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Effect of Planting Windows, Weed Control and Varieties on Productivity and Profitability of Potato (*Solanum tuberosum* L.) in Central India

S. P. Singh[1*], V. K. Dua[2], S. K. Sharma[1], M. J. Sadaworti[1], S. Roy[1] and S. K. Gupta[1]

[1]ICAR-Central Potato Research Station, Gwalior, Madhya Pradesh (474 020), India
[2]ICAR-Central Potato Research Institute, Shimla, Himachal Pradesh (171 001), India

Corresponding Author

S. P. Singh
e-mail: drshivpratapsingh@yahoo.co.in

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Abstract

A field experiment was conducted during *rabi* seasons (winter) of 2011–12 and 2012–13 to assess the effect of planting dates, weed control and varieties on productivity and profitability of potato under Gwalior region of Central India. The field was infested with *Chenoporium album* (Bathua), *Chenopodium murale* (Kharbathua), *Celosia argentia* (Safed) and *Trianthema monogyna* (Patharchata). Highest weed density (176 sq m^{-1}) was recorded with 15th September planted crop which was significantly higher over all other planting dates. Delaying date of planting from 15th September to 15th November increased tuber yield in weedy check (10.8 to 30.1 t ha^{-1}) and weed control (12.6 to 38.5 t ha^{-1}) treatments which show that at optimum temperature crop competes in better way with weeds. Among different varieties tested, Kufri Jyoti showed least competition with weeds. Highest tuber yield was recorded with 15th November planted crop. Among varieties, Kufri Khyati gave highest tuber yield (30.1 t ha^{-1}) under weed control condition and Kufri Surya (22.6 t ha^{-1}) under weedy check condition. Nutrient uptake by weeds was highest in early and late planting situations compared to main crop. Delaying date of planting increased water use efficiency from 27 kg tuber ha^{-1}-mm to 128 kg ha^{-1}-mm. Hence, Kufri Surya may be preferred for planting over Kufri Khyati and Kufri Jyoti in early plantings where adoption of weed control is bare minimum. Extra early planting in the month of September should be avoided to increase efficiency of applied nutrient and water inputs. Unused inputs damage environment in addition to decreasing profit from cropping.

Keywords: Kufri Jyoti, Kufri Khyati, Kufri Surya, potato, weedy check, water use efficiency

1. Introduction

In the agro ecosystems, ideal environmental conditions provided for optimal crop productivity are being exploited by the associated weeds. Presence of weeds in general reduces crop yields by 31.5 to 22.7% in winter season and 36.5% in summer and Kharif season and in some cases cause complete devastation of crop (Singh et al., 2017). The yield losses in potato crop due to weeds ranged from 10-80% (Lal and Grewal, 1991; Singh, 2016). Potato with an area 1.9 mha, is the most widely cultivated vegetable crop during *rabi* season. Potato plays a vital role in food security for ever increasing world population (Thiele et al., 2010; Scott and Sourez, 2011; Scott and Sourez, 2012). It is highly capital and labour intensive crop (Kushwah and Singh, 2011; Gaur et al., 2017). Weeds are naturally efficient and aggressive in utilizing the resources – nutrients and moisture and can compete with the crops to cause economic loss. Controlling weeds enhances the use efficiency of applied nutrients by crops (Singh and Dua. 2015; Gaur et al., 2017). Owing to favourable weather conditions and slow emergence and growth during initial stages, wider row spacing and frequent irrigations to the crop result in luxuriant growth of weeds, which offer severe crop weed competition. Shortage of labourer in agriculture sector makes it difficult to manage weeds at most critical stages of crop growth. Mechanization of potato planting and reduction in size of farm holding, hoeing and earthing up operation is being vanished. This is also encouraging weed growth in potato fields.

