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Integrated Weed Management Studies in Potato (*Solanum tuberosum* L.) Crop

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A B S T R A C T

The experiment was conducted in Department of Agronomy, College of Agriculture (RVSKVV), Gwalior (M.P.) during the *rabi* season of 2017-2018. The trial was laid out in a randomized block design replicated three times with 10 treatments namely T_1 [White plastic mulch (50 micron)], T_2 [Black plastic mulch (50 micron)], T_3 (Straw mulching @ 5 t/ha at 5 DAP), T_4 (One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP), T_5 (2 HW at 20 & 40 DAP), T_6 (One hand hoeing at 20 DAP), T_7 (Hoeing at 20 DAP & one HW at 40 DAP), T_8 [Recommended herbicide (Metribuzine 0.5 kg /ha as PE)], T_9 [Recommended herbicide (metribuzine 0.5 kg /ha as PE)+ 1 HW at 40 DAP] and T_{10} (Weedy check). All the integrated weed management practices gave more tuber yield than weedy check. Amongst different weed control treatments, Two hand weeding at 20 & 40 DAP was the most effective treatment for reducing weed population and weed dry weight and improving the growth. On the basis of above findings, it may be concluded that the maximum potato yield and net return were obtained from Two H.W. 20 & 40 DAP, followed by One H.W. at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP. In the scarcity of labourer, the farmer may chose the second option i.e., One H.W. at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP or Straw mulching @ 5 t/ha at 5 DAP. B:C ratio was obtained higher in Two H.W. 20 & 40 DAP followed by One H.W. at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP.

Introduction

India stands second largest producer of potato in the world, contributing 10% of the world's total potato production. In 2015-16, potato was cultivated on 2.13 million hectares in India, with a production of 43.77 million tonnes and productivity of 23.07 tones/ha. While, in Madhya Pradesh potato is cultivated on 141.05 thousand ha area with a production of 3161 thousand tonnes & productivity of 22410 kg/ha in (DAC, GOI 2015-16). It covers 6.6% of total area & contributes 7.22% in national potato production. Integrated weed management (IWM) can be a holistic approach to weed management that integrates different methods of weed control to provide crop an advantage over weeds. It is practiced globally at varying levels of adoption from farm to farm. IWM has the potential to restrict weed populations to manageable levels, reduce the adverse environmental impact of individual weed management practices, increase cropping system sustainability, and

reduce selection pressure for weed resistance to herbicides (Harker and O'Donovan, 2013). Plastic mulches have various beneficial effects on crop production in arid regions, including crop earliness, crop cleanliness, prevent soil erosion, conservation of soil moisture and weed control as well as fertility and improving yield and the control of weeds, pests and diseases (Kumar and Lal, 2012; Hidayat *et al.,* 2013). Immirzi *et al.,* (2009) reported that the main advantages of the plastic mulches are the decreased use of chemicals in weed control, reduced water consumption, faster crop development, improved plant health and better yield quality. Different types and colours of plastic mulch have characteristic optical properties that change the levels of light radiation reaching the soil, causing increases or decreases in the soil temperature (Kasirajan and Ngouajio, 2012). Efficiency of plastic mulches varied according to the plastic colour i.e. white, black, blue, brown, green, red and yellow (Mahmood *et al.,* 2002; Grundy and Bond, 2007; Dvořák *et al.,* 2012).

Materials and Methods

The experiment was conducted in field of the College of Agriculture (RVSKVV), Gwalior (M.P.). The topography of the field was uniform with proper drainage. The soil of the experimental field was sandy clay loam. Few soil samples of the surface soil up to 15 cm, depth were taken randomly before sowing and a composite sample made after mixing all these, was analyzed in the laboratory for mechanical and chemical composition. The experiment was conducted in randomized block design replicated three times with 10 treatments as follows, T_1 [White plastic mulch (50 micron)], T_2 [Black plastic mulch (50 micron)], T_3 (Straw mulching @ 5 t/ha at 5 DAP), T_4 (One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP), T_5 (2 HW at 20 & 40 DAP), T_6 (One hand hoeing at 20 DAP), T_7 (Hoeing at 20 DAP & one HW at 40 DAP), T_8 [Recommended herbicide (Metribuzine 0.5 kg /ha as PE)], T_9 [Recommended herbicide (metribuzine 0.5 kg /ha as PE)+ 1 HW at 40 DAP] and and T_{10} (Weedy check). Sampling was done at 30 and 60 days after planting and at harvest for growth analysis. Five plants from net area of each plot were randomly selected from three successive stage by selecting row in the first stage, plant of one-meter running row from selected row in the second stage and ultimate sample unit from selected plants of one-meter running row in third stage of selection with the help of simple random sampling without replacement.

