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Weed management in potato (*Solanum tuberosum* L.) using manual and chemical methods

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Abstract
In order to evaluate the manual and chemical methods for weed control in potato crop, a field experiment was conducted during the *rabi* season of 2014-15 at Vegetable Research Centre, G.B.P.U.A. & T., Pantnagar, U.S. Nagar, Uttarakhand. The experimental field was laid out in Randomized Block Design with 3 replications and 7 treatments out of which treatment T_2 (weed free) recorded the maximum plant height (34.15 and 55.17cm) and number of haulms/hill found non-significant at both, 30 and 45 days after planting (DAP) respectively, along with maximum potato marketable tuber yield (353.01 q/ha) followed by treatment T_6 metribuzin @ 0.75 kg a.i./ha as pre emergence (305.43 q/ha). However, the results indicated that application of metribuzin @ 0.75 kg a.i./ha as pre emergence *i.e.*, treatment T_6 was more effective to weed control whereas, total number of monocot weeds (41.33) and dicot weeds (1.33) were found minimum under treatment T_2 (weed free) and T_7 (metribuzin @ 0.75 kg a.i. / ha post emergence) during growth stage 60 DAP. Grade wise maximum number of tubers per plot, A grade, B grade, C grade, D grade were found in Treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence, T_7, T_2 (weed free), T_3 (hand weeding at 30 DAP) respectively.

Keywords: potato, *Solanum tuberosum* L., metribuzin, weed control, chemical control, hand weeding

Introduction
Potato (*Solanum tuberosum* L.) is the most important vegetable crop of the world. In India, potato is being cultivated on 2153 thousand hectare area with a total annual production of 50327 thousands MT. It has 27.27 per cent share of total vegetable production in India with a productivity of 23.37 t/ha (Anonymous, 2018) [1]. About 90% of the total potato area is located in subtropical plains, 6% in the hills and 4% in the plateau region of peninsular region (Chadha, 2009). In Uttarakhand state potato is an important crop as it is a good source of income and employment generation. Yield losses in potato due to weeds occur in several ways. Among these, competition between potato plants and weeds for nutrients is the major contributing factor. The nutrient losses caused by weeds in the potato crop at Shimla amounted to 43, 8 and 49 kg N, P and K per hectare respectively (Nankar and Singh, 1982) [10]. Manorama *et al.* (2010) [8] suggested that the pre-emergence application of herbicide like metribuzin (0.7-1.0 kg/ha) can be applied within 3-5 days after planting the crop or just before the emergence of weeds and the crop. It creates a favourable atmosphere for weeds and, if early control measures are not taken, they completely smother the potato plants in early stages of growth resulting in lower yields.

Material and Methods
The research work was carried out during the *rabi* season 2014-15 at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, District- Udham Singh Nagar, Uttarakhand. The experiment consisted of three replications and seven treatments as follows, T_1 (weedy check), T_2 (weed free), T_3 (hand weeding at 30 DAP*), T_4 (hand weeding at 40 DAP), T_5 (hand weeding at 50 DAP), T_6 (herbicide metribuzin @ 0.75 kg a.i. / ha pre emergence), T_7 (herbicide metribuzin @ 0.75 kg a.i. / ha post emergence). The height of each tagged plant was measured successively at 30, 45 DAP stage from the base to the tip of longest leaf by straightening. It was measured with the help of meter scale and the data were recorded in centimeter (cm). The mean plant height was calculated by summing up the length of five plants and dividing by five. The total numbers of haulms present per hill were counted at 30, 45 DAP stage from the tagged plants in each plot and averaged at all the four stages. Number of monocot and dicot weeds were counted species wise at 60 DAP stage

from each plot by randomly throwing a square of 1m^2 area and the weeds which comes inside it are counted. After harvesting, grading of tubers was done into four grades on the basis of their weight viz., A (>75 g), B (50-75 g), C (25-50 g) and D (<25 g) and the grade wise number of tubers were counted. The total number of harvested tubers in each plot were weigh according to the grades and grade wise weight of tubers per plot was calculated and expressed in kilogram. The diseased and damaged tubers were sorted out and the marketable yield of harvested tubers per hectare was calculated on the basis of marketable yield of tubers per plot and converted into quintals per hectare. The cost of cultivation was calculated by taking all considerations of expenditure incurred on the basis of existing market rate of inputs. Total output was calculated by multiplying per hectare yield of tubers under various treatments with prevailing selling rates of tubers in the local market. The benefit: cost ratio was computed by adopting following formula:

$$\text{Benefit: Cost ratio} = \frac{\text{Gross income (Rs./ha)}}{\text{Total expenditure (Rs./ha)}}$$

The data recorded during the course of experiment were subjected to analysis through computer by using STPR3 programme, designed and developed by department of Mathematics and Statistics, College of Basic Sciences and Humanities, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand.

