71	16.8	1.5	28.6	0.28	0.87	0.24	0.85
Interaction (DOP × Variety) CD (P=0.05)	NS	NS	4.1	81.1	NS	NS	0.67	NS
SEm±	32.42	29.1	2.5	49.6	0.49	1.50	0.41	1.47
Interaction (Year × DOP × Variety) CD (P=0.05)	NS	NS	7.2	NS	NS	NS	1.16	NS

NS, Non-significant

and 7 November (263 thousand/ha) planting recorded significantly higher tubers over 10 October (210 thousand/ha) planting date. In case of tuber yield/ha, only 7 November (3.65 tonnes/ha) planted seed crop recorded significantly higher tubers over 10 October (2.81 tonnes/ha). Among varieties, Kufri Sindhuri (308) and Kufri Chipsona 1 (233) recorded significantly higher <25 g seed tuber number over Kufri Chandramukhi, similar trend was recorded in case of seed tuber yield/ha (Table 2). In year × DOP interaction, 7 November planting of 2013-14 recorded significantly higher <25 g tuber number and weight (307 thousand/ha and 4.6 tonnes/ha). In year × variety interaction, Kufri Sindhuri of 2013-14 recorded significantly higher <25 g tuber number and weight (367 thousand/ha and 4.8 tonnes/ha). Delay in planting significantly increased the number of small sized tubers (<35 mm). The highest percentage of small sized tubers (75.79%) was recorded in plots planted on 15 October. The other three sowing dates showed statistically similar percentage of small sized tubers (Khan *et al*. 2011).

In case of 25-125 g seed tubers, year 2014-15 recorded significantly higher tuber number (319 thousand/ha) over other two years, but in case of tuber weight, it was non-significant. The 24 October onward planting recorded significantly increasing trend in tuber number and weight over 10 and 17 October planting (Table 2). Kufri Sindhuri (346 thousand and 17.82 tonnes/ha) and Kufri chipsona 1 (306 thousand/ha and 16.60 tonnes/ha) recorded significantly higher tuber number and weight over Kufri Chandramukhi. In year × DOP interaction, 7 November planting of 2012-13 recorded significantly higher tuber number and weight 25-125 g tubers (380 thousand/ha and 21.53 tonnes/ha). In Year × variety interaction, Kufri Sindhuri of 2014-15 recorded significantly higher tuber number and weight (389 thousand/ha and 18.01 tonnes/ha). Maximum medium (35-55 mm) sized tubers (15.63%) were harvested when crop was planted on September-24 followed by 15.21 and 15.13% when planted on 1st October and 7 October respectively (Khan *et al*. 2011). Planting the crop on 15 October produced least percentage of medium sized tubers (14.54%) (Khan *et al*. 2011). Non-significant difference was recorded for tuber number in <25 g category but significantly higher tuber number were recorded in 20 October (295 thousand/ha)

planting than 5th October planting (200 thousand/ha) in 25-125 g category, for tuber yield (tonnes/ha) there were non-significant difference in both the category (Sadawarti *et al.* 2014). This supports the present investigation where with delay in date of planting, there is increase in number and weight of 25-125g category tubers which is the best size for further multiplication in seed production system .