Results and Discussion

Growth parameters

All the integrated weed management treatments except T_8, T_6, T_1 and T_9 increased the plant height significantly over weedy check. The maximum plant height was recorded under T_5 (2 HW at 20 & 40 DAP) which was, statistically at par with T_4 and T_7 at 30 DAP. At 60 DAP, treatment T_8 and T_1 were found least effective in increasing plant height as they recorded statistically similar plant height to weedy check. Among the all weed control treatments, T_5 (2 HW at 20 & 40 DAP) was significantly superior in enhancing the plant height and it was statistically at par with T_4, T_3 and T_2. At harvest, all the integrated weed management treatments except T_8, T_1, T_6 and T_7 were significantly superior in increasing the plant height over weedy check. The treatment T_5 (2 HW at 20 & 40 DAP) showed highest plant height being at par with T_4, T_3 and T_2. Arora *et al.,* (2009) Kumar *et al.,* (1998), and Thakral (1989) in potato who reported that different weed control treatments significantly influenced the plant height.

All the integrated weed management treatments except T_7, T_6, T_8 and T_1 significantly increased the number of leaves per plant over weedy check. The maximum number of leaves was recorded under the treatment T_5 (2 HW at 20 & 40 DAP) which was statistically at par with T_4, T_3 and T_2 at 30 DAP. At 60 DAP, all the integrated weed management treatments except T_1, T_2, T_8, T_9 and T_3 significantly increased the number of leaves per plant over weedy check. The maximum number of leaves was recorded under the treatment T_5 (2 HW at 20 & 40 DAP) which was statistically at par with T_7, T_4, T_6, T_3, T_9 and T_8. At harvest, all the weed control treatments increased the number of leaves per plant significantly over weedy check. Among the weed control treatment, T_5 (2 HW at 20 & 40 DAP) treatment resulted in significantly highest leaves over rest of the treatments which was found at par to each others at harvest. The results are also in line with findings of Singh *et al.,* (2006).

The different weed control treatments did not affect number of stem per plant. The number of stem per plant recorded at 30 DAP, ranged between 3.00 T_{10} (Weedy check) to 4.89 T_5 (2 HW at 20 & 40 DAP) while at harvest stage it ranged from 3.00 T_{10} (Weedy check) to 5.78 T_5 (2 HW at 20 & 40 DAP). At 60 DAP, all the weed control treatments increased the number of stem per plant significantly over weedy check. Among the weed control treatment, T_5 (2 HW at 20 & 40 DAP) treatment resulted in significantly higher number of stem per plant over rest of the treatments which were found at par to each others at 60 DAP. These finding are in close vicinity, Robert (1975), Sandhu *et al.,* (1976) and Bhalla (1980).

Significant differences in dry matter production per plant were recorded due to various treatments. Similarly observed all the weed control treatments increased the dry matter production per plant significantly over weedy check. Among the weed control treatment T_5 (2 HW at 20 & 40 DAP) treatments similarly resulted in significantly highest dry matter production over rest of the treatments which were found at par to each others at all stages.

Maximum fresh weight per plant were noted under treatment T_5 (2 HW at 20 & 40 DAP), followed by treatments T_4 and T_3. Minimum fresh weight per plant was noted under treatment T_{10} (weedy check), which was significantly less than other weed management practices at 30 DAP. Maximum fresh weight per plant at 60 DAP were recorded under T_5 (2 HW at 20 & 40 DAP), which was at par with T_4, T_3 and T_2. Minimum fresh weight per plant was noted under T_{10} (weedy check), which was significantly less than that recoded under any of the treatment. At harvest stages, maximum fresh weight per plant were recorded under T_5 (2 HW at 20 & 40 DAP), which was at par with T_4 and T_3. Minimum fresh weight per plant was noted under T_{10} (weedy check), which was significantly less than that recoded under any of the treatment.