Application of paraquat, pendimethalin, alachlor etc. have been found effective for control of weeds as pre emergence herbicide. However, information on date of planting window and its effect on weed control in combinations with herbicides is lacking. Weeds cause enormous losses in crop yield. Weeds are major impediment to crop production through their ability to compete for resources and their impact on product quality. The problem of weeds may vary with fertility levels; since the elevated soil fertility due to FYM or fertilizer application usually stimulate the growth of weeds much earlier than the growth of crop, thus reducing the crop yield (Rawat et al., 2012; Singh et al., 2017). Potato weed control is necessary to reduce competition for nutrients, moisture, and radiant energy and obtain maximum fertilizer and water use efficiency.

2. Materials and Methods

A field experiment was conducted during *rabi* seasons (winter) of 2011-12 and 2012-13 at the experimental site (26°N and 78°E and 207 m amsl) of Central Potato Research Station, Gwalior (Madhya Pradesh). The soil of experimental site was silty clay loam with pH 8.5, organic carbon 0.23%, available N, P and K 125 (low), 41.6 (high) and 470 (high) kg ha^{-1}, respectively. Treatments consisted of 5 dates of planting (15th September, 30th September, 15th October, 30th October and 15th November–planting windows), with integrated weed control i.e. combination of chemical (application of herbicide paraquat), mechanical (in-crop cultivation-hoeing) and cultural (competitive cultivar) and weedy check treatments with three potato varieties. The potato varieties used for experiment were Kufri Jyoti, Kufri Surya and Kufri Khyati.

The pre emergence herbicide (paraquat) was applied after first irrigation as pre emergence. In weed control treatments, one hand weeding at 70 DAP in combination with hoeing which was done at 30 days stage of crop growth. The herbicide was applied with the help of Knap sack sprayer fitted with flat fan nozzle using spray volume of 800 litre ha^{-1}. The crop was raised under irrigated conditions and applied eight irrigations in 15th September and 30th September planted crops, seven irrigations in 15th October and 30th October planted crop and six irrigation in 15th November planted crop. Well sprouted medium size seed tubers (30-35 g) were planted at 60x20 cm^2 spacing in the ridges at a depth of 5-7 cm so that tuber emergence start at 8-10 days after planting (DAP).

Recommended doses of N, P and K were applied @ 180:34.9:100 kg ha^{-1}, respectively. Half 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. Earthing up was done after weeding at 25 DAP. 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.

Soil samples were collected from 0–15 cm depth before planting during first year and at harvest of crop and were analyzed for OC and Available N, P and K contents. 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. N, P and K content and uptake by potato tuber, haulm and weeds were analysed through prescribed laboratory procedure. Water use efficiency was also worked out with the following formula WUE=Tuber yield (kg ha^{-1})÷Water applied through irrigation (mm). The crop was harvested by uprooting haulms at 90 DAP.

The observations on weeds were recorded twice, when the crop was on an average 15 cm height and just before dehaulming. Economics was computed using prevailing market prices for inputs and outputs such as tuber (INR 8, 7, 5, 4 and 4 kg^{-1}, respectively for 15th September to 15th November planted crops), manual labour (INR 200 day^{-1}), and herbicide (INR 1700+2000+600 ha^{-1} as chemical, application and labour charges, respectively).

Relative production efficiency (RPE) and relative economic efficiency were calculated by using following formula (Urkurkar et al., 2006). Data on weeds were subjected to square – root transformation (√(x+1) before statistical analysis.

$$\text{Relative production efficiency (RPE)} = \frac{\text{Production in treated plot - production in weedy check}}{\text{Production in weedy check}} \times 100$$

$$\text{Relative economic efficiency (RPE)} = \frac{\text{Net Return of treated plot - Net Return of weedy check}}{\text{Net return of weedy check}} \times 100$$

Measured quantity of irrigation water was applied in all the irrigations. Water use efficiency (WUE) was also worked out with the following formula:

$$\text{WUE} = \frac{\text{Tuber yield (kg ha}^{-1}\text{)}}{\text{Water applied through irrigation (mm)}}$$