Planting of 2012-13 (21 thousand and 3.15 tonnes/ha) and 2013-14 (15 thousand and 2.33 tonnes/ha) recorded significantly higher > 125 g tubers number and weight over the year 2014-15. All the dates recorded significantly higher seed tuber number and weight over 7 November planting date (10 thousand/ha and 1.55 tonnes/ha). Kufri Chandramukhi (20 thousand/ha) and Kufri Sindhuri (15 thousand/ha) recorded the significantly higher seed tuber number over Kufri Chipsona 1 (12 thousand/ha). In case of tuber weight, only Kufri Chandramukhi (3.24 tonnes/ha) recorded significantly higher tuber weight over other two varieties (Table 2). In Year × DOP interaction, 10 October planting of 2012-13 recorded significantly highest tuber number and weight (30 thousand/ha and 4.87 tonnes/ha). In DOP and variety interaction, Kufri chandramukhi of 10 October recorded significantly higher tuber number (27 thousand/ha and 4.59 tonnes/ha). In year × DOP × variety interaction, Kufri Chandramukhi of 10 October planting of 2012-13 recorded significantly higher tuber number and weight (47 thousand/ha and 7.99 tonnes/ha). Khan *et al.* (2011) recorded maximum percentage of large tubers (11.29%) in plots planted on 24 September followed by 11.88% by planting both on 1 October and 7 October. The lowest percentage of large tubers (9.67%) was observed by planting potato on October 15. Similar trend was reported in the present study. Non-significant but higher tuber number and weight was recorded in 20 October planting than 5 October planting (Sadawarti *et al*. 2014). Hence, it is important to note that later date of planting (7 November) resulted in higher proportion of small and medium size category tubers of which is most important to increase the area and quality of seed in further generation of multiplication.

Planting of 2013-14 (581 thousand/ha) recorded significantly higher total tuber number over other two years and in case of total tuber weight 2012-13 (23.51 tonnes/ha) and 2013-14 (23.12 tonnes/ha) recorded significantly higher tuber weight over the year 2014-15. The lower yield during year 2014-15 may be due to higher vegetative growth due to frequent rainfall during seed production period (Fig 3). Significantly higher total tuber number and yield was recorded from 24 October , 31 October and 7 November planting over other two earlier planting date and highest was in 7 November planting date (634 thousand/ha and 25.39 tonnes/ha). Significantly higher tuber number was recorded in Kufri Sindhuri (669 thousand/ha) and Kufri Chipsona 1 (551 thousand/ha) over Kufri Chandramukhi (431 thousand/ha) and only Kufri Sindhuri in case of weight (23.87 tonnes/ha) [Table 2]. In year × DOP interaction, 7 November planting of 2012-13 recorded significantly higher tuber number and weight (676 thousand/ha and 27.67 tonnes/ha and 27.99 tonnes/ha). In year × variety interaction, Kufri Sindhuri of 2013-14 recorded significantly higher total tuber number (703 thousand/ha) and tuber weight in 2012-13 (25.24 tonnes/ha). In DOP × variety interaction, Kufri Sindhuri of 24 October planting recorded significantly higher tuber number (751 thousand/ha) and 7 November planting in case of tuber yield (27.36 tonnes/ha).

Performance of Kufri Sindhuri in terms of total yield was significantly higher (29.54 tonnes/ha) over Kufri Lauvkar, Kufri Chandramukhi and Kufri Chipsona 1 in 20 October planting as compared to 5 October early planting in seed potato production (Sadawarti *et al*. 2014). Ezikel (1997) reported that higher temperature during the growth of the seed crop (16 September planting date) caused 15-19% reduction in the yielding ability of progeny tubers compared with lower temperature (in 3 November planting date) at Modipuram, Uttar Pradesh. Seed production in a temperature range of 25-28°C was found to reduce yield when compared with cooler grown seed at 16-22°C (Bodlaender 1972). In the present study, maximum/minimum temperature for 2012-13 and 2013-14 planting years was in the range of 17-32°C/ 2.5-12°C and 15-32°C/0.4-12°C for later date of planting like 31 October and 7 November under Gwalior conditions resulting in the higher total seed number and yield (Fig 1).

Health standard

Severe mosaic

In breeder seed potato production programme, production of disease free high quality seed is utmost important. Hence roguing of disease plant especially mosaic and off-type is important activity. No severe mosaic was recorded in first roguing in all the planting year, date of planting and varieties. In second roguing, non-significant lower severe mosaic was recorded in 2012-13 and 2013-14 over 2014-15 planting, among date of planting, 31 October planting (0.03%) recorded non-significantly lower severe mosaic over 24 October planting (0.08%). Among varieties, Kufri Sindhuri and Kufri Chipsona 1 (0.02%) recorded non-significantly lower severe mosaic over Kufri Chandrmukhi (0.12%). No significant differences were recorded among interactions (Table 3). In third roguing, no significant differences were recorded among planting year, date of planting, varieties and their interactions but non significantly lower severe mosaic was found in planting year 2014-15, in 10 October planting and in Kufri Sindhuri and Kufri Chipsona 1 (Table 3). The severe mosaic in each date of planting and varieties were far below maximum permissible limit under Indian minimum seed certification standards, viz. 0.50% for foundation-1, 0.75% for foundation-2 and 1% for certified seed (IMSCS 2013).