Maximum dry weight per plant were recorded under treatment T_5 (2 HW at 20 & 40 DAP), which was at par with T_4, T_9, T_3, T_7, T_8 and T_2. Minimum dry weight per plant was noted under treatment T_{10} (weedy check), which was significantly less than other weed management practices at 30 DAP. Maximum dry weight per plant at 60 DAP were recorded under T_5 (2 HW at 20 & 40 DAP), which was at par with T_2, T_3, T_9, T_4 and T_7. Minimum dry weight per plant was noted under T_{10} (weedy check), which was significantly less than that recoded under any of the treatment. At harvest stage, maximum dry weight per plant was recorded under T_5 (2 HW at 20 & 40 DAP), which was at par with T_2, T_4, T_3, T_9 and T_7. Minimum dry weight per plant was

noted under T_{10} (weedy check), which was significantly less than that recoded under any of the treatment. These finding are in close vicinity, Sandhu *et al.*, (1976), Bhalla (1980), Gill *et al.*, (1983). Shekhawat and Maliwal (1989) (Table 1–3).

Table.1 Plant height (cm) and number of leaves per plant of potato at different crop stages as influenced by integrated weed management

Treatments	Plant height (cm)			No. of leaves per plant		
	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest
T_1-White plastic mulch (50 micron)	21.56	42.78	46.00	31.67	35.11	21.56
T_2-Black plastic mulch (50 micron)	23.56	51.11	52.56	32.44	36.89	19.28
T_3-Straw mulching @ 5 t/ha at 5 DAP	23.78	49.56	52.22	33.00	49.11	20.17
T_4-One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	25.56	51.44	53.78	36.67	50.44	20.83
T_5-Two hand weeding at 20 & 40 DAP	26.78	53.89	58.11	41.11	58.67	23.28
T_6-One hand hoeing at 20 DAP	20.67	44.89	47.11	26.78	50.00	16.89
T_7-Hoeing at 20 DAP & one HW at 40 DAP	24.33	45.00	47.33	26.22	52.00	18.28
T_8-Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	20.22	40.00	43.78	31.11	41.78	18.89
T_9-Recommended herbicide (metribuzine 0.5 kg/ha as PE)+ 1 HW at 40 DAP	22.22	45.89	49.22	37.44	42.22	20.61
T_{10}-Weedy Check	19.56	36.67	39.78	21.89	31.56	16.50
S.E.(m) ±	**0.96**	**2.62**	**2.06**	**3.59**	**6.13**	**2.00**
CD (at 5%)	**2.798**	**7.667**	**6.029**	**10.515**	**17.954**	**5.854**

Table.2 Number of leaves per plant and number of stem per plant of potato at successive crop growth stages as influenced by integrated weed management

Treatments	No of leaves per plant			No of stem per plant		
	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest
T_1-White plastic mulch (50 micron)	31.67	35.11	21.56	3.56	4.11	3.67
T_2-Black plastic mulch (50 micron)	32.44	36.89	19.28	3.78	4.00	3.89
T_3-Straw mulching @ 5 t/ha at 5 DAP	33.00	49.11	20.17	4.00	4.22	4.89
T_4-One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	36.67	50.44	20.83	4.11	5.56	5.22
T_5-Two hand weeding at 20 & 40 DAP	41.11	58.67	23.28	4.89	5.89	5.78
T_6-One hand hoeing at 20 DAP	26.78	50.00	16.89	3.33	3.89	4.11
T_7-Hoeing at 20 DAP & one HW at 40 DAP	26.22	52.00	18.28	3.78	3.78	4.33
T_8-Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	31.11	41.78	18.89	3.44	3.56	4.67
T_9-Recommended herbicide (metribuzine 0.5 kg/ha as PE)+ 1 HW at 40 DAP	37.44	42.22	20.61	4.44	4.56	4.78
T_{10}-Weedy Check	21.89	31.56	16.50	3.00	3.33	3.00
S.E.(m) ±	**3.59**	**6.13**	**2.00**	**0.50**	**0.59**	**0.51**
CD (at 5%)	**10.515**	**17.954**	**5.854**	**NS**	**1.727**	**NS**