3. Results and Discussion

3.1. Effect of planting windows, varieties and weed control measures on weed density

The field was infested with *Chenoporium album* (Bathua), *Chenopodium murale* (Kharbathua), *Celosia argentia* (Safed) and *Trianthema monogyna* (Patharchata). Among monocot grasses *Cyperus rotundus* (motha), *Echinochloa Crusgallis* (sanwa) were prominent weeds. In general, delaying or postponing date of planting reduced number of weed count. Highest weed density (176 m^{-2}) was recorded with 15th September planted crop which was significantly higher over all other dates. Weed density reduced due to delayed plantings up to 15th October there after it increased significantly. Results are in conformity with Singh et al. (2017); Nadula and Reddy (2012). Among different varieties, highest weed count was recorded with Kufri Jyoti which was significantly higher over other two varieties. Weed count in Kufri Surya and Kufri Khyati were statistically on par. Highest weed fresh weight (2846 g sq m^{-1}) was recorded with 15th September planted crop which was significantly higher over all other dates. Weed fresh weight reduced due to delayed plantings up to 15th October there after it increased significantly. Among varieties highest weed fresh weight was recorded with Kufri Jyoti which was significantly higher over other two varieties. Significantly lowest weed fresh weight was recorded in Kufri

Khyati. Highest weed dry weight (148 g sq m^{-1}) was recorded with 15th September planted crop which was significantly higher over all other dates. Weed dry weight reduced due to delayed plantings up to 15th October there after it increased significantly. Among varieties highest weed dry weight (122 m^{-2}) was recorded with Kufri Jyoti which was significantly higher over other two varieties (Table 1).

Table 1: Effect of planting windows, varieties and weed control measures on weed density, weed fresh weight and weed dry weight (two years mean data)

DOP	Weed density (No. m^{-2})		Weed fresh weight (g m^{-2})		Weed dry weight (g m^{-2})	
	WC	WF	WC	WF	WC	WF
15th September	13.3 (176)	0	53.4 (2846)	0	12.2 (148)	0
30th September	6.7 (44)	0	42.2 (1781)	0	10.1 (101)	0
15th October	6.4 (40)	0	30.8 (946)	0	5.2 (26)	0
30th October	9.6 (92)	0	42.1 (1774)	0	11.5 (131)	0
15th November	10.4 (108)	0	41.1 (1687)	0	7.3 (52)	0
CD (*p*=0.05)	3.7 (8)	0	5.4 (42)	0	3.5 (15)	0
K. Jyoti	10.2 (104)	0	44.3 (1963)	0	11.1 (122)	0
K. Surya	9.3 (86	0	43.5 (1888)	0	9.7 (93)	0
K. Khayati	9.3 (85)	0	39.6 (1569)	0	7.7 (59)	0
CD (*p*=0.05)	2.6 (5)	0	6.5 (29)	0	4.2 (13)	0

DOP: Date of planting; WC: Weedy check; WF: Weed Free; WUE: Water use efficiency; * Figures in parenthesis indicate original values

3.2. Effect of planting windows, varieties and weed control measures on tuber production

All the weed free plots recorded higher number of tubers over weedy check plots. In general, increasing date of planting could not increase number of tubers significantly in weedy check treatments. Highest number of tubers (443,000 ha^{-1}) was recorded with 15th November planted crop which was significant over 15th and 30th September planted crops. Number of tubers was statistically on par in all the three varieties. Comparatively lower tuber yield was recorded with weedy check treatments compared to weed free treatments. Increasing date of planting increased tuber yield significantly both in weedy check and weed free plots. Increase in tuber yield between 30th October and 15th November was found to be non-significant. Among weed free treatments, Kufri Khyati produced significantly higher tuber yield (30.1 t ha^{-1}) over Kufri Surya and Kufri Jyoti (Table 2). In weedy check treatments, yields between Kufri Khyati and Kufri Surya were statistically on par though they were significantly higher over Kufri Jyoti. Results are in conformity with Singh and Bhatnagar (2014).