Result and Discussion

Growth parameters

Plant height as affected by different weed management treatments have been presented in table 1. The various weed control treatments significantly influences the plant height at 45 DAP stage but not at 30 DAP. The maximum plant height at both stages of crop growth was recorded with weed free treatment (T_2). At 45 days stage, it was statistically at par with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence) and T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) and significantly higher than rest of treatments. At 60 days stage, it was statistically at par with treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) and T_1 (weedy check). Whereas, minimum plant height was recorded in T_5 (hand weeding at 50 DAP) at 30DAP and at 45 days stage where it was recorded in treatment T_4 (hand weeding at 40 DAP). Critical observation of the data (table 1) indicated that maximum plant height was found under weed free plot which was significantly higher than the rest of the plots. This trend was possibly due to the minimized weed competition in weed free plot which allow the crop for proper growth with less weed competition as compared to other weed treatments. The results obtained by Dua (2000) [6] and Channappagoudar (2007b) [5] support these findings.

The number of haulms per hill as affected by different weed management treatments have been presented in table 1. It is evident from the table that the number of haulms per hill at both stages of crop growth was not significantly affected by various weed control treatments. The maximum number of haulms per hill was recorded under treatment T_3 (hand weeding at 30 DAP) at 30 DAP and T_2 (weed free) at 45 DAP stage of crop growth whereas, the minimum was recorded with treatment T_5 (hand weeding at 50 DAP) at 30 days stage and T_3 (hand weeding at 30 DAP) at 45 stage of crop growth. The results indicated that the various weed management treatments didn't have any impact on number of haulms per hill of potato tubers. The number of haulms per hill depends on the cultivar, seed size and its physiological stage of the seed tuber. Our results were in close conformity with Chandrakar *et al*. (2013) [3] and Dua (2000) [6].

The effect of various weed management treatments on number of monocot weeds per m^2 at different growth stages of crop have been presented in table 1. It is evident from the table that number of monocot weeds per m^2 was significantly affected by application of various weed control treatments at 60 DAP stage of crop growth. At 60 days stage the maximum number of monocot weeds was recorded in treatment T_5 (hand weeding at 50 DAP) which was at par with treatment T_3 (hand weeding at 30 DAP), T_4 (hand weeding at 40 DAP), T_1 (weedy check) and T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence) whereas, the minimum number was found in T_2 (weed free) which was at par with treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence). The effect of various weed management treatments on the number of dicot weeds per m^2 at different growth stages of crop have been presented in table 1. It is evident from the table that number of dicot weeds per m^2 was found significant at 60 DAP growth stages by application of various weed control treatments. At 60 days stage the maximum dicot weeds was recorded in treatment T_4 (hand weeding at 40 DAP) which was at par with treatment T_3 (hand weeding at 30 DAP), T_5 (hand weeding at 50 DAP), and T_1 (weedy check) whereas, the minimum number dicot weeds was found in treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) which was at par with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence) and T_2 (weed free). The critical observation of data (Table 1) revealed that the number of monocot and dicot weeds per m^2 was significantly lowest in treatment T_2 (weed free) because of the season long weed free condition. Similar findings were obtained by Channappagoudar *et al*. (2007a) [4] and Mukhopadhyay *et al*. (2002) [9] who found minimum number of dicot weeds under weed control treatments over the weedy check.

Yield parameters

Grade wise number of tubers per plot

The effect of weed management treatments with respect to grade wise number of tubers of potato per plot have been presented in table 2. Grade wise number of tubers per plot were significantly influenced in each grade by the application of various weed control treatments. Potato tubers graded as grade A (>75g) recorded highest number of tubers per plot in the treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) which was statistically at par with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence), T_2 (weed free) and T_5 (hand weeding at 50 DAP) whereas, the lowest was recorded in treatment T_1 (weedy check) which was statistically at par with treatment T_3 (hand weeding at 30 DAP) and T_4 (hand weeding at 40 DAP).

Treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) have maximum number of grade B (50-75gm) potato tubers per plot which was statistically at par with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence), T_2 (weed free) and T_5 (hand weeding at 50 DAP) whereas, minimum number of tubers was recorded in treatment T_3 (hand weeding at 30 DAP) which was statistically at par with treatment T_4 (hand weeding at 40 DAP) and T_1 (weedy check).

The maximum number of tubers per plot under grade C (25-50gm) was recorded in treatment T_2 (weed free) which was statistically at par with treatment T_3 (hand weeding at 30 DAP) whereas, the lowest was observed in treatment T_1 (weedy check) which was statistically at par with treatment T_7

(metribuzin @ 0.75 kg a.i./ha post emergence), T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence), T_4 (hand weeding at 40 DAP) and T_5 (hand weeding at 50 DAP).