Table.3 Dry matter production per plant, fresh weight per plant and Dry weight per plant of potato at successive crop growth stages as influenced by integrated weed management

Treatments	Dry matter production (g/plant)			Fresh weight per plant (g)			Dry weight per plant (g)		
	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest
T_1-White plastic mulch (50 micron)	0.80	1.03	1.17	95.33	261.53	464.27	5.68	7.01	13.70
T_2-Black plastic mulch (50 micron)	0.97	1.30	1.50	98.42	303.79	433.19	5.82	8.08	15.79
T_3-Straw mulching @ 5 t/ha at 5 DAP	1.44	1.77	1.97	100.67	308.17	496.16	5.96	7.91	15.46
T_4-One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	1.64	1.80	2.03	103.25	319.35	508.44	6.12	7.85	15.67
T_5-Two hand weeding at 20 & 40 DAP	2.17	2.43	2.57	114.75	338.60	530.02	6.23	8.36	16.01
T_6-One hand hoeing at 20 DAP	0.54	0.77	0.97	88.67	273.31	417.86	5.54	7.33	14.32
T_7-Hoeing at 20 DAP & one HW at 40 DAP	0.59	0.77	0.93	95.25	292.92	446.12	5.95	7.60	15.18
T_8-Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	1.08	1.47	1.70	99.67	275.16	480.99	5.90	7.38	14.42
T_9-Recommended herbicide (metribuzine 0.5 kg/ha as PE)+ 1 HW at 40 DAP	1.17	1.27	1.47	97.33	295.05	481.52	6.08	7.91	15.46
T_{10}-Weedy Check	0.30	0.43	0.53	79.83	206.29	323.63	4.32	5.00	9.93
S.E.(m) ±	**0.600**	**0.614**	**0.629**	**3.572**	**12.728**	**15.460**	**0.183**	**0.288**	**0.484**
CD (at 5%)	**1.800**	**1.839**	**1.885**	**10.456**	**37.259**	**45.257**	**0.535**	**0.843**	**1.417**

Table.4 Effect of integrated weed management practices on AGR, RGR and CGR and Root: Shoot ratio at harvest

Treatments	Physiological parameters			
	AGR (g/day)	RGR (g/day/m^2)	CGR (g/m^2/day)	Root: Shoot Ratio
T_1-White plastic mulch (50 micron)	13.61	1.15	12.79	2.74
T_2-Black plastic mulch (50 micron)	15.69	1.48	14.86	2.54
T_3-Straw mulching @ 5 t/ha at 5 DAP	15.36	1.94	14.51	3.89
T_4-One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	15.57	2.01	14.70	4.61
T_5-Two hand weeding at 20 & 40 DAP	15.91	2.53	15.02	7.24
T_6-One hand hoeing at 20 DAP	14.23	0.96	13.43	2.62
T_7-Hoeing at 20 DAP & one HW at 40 DAP	15.08	0.92	14.22	2.66
T_8-Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	14.32	1.68	13.47	3.84
T_9-Recommended herbicide (metribuzine 0.5 kg/ha as PE)+ 1 HW at 40 DAP	15.36	1.45	14.49	3.73
T_{10}-Weedy Check	9.86	0.53	9.24	3.35
S.E.(m) ±	**0.485**	**0.619**	**0.490**	**0.834**
CD (at 5%)	**1.418**	**NS**	**1.436**	**2.441**

Table.5 Effect of different weed control measures on Number of tuber per plant, Fresh weight of tuber per plant (g) and Dry weight of tuber (g/plant) at 30, 60 DAP & harvest of potato