3.3. Effect of planting windows, varieties and weed control measures on nutrient uptake

Nitrogen uptake increased with increasing date of planting. Nitrogen uptake by weeds was recorded to the tune of 43 kg ha^{-1} with 15th September planted crop. Total uptake of nitrogen was almost same in weed control and weedy check treatments. Nitrogen uptake by weeds was in competition with potato crop. Uptake by weeds was highest in early and late planting situations. Total uptake of nitrogen was highest with Kufri Khyati followed by Kufri Surya in control as well as weedy check plots. It was interesting to note that nitrogen removal from weedy check plots higher than that of weed control plots in Kufri Jyoti. It might be due to higher efficiency of weeds in N uptake as compared to potato having sparse root system (Sud et al., 1999). In weed free plots, P uptake by haulms was highest with 30th September planted crop which was significantly higher over other planting dates. P uptake by tubers was highest (19.4 kg ha^{-1}) with 30th October planted crop which was significantly higher over all other planting dates. Total uptake of P (both by haulm+tuber) was highest with 30th October planted crop which was significantly higher over all other planting dates. Among varieties P uptake was significantly lower by Kufri Jyoti in comparison to Kufri Surya and Kufri Khyati. In weedy check plots highest P uptake by haulms was recorded with 30th September planted crop which was significantly higher over other planting dates. Highest P uptake by tubers was recorded with 15th November planted crop which was significantly higher over all other planting dates. Highest P uptake by weeds was recorded with 15th September planted crop which was significantly higher over other planting dates. Uptake by weeds reduced up to 15th October planting window thereafter it increased in 30th October planting and it further reduced in 15th November planting window significantly. Total uptake (haulm+tuber+weeds) of P was highest with 30th October planted crop which was significantly higher over all other planting dates. Among varieties highest total P uptake was recorded with Kufri Khyati which was significantly higher over Kufri Surya and Kufri Jyoti. Lowest P uptake was recorded with Kufri Jyoti among all the three varieties. In weed free plots K uptake by haulms was highest with 30th September planted crop which was significantly higher over other planting dates. K uptake by tubers was highest (131 kg ha^{-1}) with 15th November

Table 2: Effect of planting windows, varieties and weed control measures on tuber number, tuber yield, production efficiency and water use efficiency (two years mean data)

DOP	Number of tubers ('000/ha)		Yields of tubers (t ha^{-1})		Relative production efficiency (%)	Relative economic efficiency (%)	WUE in weedy check	WUE in weedy free
	WC	WF	WC	WF				
15th September	308	312	10.8	12.6	116.76	56.7	27	32
30th September	295	326	16.1	20.9	29.8	66.4	40	52
15th October	318	364	22.2	27.6	24.3	53.5	63	79
30th October	369	373	29.5	34.4	16.6	31.0	84	98
15th November	382	443	30.1	38.5	27.9	56.6	100	128
CD (p=0.05)	75	89	3.8	4.0	-	-	-	-
K.Jyoti	325	356	20.1	23.2	15.4	29.7	57	66
K.Surya	333	375	22.6	27.1	19.9	36.1	65	77
K.Khayati	345	359	22.5	30.1	33.8	66.7	64	86
CD (p=0.05)	57	62	1.5	1.6	--	--	--	--

WUE: Water use efficiency

planted crop which was significantly higher over all other planting dates. Total uptake of K (both by haulm + tuber) was highest 154 kg ha^{-1} with 15th November planted crop which was significantly higher over all other planting dates. Among varieties K uptake was significantly higher in Kufri Khyati in comparison to Kufri Surya and Kufri Jyoti. In weedy check plots highest K uptake by haulms (44 kg ha^{-1}) was recorded with 30th September planted crop which was significantly higher over other planting dates. Highest K uptake by tubers was recorded with 15th November planted crop which was significantly higher over all other planting dates. Highest K uptake by weeds was recorded with 15th September planted crop which was significantly higher over other planting dates. Uptake by weeds reduced up to 15th October planted crop which increased in 30th October planting however it further reduced in 15th November planted crop significantly. Total uptake (haulm+tuber+weeds) of K was highest (125 kg ha^{-1}) with 15th November planted crop which was significantly higher over all other planting dates. Among varieties highest total K uptake (121 kg ha^{-1}) was recorded with Kufri Surya which was significantly higher over Kufri Jyoti (Table 3). Lowest Kufri uptake was recorded with Kufri Jyoti among all the three varieties. These Results are in conformity with Singh et al. (2017); Singh and Lal (2013).