Mild mosaic

No mild mosaic was recorded in first roguing in all the planting year, date of planting and varieties. In second roguing, there was no significant difference among planting

Table 3 Health parameters (*per cent*) during crop growth period, planting date and in variety and their interaction

Date of planting/Varieties	Health standard								
	Severe mosaic			Mild mosaic			Off type		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Planting year (Main factor)									
2012-13	0.00	0.02	0.13	0.00	0.09	0.05	0.048	0.00	0.00
2013-14	0.00	0.05	0.09	0.00	0.09	0.05	0.032	0.00	0.00
2014-15	0.00	0.09	0.05	0.00	0.03	0.03	0.048	0.00	0.00
SEm±	NS	0.025	0.032	NS	0.027	0.023	0.023	NS	NS
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date of planting (Main factor)									
10th Oct	0.00	0.05	0.03	0.00	0.08	0.05	0.05	0.00	0.00
17th Oct	0.00	0.05	0.13	0.00	0.11	0.03	0.03	0.00	0.00
24th Oct	0.00	0.08	0.05	0.00	0.08	0.05	0.08	0.00	0.00
31st Oct	0.00	0.03	0.08	0.00	0.05	0.05	0.00	0.00	0.00
7th Nov	0.00	0.05	0.13	0.00	0.05	0.03	0.05	0.00	0.00
SEm±	NS	0.032	0.042	NS	0.034	0.030	0.030	NS	NS
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Varieties									
K. Chandramukhi	0.00	0.13	0.14	0.00	0.14	0.11	0.06	0.00	0.00
K. Sindhuri	0.00	0.02	0.06	0.00	0.03	0.02	0.03	0.00	0.00
K. Chipsona-1	0.00	0.02	0.05	0.00	0.05	0.00	0.03	0.00	0.00
SEm±	NS	0.30	0.040	NS	0.035	0.026	0.026	NS	NS
CD (P=0.05)	NS	0.084	NS	NS	NS	0.073	NS	NS	NS
SEm±	NS	0.025	0.072	NS	0.060	0.053	0.053	NS	NS
Interaction (Year × DOP) CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	NS	0.056	0.070	NS	NS	0.045	0.045	NS	NS
Interaction (Year × Variety) CD (P=0.05)	NS	NS	NS	NS	0.061	NS	NS	NS	NS
SEm±	NS	0.066	0.090	NS	0.079	0.058	0.058	NS	NS
Interaction (DOP × Variety) CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	NS	0.115	0.157	NS	0.137	0.100	0.100	NS	NS
Interaction (Year × DOP × Variety) CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS, Non-Significant

year, date of planting and varieties but lowest was recorded in planting year 2014-15 in 31 October and 7 November planting (0.05%) in Kufri Sindhuri (0.03%). No significant differences were recorded among planting year, date of planting, varieties and their interactions (Table 3). In third roguing, significantly lower mild mosaic plants were reported in Kufri Chipsona 1 (0.0%) and Kufri Sindhuri (0.02%) over Kufri Chandramukhi (0.11%). The mild mosaic in each date of planting and varieties were far below maximum permissible limit under Indian minimum seed certification standards, viz. 1.0% for foundation-1, 2.0% for foundation-2 and 3% for certified seed (IMSCS 2013).