Treatments	No. of tuber per plant			Fresh weight of tuber (gm)			Dry weight of tuber (g/plant)		
	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest
T_1-White plastic mulch (50 micron)	3.56	12.67	14.67	50.40	100.81	403.22	4.71	9.42	37.67
T_2-Black plastic mulch (50 micron)	3.89	11.33	13.00	51.07	102.14	408.56	5.00	10.00	40.00
T_3-Straw mulching @ 5 t/ha at 5 DAP	4.67	17.00	19.00	52.92	105.83	423.33	7.54	15.08	60.33
T_4-One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	4.89	17.33	19.33	57.01	114.03	456.11	9.08	18.17	72.67
T_5-Two hand weeding at 20 & 40 DAP	5.67	21.67	23.33	74.83	149.67	598.67	14.42	28.83	115.33
T_6-One hand hoeing at 20 DAP	3.67	10.67	12.33	53.17	106.33	425.33	4.67	9.33	37.33
T_7-Hoeing at 20 DAP & one HW at 40 DAP	3.44	15.33	17.33	67.67	135.33	541.33	5.00	10.00	40.00
T_8-Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	3.22	12.33	14.33	69.46	138.92	555.67	6.83	13.67	54.67
T_9-Recommended herbicide (metribuzine 0.5 kg/ha as PE)+ 1 HW at 40 DAP	3.56	14.00	16.00	69.78	139.56	558.22	7.33	14.67	58.67
T_{10}-Weedy Check	0.44	9.00	11.00	49.97	99.94	399.78	4.17	8.33	33.33
S.E.(m) ±	**0.37**	**2.39**	**2.343**	**4.927**	**9.854**	**39.416**	**1.598**	**3.197**	**12.787**
CD (at 5%)	**1.086**	**6.985**	**6.860**	**14.423**	**28.847**	**115.387**	**4.679**	**9.358**	**37.432**

Table.6 Effect of different weed control measures on Number of tubers (grade wise on the basis of weight and size) at harvest and Tuber yield (grade wise on the basis of weight and size) at harvest (kg/plot and tonne/ha)

Treatments	Number of tubers (grade wise on the basis of weight and size) at harvest			Tuber yield (grade wise on the basis of weight and size) at harvest (kg/plot and tonne/ha)		
	<25 (gm)	50-75 (gm)	>75 (gm)	<25 (gm)	50-75 (gm)	>75 (gm)
T_1-White plastic mulch (50 micron)	270.00	251.67	41.67	7.33	16.00	6.67
T_2-Black plastic mulch (50 micron)	276.67	253.33	44.00	7.67	16.67	7.67
T_3-Straw mulching @ 5 t/ha at 5 DAP	292.00	287.33	52.67	8.00	18.33	8.33
T_4-One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	306.67	293.33	52.00	8.00	19.33	8.67
T_5-Two hand weeding at 20 & 40 DAP	345.33	295.00	60.67	10.00	19.67	10.00
T_6-One hand hoeing at 20 DAP	260.00	210.00	36.67	6.67	14.00	6.33
T_7-Hoeing at 20 DAP & one HW at 40 DAP	263.33	233.33	39.33	6.67	16.00	6.33
T_8-Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	278.33	268.67	44.33	7.67	17.00	8.00
T_9-Recommended herbicide (metribuzine 0.5 kg/ha as PE)+ 1 HW at 40 DAP	286.67	285.33	48.67	7.67	18.33	8.00
T_{10}-Weedy Check	176.67	190.00	33.67	4.67	11.67	5.00
S.E.(m) ±	**35.307**	**19.947**	**5.658**	**0.899**	**1.311**	**1.185**
CD (at 5%)	**NS**	**58.394**	**NS**	**NS**	**3.838**	**NS**

Table.7 Effect of different treatments on harvest index (%) and weed index (%)

Treatments	Harvest index (%)	Weed index (%)
White plastic mulch (50 micron)	53.38	29.62
Black plastic mulch (50 micron)	55.57	25.11
Straw mulching @ 5 t/ha at 5 DAP	62.92	16.57
One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	63.45	5.71
Two hand weeding at 20 & 40 DAP	65.66	0.00
One hand hoeing at 20 DAP	54.79	39.27
Hoeing at 20 DAP & one HW at 40 DAP	56.64	33.69
Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	58.92	21.26
Recommended herbicide (metribuzine 0.5 kg/ha as PE) + 1 HW at 40 DAP	60.53	19.39
Weedy Check	51.11	47.22

Table.8 Economics of potato as influenced by integrated weed management practices