3.4. Effect of planting windows, varieties and weed control measures on fertility status of soil

In general, lower organic carbon (0.21 – 0.25%) was recorded in weed control treatments compared to weedy check treatment irrespective of variety and date of plantings. Among date of plantings comparatively highest OC (0.44%) was recorded in 30th September followed by 15th October planting dates. Among varieties, highest OC (0.41%) was recorded in Kufri Surya compared to other varieties. Among varieties, highest available N (174 kg ha^{-1}) was recorded in Kufri Jyoti compared to other two varieties. Among date of plantings, lowest available 186 kg ha^{-1} N was recorded with 15th September planted crop which might be due to higher volatilisation loss (Figure 1-6).

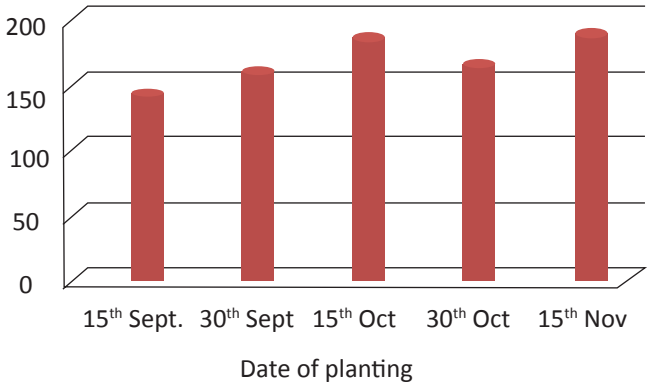

Figure 1: Available N (kg ha^{-1}) in soil

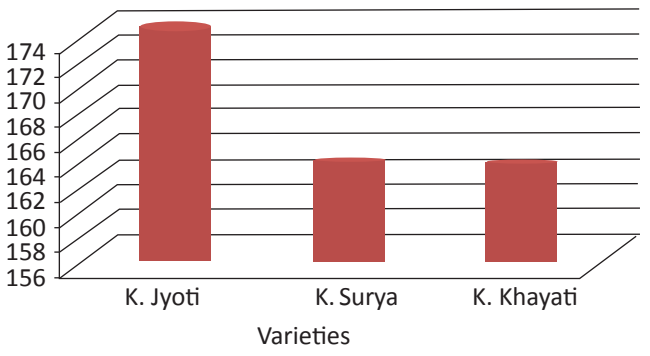

Figure 2: Available N (kg ha^{-1}) in soil

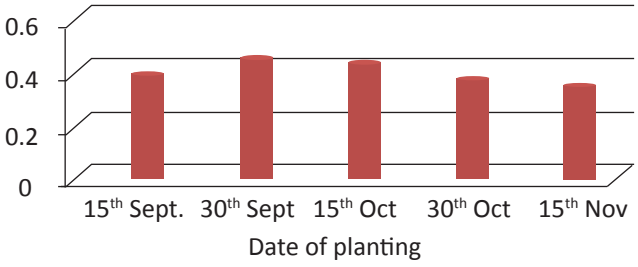

Figure 3: OC(%) in soil - weedy check treatments

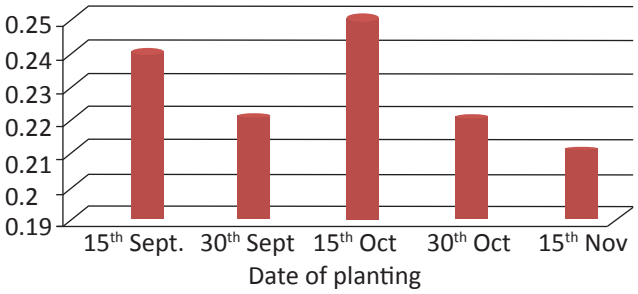

Figure 4: OC (%) in soil - weed free treatments

3.5. Effect of planting windows, varieties and weed control measures on economics

Cost of cultivation was same at all the dates of planting. In Weedy check treatments, gross return (INR 1,20,400 ha^{-1}) was highest with 15th November planted crop. In general, net return increased with increasing date of planting. Highest net return (INR 51,800 ha^{-1}) was recorded with 15th November planted crop which was closely followed by 30th October planted crop. Benefit:cost ratio (1.8) was also highest with 15th November planted crop. Among varieties highest gross return