The maximum number of potato tubers per plot graded under grade D (<25gm) was recorded in treatment T_3 (hand weeding at 30 DAP) which was statistically at par with treatment T_1 (weedy check), T_2 (weed free), T_5 (hand weeding at 50 DAP), T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence) and T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) whereas, the minimum number was observed in treatment T_4 (hand weeding at 40 DAP).

The critical observation of data (Table 2) revealed that the number of tubers of grade A and B was recorded highest with the treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) whereas, C and D grade potato tubers was recorded maximum with weed free and hand weeding at 30 days treatments, respectively. The grade wise increase in number of tubers may be due to improved early root development and growth of plants by various weed management treatments which reduces the competition and enhances the growth of roots and stolon leads to increase in the graded number of tubers. The results are also in agreement in findings of Panghal *et al.* (2005) [11] who reported an increase in number of tubers with the weed free over control.

Grade wise weight of tubers per plot

The effect of weed management treatments with respect to grade wise weight of tubers of potato per plot have been presented in table 2. It is evident from the table that the grade wise weight of tubers was significantly affected for grade A (>75g), B (50-75g), C (25-50g) and D (<25g) by various weed control treatments.

Table 1: Effect of various weed control treatments on plant height, number of haulms per hill, number of monocot and dicot weeds per m^2, marketable yield, economics and net profit per hectare.

Treatment	Plant height (cm)		Number of haulms/hill		Number of monocot weeds per m^2	Number of dicot weeds per m^2	Marketable yield (q/ha)	Total expenditure (₹)	Gross income (₹)	B:C ratio
	30 DAP	45 DAP	30 DAP	45 DAP	60 DAP	60 DAP				
T_1- Weedy check	33.12	50.38	3.60	4.40	16.37 (270.65)	5.71 (33.33)	259.36	150987.44	259360	1.72
T_2-Weed free	34.15	55.17	3.60	4.80	6.46 (41.33)	1.87 (4.00)	353.01	204174.64	353010	1.73
T_3- Hand weeding at 50 DAP	32.93	48.53	3.67	4.07	17.93 (330.65)	7.19 (53.30)	295.47	157230.64	295470	1.88
T_4- Hand weeding at 50 DAP	33.03	47.04	3.73	4.40	17.12 (306.64)	7.27 (52.04)	269.31	155899.44	269310	1.73
T_5- Hand weeding at 50 DAP	32.72	48.41	3.20	4.20	18.28 (337.35)	6.91 (50.65)	266.84	155771.44	266840	1.71
T_6- Metribuzin @ 0.75 kg a.i. / ha pre emergence	33.63	53.73	3.60	4.47	12.21 (150.65)	1.66 (2.65)	305.43	157932.64	305430	1.93
T_7- Metribuzin @ 0.75 kg a.i. / ha post emergence	33.25	52.56	3.47	4.60	10.79 (129.35)	1.41 (1.33)	300.18	157651.04	300180	1.90
SEm±	0.92	1.31	0.23	0.28	2.01	0.94	12.88			
CD (P=0.05)	NS	4.03	NS	NS	6.18	2.89	39.67			

Original values in parenthesis and figures outside the parenthesis are transformed to $\sqrt{n+1}$

Selling price of potato is ₹ 1000 /quintal.

Table 2: Effect of weed control treatments on grade wise number of tubers per plot, and grade wise weight of tubers (kg/plot)

Treatment	Grade wise number of tubers per plot				Grade wise weight of tubers (kg/plot)			
	A (>75g)	B (50-75g)	C (25-50g)	D (<25g)	A (>75g)	B (50-75g)	C (25-50g)	D (<25g)
T_1- Weedy check	44.00	102.00	127.00	127.33	6.68	7.98	11.3	2.58
T_2-Weed free	82.00	133.33	199.33	144.33	11.17	12.50	11.92	2.92
T_3- Hand weeding at 50 DAP	51.00	99.67	189.00	146.33	8.50	10.17	10.47	3.33
T_4- Hand weeding at 50 DAP	60.67	112.00	154.00	100.33	8.82	9.75	8.42	2.58
T_5- Hand weeding at 50 DAP	69.67	135.00	148.33	136.00	8.70	10.50	7.67	2.33
T_6- Metribuzin @ 0.75 kg a.i. / ha pre emergence	85.00	140.33	145.00	129.00	11.67	12.03	7.42	2.25
T_7- Metribuzin @ 0.75 kg a.i. / ha post emergence	85.67	151.67	133.00	137.33	12.25	11.33	6.7	2.57
S.Em.±	8.09	8.13	10.18	8.72	1.00	0.84	0.68	0.20
C.D. (0.05)	24.91	25.04	31.37	26.87	3.07	2.58	2.1	0.6

Potato tubers graded as grade A (>75g) recorded highest weight per plot in the treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) which was statistically at par with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence) and T_2 (weed free) whereas, the lowest weight was recorded in treatment T_1 (weedy check) which was statistically at par with treatment T_3 (hand weeding at 30 DAP), T_5 (hand weeding at 50 DAP) and T_4 (hand weeding at 40 DAP).