Treatments	Tuber yield (t/ha)	Total cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C Ratio
White plastic mulch (50 micron)	15.75	156968	236250	91792	0.57
Black plastic mulch (50 micron)	16.76	146968	251405	116937	0.79
Straw mulching @ 5 t/ha at 5 DAP	18.67	102694	280035	189841	1.92
One HW at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP	21.10	106804	316565	222261	2.15
Two hand weeding at 20 & 40 DAP	22.38	102448	335635	245677	2.51
One hand hoeing at 20 DAP	13.59	97242	203875	119133	1.27
Hoeing at 20 DAP & one HW at 40 DAP	14.84	101352	222640	133788	1.35
Recommended herbicide (Metribuzine 0.5 kg/ha as PE)	17.62	96870	264330	179960	1.94
Recommended herbicide (metribuzine 0.5 kg/ha as PE) + 1 HW at 40 DAP	18.04	99872	270525	183158	1.91
Weedy Check	11.81	95872	177195	93823	0.99
S.E.(m) ±	**1.53**	**30046.15**	**22926**	**30046.15**	
CD (at 5%)	**4.47**	**87957.76**	**67113**	**87957.76**	

Physiological parameters

Maximum absolute growth rate (AGR) were recorded under T_5 (2 HW at 20 & 40 DAP), which was at par with T_2, T_4, T_3, T_9 and T_7. Minimum AGR was noted under T_{10} (weedy check), which was significantly less than that recoded under any of the treatment. The different weed control treatments did not affect relative growth rate (RGR). The RGR recorded ranged between 0.53 (Weedy check) to 2.53 (2 HW at 20 & 40 DAP). Maximum crop growth rate (CGR) were recorded under T_5 (2 HW at 20 & 40 DAP), which was at par with T_2, T_4, T_3, T_9 and T_7 except rest of the treatments. Minimum CGR was noted under T_{10} (weedy check), which was significantly less than that recoded under any of the treatment. Observed all the weed control treatments increased the root and shoot ratio significantly over weedy check. Among the weed control treatment T_{10} (weedy check), treatments similarly resulted in significantly minimum root and shoot ratio, rest of the treatments were found at par to each others at harvest stages (Table 4).

Yield attributes and yield

The treatment T_5 (2 HW at 20 & 40 DAP) gave the maximum number of tuber per plant, which was significantly higher to the rest of the treatments except treatment T_4 and T_3. The lowest number of tuber per plant was noted in treatment T_{10} (Weedy check) at 30 DAP.

The treatment T_5 (2 HW at 20 & 40 DAP) gave the maximum number of tuber per plant, which was significantly higher to the rest of the treatments except treatment T_4, T_3 and T_7. The lowest number of tuber per plant (9.00/plant) was noted in treatment T_{10} (Weedy check) which was at par with T_6, T_2, T_8, T_1 and T_9 at 60 DAP. At harvest stage, the treatment T_5 (2 HW at 20 & 40 DAP) gave the maximum number of tuber per plant, which was significantly higher to the rest of the treatments except treatment T_4, T_3 and T_7.

The lowest number of tuber per plant was noted in treatment T_{10} (Weedy check) which was at par with T_6, T_2, T_8, T_1, T_9 and T_7. The yield and yield attributing characters viz., fresh weight of tuber, dry weight of tuber, number of tuber (grade wise on the basis of weight), and tuber yield (grade wise on the basis of weight) were significantly influenced by the treatments. The maximum fresh weight of tuber per plant was recorded with treatment T_5. Further, treatment T_9, T_8 and T_7 recorded were statistically the same to each other. The minimum fresh weight of tuber per plant was noted in treatment T_{10} (weedy check) which was at par with T_1, T_2, T_3 and T_6 at 30 DAP. At 60 DAP, the maximum fresh weight of tuber per plant was recorded with treatment T_5. Further, treatment T_9, T_8 and T_7 recorded were statistically the same to each other. The minimum fresh weight of tuber per plant was noted in treatment T_{10} (weedy check) which was at par with T_1, T_2, T_3 and T_6. At harvest stage, the maximum fresh weight of tuber per plant was recorded with treatment T_5. Further, treatment T_9, T_8 and T_7 recorded treatments were statistically the same to each other. The minimum fresh weight of tuber per plant was noted in treatment T_{10} (weedy check) which was at par with T_1, T_2, T_3, T_4 and T_6. Minimum dry weight of tuber per plant was recorded with treatment T_{10} (weedy check). Further, treatment T_6, T_1, T_2, T_7, T_8, T_9 and T_3 recorded treatments were statistically the same to each other. The maximum dry weight of tuber per plant was noted in treatment T_5 (2 HW at 20 & 40 DAP), at 30 DAP. At 60 DAP, minimum dry weight of tuber per plant was recorded with treatment T_{10} (weedy check). Further, treatment T_6, T_1, T_2, T_7, T_8, T_9 and T_3 recorded treatments were statistically the same to each other. The maximum dry weight of tuber per plant was