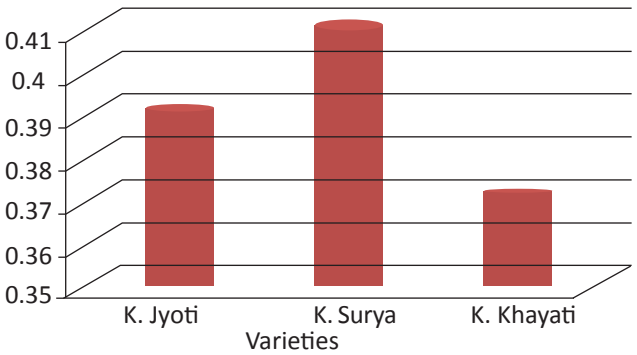

Figure 5: OC (%) in soil of weedy check treatments

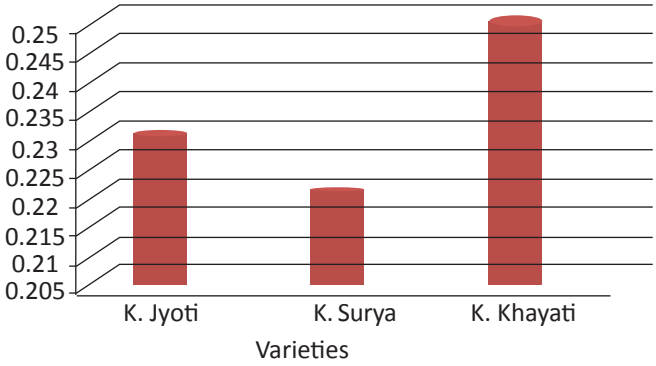

Figure 6: OC (%) in soil of weed free treatments

was recorded with Kufri Surya which was closely followed by Kufri Khyati. Highest net return was also recorded with Kufri Surya which was closely followed by Kufri Khyati. Benefit : cost ratio was same with Kufri Surya and Kufri Khyati. In weed free treatments, cost of cultivation increased by INR 4,300 ha^{-1}. In weed free plots also highest gross return, net return and B : C

Table 3: Effect of planting windows, varieties and weed control measures on N, P and K uptake of potato tubers, haulms and weeds (two years mean data)

DOP	N uptake							P uptake						
	Weed free			Weedy check				Weed free			Weedy check			
	Haulm	Tuber	Total	Haulm	Tuber	Weeds	Total	Haulm	Tuber	Total	Haulm	Tuber	Weeds	Total
15th Sep	20	49	69	18	42	43	103	2.1	8.2	10.3	2.0	5.3	5.6	12.9
30th Sep	45	114	159	43	88	29	160	4.0	11.2	15.2	3.9	9.2	3.5	16.6
15th Oct	34	125	159	31	100	8	139	3.3	15.0	18.3	3.0	11.1	1.0	15.1
30th Oct	33	186	219	30	159	38	223	3.0	19.4	22.4	2.7	13.1	4.3	20.1
15th Nov	23	200	223	22	156	15	193	2.2	18.6	20.8	1.9	13.9	1.6	17.4
CD (p=0.05)	1.8	5.8	3.5	1.7	4.9	3.2	3.6	0.6	0.8	0.8	0.5	0.6	1.0	1.2
K. Jyoti	28	117	145	25	101	35	161	2.7	13.8	16.5	2.5	10.2	3.2	15.9
K. Surya	34	141	175	32	118	27	177	3.3	15.4	18.7	3.1	11.3	2.0	16.4
K. Khayati	34	155	189	30	116	17	163	3.3	15.3	18.6	3.3	12.05	4.2	19.
CD (p=0.05)	1.3	4.9	2.8	1.5	4.1	3.0	2.9	0.5	0.6	0.6	0.4	0.5	0.8	15.9

Table 3: Continue...