Potato tubers graded as grade B (50-75g) showed maximum weight per plot in the treatment T_2 (weed free) which was statistically at par with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence), T_7 (metribuzin @ 0.75 kg a.i./ha post emergence), T_5 (hand weeding at 50 DAP), and T_3 (hand weeding at 30 DAP) whereas, the minimum weight was recorded in treatment T_1 (weedy check) which was statistically at par with treatment T_4 (hand weeding at 40 DAP).

In the grade C (25-50g) highest weight per plot of potato tuber was recorded in treatment T_2 (weed free) which was statistically at par with treatment T_1 (weedy check) and T_3 (hand weeding at 30 DAP) whereas, the lowest was observed in treatment T_7 (metribuzin @ 0.75 kg a.i./ha post emergence) which was statistically at par with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence), T_5 (hand weeding at 50 DAP) and T_4 (hand weeding at 40 DAP).

The maximum weight of potato tuber per plot under grade D (<25g) was recorded in treatment T_3 (hand weeding at 30 DAP) which was statistically at par with treatment T_2 (weed free) whereas, the minimum weight was observed in treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence) which was statistically at par with treatment T_5 (hand weeding at 50

DAP), T_7 (metribuzin @ 0.75 kg a.i./ha post emergence), T_1 (weedy check) and T_4 (hand weeding at 40 DAP).

The critical observation of data (Table 2) revealed that the weight of tubers of grade A (>75g) was recorded highest with the treatment T_7 whereas, B(50-75g), C (25-50g) and D (<25g) grade potato tubers was recorded maximum with treatment hand weeding at 30 days and weed free, respectively. The increase in grade wise weight of tubers is might be due to the early root development and growth of plant because of less weed competition which leads to proper aeration in root zone, availability of nutrient, water, space and sunlight which resulted in better growth of photosynthetic organs, translocation of nutrients and photosynthates to developing plant parts. These findings are also supported by Singh *et al*. (2007) [12], who also found higher number of tubers under different weed control treatments as compared to weedy check.

Marketable yield per hectare

The effect of weed management treatments with respect to marketable yield have been presented in table 1. It is evident from the data that the marketable yield was significantly affected by various weed control treatments.

The maximum marketable yield (353.01 q/ha) was observed in treatment T_2 (weed free) which was found statistically at par with rest of the treatments whereas, the minimum marketable yield (259.36 q/ha) was observed in treatment T_1 (weedy check) which was statistically at par with T_5 (hand weeding at 50 DAP), T_4 (hand weeding at 40 DAP) and T_3 (hand weeding at 30 DAP). A critical observation of the data (Table 1) revealed that the marketable yield of tubers was increased with different weed management treatments. The increase in marketable yield in weed free might be due to minimum competition in the root zone, which leads to availability of space and proper aeration in root zone which resulted in better growth and development of the tubers. The results are in agreement with the findings of Kumar *et al*. (2009) [7] who also reported the maximum marketable yield with weed free and minimum in weedy check treatment.

Economics of the treatments

Data regarding to the economics of various weed control treatments on potato have been presented in table 1. It is evident from the data that with fixed cost of cultivation ₹ 137701.00 per ha, the highest total expenditure (₹ 204174.64) was recorded in treatment T_2 (Weed free), whereas the lowest total expenditure (₹ 150987.44) was recorded with treatment T_1 (Weedy check). The highest total output or gross income of ₹ 353010.00/ha was associated with the treatment T_2 (Weed free). Lowest gross return of ₹ 259360.00/ha was recorded with the treatment T_1 (Weedy check). The benefit: cost ratio indicates production efficiency of the treatments. It indicates the value of rupees obtained in production system per rupee invested. It is calculated by dividing the total expenditure by gross income. Highest benefit: cost ratio of 1.93 was procured with treatment T_6 (metribuzin @ 0.75 kg a.i./ha pre emergence). The lowest benefit: cost ratio of 1.71 was procured under T_5 (Hand weeding at 50 DAP).

Conclusion

The findings of present investigation revealed that there is significant effect of different weed control treatments on the yield of potato tubers. Among all treatments T2 (weed free) was found superior in yield (353.01 q/ha) but to keep the weed free condition it required more number of hand weedings thereby increasing labour cost which increases its input cost. Hence, in terms of economics, treatment T6 (metribuzin @ 0.75 kg a.i./ha pre emergence) was found superior with yield (305.43 q/ha) and B:C ratio 1.93 and can be recommended. However, further more research needs to be done for commercial recommendation.

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