noted in treatment T_5 (2 HW at 20 & 40 DAP). At harvest stage, minimum dry weight of tuber per plant was recorded with treatment T_{10} (weedy check). Further, treatment T_6, T_1, T_2, T_7, T_8, T_9 and T_3 recorded treatments were statistically the same to each other. The maximum dry weight of tuber per plant was noted in treatment T_5 (2 HW at 20 & 40 DAP). Number of tubers per plot did not respond to various weed control treatments at <25 gm and >75 gm. The treatment T_5 produced significantly higher number of tuber per plot under 50-75 gm as compared to rest treatment and it was at par with T_4, T_3, T_9, T_8, T_2 and T_1 treatments were statistically at par to each other. However, treatment T_{10} (weedy check) gave inferior number of tuber per plot as compared to other treatments except T_6 and T_7. Tuber yield did not respond to various weed control treatments at <25 gm and >75 gm. However, it varied from 4.67 to 10.00 gm and 5.00 to 10.00 gm, respectively tuber yield per plot at <25 gm and >75 gm. Treatment T_5 (2 HW at 20 & 40 DAP) gave maximum and significantly higher tuber yield (22.38 t/ha). The significantly lower seed yield was produced under T_{10} (Weedy check). Harvest Index was maximum recorded under T_5 (2 HW at 20 & 40 DAP) followed by T_4. Minimum harvest index was noted in T_{10} (Weedy check). Treatment T_5 (2 HW at 20 & 40 DAP) gave the completely weed control. T_4 recorded lowest weed index, followed by T_3 and T_9. Similarly, weedy check resulted in maximum weed index followed by T_6. Two hands weeding at 20 and 40 DAP were found most effective treatment for control of weeds in potato crop. Shekhawat and Maliwal (1989) reported that number of tuber per plant at harvest increased with application of herbicides or hand weeding (6.50- 6.75) as compared to untreated control (4.25). This might be due to the fact that hand weeding in potato affects the crop yield reported by Thakral *et al.,* (1989) and Singh *et al.,* (2014). These results are in close proximity of the finding made by Singh and Bhan (1999), and Abouziena *et al.,* (2015) (Table 5–7).

Economic analysis of the treatments

The maximum net return of Rs 245677/ha was found with treatment T_5 (2 HW at 20 & 40 DAP). All other treatments were at par with T_4 (Rs. 222261/ha), T_3 (Rs. 189841/ha), T_9 (Rs. 183158/ha) and T_8 (Rs. 179960/ha). However, T_1 [white plastic mulch (50 micron)] recorded minimum net income (Rs 91792/ha) as compared to other treatments. But B:C ratio was higher (2.51) in the treatment of 2 HW at 20 and 40 DAP, followed by 1 H.W. at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP. Minimum B:C ratio was obtained in treatment weedy check. All these above treatments, were most effective weed control treatments recorded higher yield and weed control efficiency, also recorded higher benefit cost ratio. Similar finding were also reported by Habib *et al.,* (1991), Singh *et al.,* (2007), Singh (2010) and Yadav *et al.,* (2014) (Table 8).

In cconclusion, the integrated weed management practices gave more tuber yield than weedy check. Amongst different weed control treatments, Two hand weeding at 20 & 40 DAP was the most effective treatment for reducing weed population and weed dry weight and improving the growth. On the basis of above findings, it may be concluded that the maximum potato yield and net return were obtained from Two H.W. 20 & 40 DAP, followed by One H.W. at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP. In the scarcity of labourer, the farmer may chose the second option i.e., One H.W. at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP or Straw mulching @ 5 t/ha at 5 DAP. B:C ratio was obtained higher in Two H.W. 20 & 40 DAP followed by One H.W. at 20 DAP + Straw mulching @ 5 t/ha at 25 DAP.

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