DOP	K uptake						
	WF			WC			
	Haulm	Tuber	Total	Haulm	Tuber	Weeds	Total
15th Sep	24	45	69	20	30	21	71
30th Sep	48	71	119	44	48	15	107
15th Oct	36	83	119	32	57	3	92
30th Oct	33	110	143	30	71	16	117
15th Nov	23	131	154	21	96	8	125
CD (*p*=0.05)	2.2	4.8	3.9	2.8	4.5	2.8	3.8
K. Jyoti	33	88	121	28	64	21	113
K. Surya	36	98	131	31	76	14	121
K. Khayati	38	114	150	30	80	10	120
CD (*p*=0.05)	1.9	4.1	3.8	2.3	3.9	2.3	3.6

WC: Weedy check; WF: Weed Free; WUE= Water use efficiency; * Figures in parenthesis indicate original values

ratio were recorded with 15th November planted crop which were significantly higher over all other treatments (Table 4). Among different varieties, highest net return and B:C ratio were recorded with Kufri Khyati which were significantly higher over Kufri Surya and Kufri Jyoti. Increasing date of planting increased water use efficiency from 27 kg tuber ha^{-1} mm to 128 kg ha^{-1}-mm. Water use efficiency was higher in weed control treatments than weedy check treatments. A considerable increase in water application without significant increase in yield is known to reduce the water use efficiency (Singh and Lal, 2013). Water use efficiency was higher in weed control treatments compared to weedy check treatments. Varieties also responded to weed control measure. Under weed controlled situations, Kufri Khyati outperformed other two varieties. The increased efficiency might be due to by use of a combination of chemical (application of herbicide paraquat), mechanical (in-crop cultivation-hoeing) and cultural (competitive cultivar) tactics (Nandula and Reddy, 2012).

Since, weed pressure was higher in 30th September planted crop hence relative production efficiency was highest in this treatment. Highest relative production efficiency was recorded in Kufri Khyati which was followed by Kufri Surya. Similar trend was observed with relative economic efficiency (Table 2).

Table 4: Effect of planting windows, varieties and weed control measures on economics of potato cultivation (two years mean data)

DOP	Cost of cultivation weedy check				Cost of cultivation weed free			
	CC (₹ ha^{-1})	GR (₹ ha^{-1})	NR (₹ ha^{-1})	B:C	CC (₹ ha^{-1})	GR (₹ ha^{-1})	NR (₹ ha^{-1})	B:C
15th September	68600	86400	17800	1.3	72900	100800	27900	1.4
30th September	68600	112700	44100	1.6	2900	146300	73400	2.0
15th October	68600	111000	42400	1.6	2900	138000	65100	1.9
30th October	68600	118000	49400	1.7	2900	137600	64700	1.9
15th November	68600	120400	51800	1.8	2900	154000	81100	2.1
CD (*p*=0.05)	--	--	--	--	--	--	--	--
K. Jyoti	68600	112560	43960	1.6	2900	129920	57020	1.8
K. Surya	68600	126560	57960	1.8	2900	151760	78860	2.1
K. Khayati	68600	126000	57400	1.8	2900	168560	95660	2.3
CD (*p*=0.05)	--	--	--	--	--	--	--	--

CC: Cost of cultivation; GR: Gross return; NR: Net return

4. Conclusion

Potato cultivars Kufri Surya (1888 and 93 g sq m^{-1} fresh and dry weights, respectively) and Kufri Khyati (1569 and 59 g sq m^{-1} fresh and dry weights, respectively) outperformed over

Kufri Jyoti (1963 and 122 g sq m^{-1} fresh and dry weights, respectively). Date of planting has direct influence on tuber yield. Highest tuber yield (30.1 and 38.5 t ha^{-1} with weedy check and weed free, respectively) was recorded with 15th November planted crop though Kufri Surya out yielded (22.6 t ha^{-1}) over other two varieties under higher temperature situation.

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