Off type

Off type was reported only in first roguing in all date of planting and varieties, there was non-significant difference among planting year, date of planting, varieties and their interaction (Table 3) but lowest was recorded in 2013-14 (0.032%), 31 October (0.0%) and in Kufri Sindhuri and Kufri Chipsona 1 (0.03%) [Table 3]. The off-type in each date of planting and varieties were far below maximum permissible limit under Indian minimum seed certification standards, viz. 0.5% for foundation-1, 0.5% for foundation-2 and 1% for certified seed (IMSCS 2013). This suggest the health standard during all the three year of experiment was very good and within the maximum permissible limit under Indian minimum seed certification standards.

Aphid population

As availability of aphid population below critical limit is most important during potato seed production. In the present investigation aphid population was far below the critical limit (3/15 compound leaves) during all the three years. The aphid population was lowest in planting year 2014-15 followed by 2013-14 and in 31 October and 7 November planting and in Kufri Chandramukhi and highest was recorded in planting year 2012-13, 17 and 24 October planting and in Kufri Sindhuri. The aphid population was higher during 4 to 8 week of recoding of data but it was far below the critical limit (maximum 0.7/15 compound leaves in 4 and 6 week in 17 and 24 October planting). The minimum aphid population during the crop three seasons is

due to intermittent rainfall leading to low temperature and high relative humidity during crop growing period in particular in 2014-15 (Fig 1-4). During the seed crop growing period, the maximum temperature were in the range of 20-22°C and minimum in the range of 5-10°C after 20 days of data recording.Temperature is the most important environmental factor that affects aphid behavior, development and reproduction. The temperature ranges from 20-25°C for the optimum development of aphid. Increasing temperature accelerates development, reproduction capacity and also enhances migration but reproduction declined and completely ceased at 30°C (Karim *et al*. 2011).

In the present study, the relative humidity was also high, more than 80% in the same data recording period especially during 2013-14 and 2014-15 and during 31 October and 7 November planting date (Fig 2). With the decrease of relative humidity, there was an increase of aphid population and it was highest when the relative humidity was around 65% in 2004-2005. The average of aphid population of three cropping seasons demonstrated the similar phenomenon as observed in the individual cropping seasons. The regression analysis proved that there was a negative correlation of aphid population with relative humidity in all the consecutive three cropping seasons (Karim *et al*. 2011). This supports the present finding.

The critical level of wingless form of *Aphis gossypii* crossed critical limit between middle of January to end of February but in case of winged form the limit was crossed between third week of January to end of February. The critical level of *Mysus persicae* (both forms together) crossed by the first week of January to the third week of February but in case of *Aphis gossypii* (both forms together) the limit was crossed between second week of January to end of February, at this time the maximum temperature varied between 21.1 and 30.3°C; the minimum temperature ranged from 10 to 16.6°C; the maximum relative humidity (RH) varied from 73 to 100% and the minimum (RH) ranged from 35 to 56%. The critical level of both the species of aphids together crossed between first week of January to second week of February under Kalyani conditions of West Bengal (Konar 1998). In the present investigation, in all the three year and in five DOP and three varieties, the critical limit was not crossed up to halum killing of the plant till the end of January. This indicates the favorable conditions for breeder seed potato production.

Based on three year of experimentation, it was concluded that in terms of aphid population which is mainly responsible for spread of viral diseases was below the critical limit in all the year of experimentation, DOP and varieties, hence Gwalior region of North central India is most suitable for breeder seed potato production. Health standard (Severe mosaic, mild mosaic and off-type) was non significantly lower during 2013-14 and 2014-15, 7 November planting and in Kufri Sindhuri and Kufri Chipsona 1. In all the years of experimentation, 7 November planting significantly recorded the higher growth attributes like germination, number of stem, compound leaves except plant height resulting in higher photosynthete ultimately leading to higher <25 g, 25-125 g grade and total tuber yield/hectare. Kufri Sindhuri and Kufri Chipsona 1 recorded the significantly higher growth attributes, seed tuber number and yield for <25 g, 25-125 g grade and total tuber yield/ hectare. Hence it can be recommended that first week of November planting is best suitable for breeder seed production under prevailing climatic situations in Gwalior region of North-Central India.

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