

EVALUATION OF WEED MANAGEMENT TECHNIQUES IN AUTUMN POTATO CROP

Atiq Ahmad Khan¹, Muhammad Qasim Khan
and Muhammad Saleem Jilani

ABSTRACT

*Cardinal variety of potato was grown in autumn of 2003-04 and 2004-05 at Agricultural Research Institute, Dera Ismail Khan. The trials were laid out in a randomized complete block design with five treatments and three replications. Treatments included; Sencor 70WP @ 625 g ha⁻¹, Galaxy @ 1.5 L ha⁻¹ and Dual Gold @ 2.0 L ha⁻¹, Manual weeding once after 45 days of planting and the weedy check. Tubers were planted in ridges 75 cm apart and all the herbicides were sprayed three days after planting. Plant growth in chemical treated plots and the plots with manual weeding was significantly improved as compared to the growth in the weedy check. It was observed that all the weed management plots produced significantly higher percentage of large tubers. While leaving the weeds throughout the season (Weedy check) resulted in maximum percentage of small tubers. Controlling the weed chemically or manually significantly improved the marketable yield as compared to weedy-check. Significantly lower population of weeds was recorded in weed-controlled plots at the end of growing season. At the end of growing season weeds found during the two year study were *Anagallis arvensis* (47.54 and 39.56%), *Cyperus rotundus* (13.11 and 18.68%), *Convolvulus arvensis* (9.84 and 12.09%), *Chenopodium album* (6.56 and 6.59%), *Rumex dentatus* (3.28 and 4.40%), *Cynodon dactylon* (6.56 and 6.59%) and *Melilotus indica* (13.11 and 12.09%), respectively.*

Key words: Potato, weed control, herbicides, hand weeding

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops. Its growth is mostly affected due to weeds which rob away

¹ Faculty of Agriculture, Gomal University, Dera Ismail Khan, NWFP, Pakistan

E-mail: atiqahmadalizai@yahoo.com

considerable amount of nutrients and result in substantial reduction in tuber yield. Weeds not only reduce yield of potato but also hinder in mechanical operations like harvesting tubers (Knezevic *et al.*, 1995). According to Jaiswal and Lal (1996a; 1996b), weeds reduce the tuber yield by 42% on the average, whereas weed control treatments increase the tuber yield by 18-82%. In a study, Sencor @ 1kg in 500 l ha⁻¹ gave the most effective weed control and the highest potato yield as compared to hand weeding (Susilowirjono, 1976). Hawton (1977) reported that cultivation under dry condition was more effective than chemical weed control in potatoes while the reverse was true under wet conditions. Jan *et al.* (2004) reported that chemical weed control increased potato yield significantly and was found to be the least expensive giving the highest marginal rate of return (14.17%) compared to other weed control measures. Similarly Hashim *et al.* (2003) reported the highest potato yield in hand-weeding (14729 kg ha⁻¹), followed by herbicidal control by Topogard (14486 kg ha⁻¹) and Sencor (14219 kg ha⁻¹).

A well-prepared land has less severe weed problem which allows the crop to compete better with the weeds during early growth stage (4-6 weeks after planting). Among weed management practices, chemical weed control is easy, effective and time saving method. Labor cost has increased tremendously during the last few years, which has made the manual weeding almost impracticable. Moreover, increasing trend in potato cultivation created a demand of some less labor intensive and efficient weed management program that does not compromise yield. Potato being a broad-leaf vegetable is seriously affected by many herbicides. Pre-emergence herbicide sole recommended for potato some time adversely affect the yield besides controlling weed flora in the field. Therefore it is imperative to figure out a safe, effective and economical weed control method for increasing productivity of potato.

MATERIALS AND METHODS

The trials were conducted at Agricultural Research Institute, Dera Ismail Khan, NWFP, during the years 2003-04 and 2004-05. The net plot size was 4 x 3 m² having inter-plant and row to row spacing 10cm and 75cm, respectively. Tubers of red-skin cultivar "Cardinal" were obtained from the potato program, National Agricultural Research Centre, Islamabad and were planted on October 1, 2003 and October 10 of the following year. Three post emergence herbicide viz. Sencor 70WP (metribuzin), Galaxy 450EC (clomazone+pendimethalin) and Dual gold 960EC (s-metolachlor) were applied at 625 g, 1.5 l, and 2 l

ha⁻¹, respectively after planting tubers using back mounted knap sack sprayer with T-jet nozzle. These herbicides were compared with hand weeding, once after 45 days of sowing (DAS), and the weedy check. All other cultural practices were performed as per standard crop requirements except the weed management. Data were collected on number of tuber of three sizes (small <35 mm, medium 35-55 mm and Large > 55 mm), relative tuber weight (tubers weighed and converted into percent large, medium and small tubers' of the total weight per plot), total marketable yields, plant growth and total fresh and dry weed biomass. All weeds were carefully hand uprooted, stored in polythene bags and dried in oven at 60°C for 48 hours. The dried weeds were weighed again to calculate weed biomass. Weed control efficiency (WCE) of each treatment was calculated using the formula (Thakral *et al.*, 1988):

$$\text{WCE \%} = \frac{\text{WDCE} - \text{WDWT}}{\text{WDWC}} \times 100$$

Where WDWC = Weed dry weight in weedy check, WDWT = Weed dry weight in treatment.

Percent increase in yield over control was calculated and standard economic analysis was also performed. Data were subjected to analysis of variance and least significance difference (LSD) test was performed to demonstrate the treatment effect, where appropriate employing MSTATC computer software.

RESULTS AND DISCUSSION

Plant growth and weed biomass

Plant and weeds growth as affected by various weed control strategies are presented in Table-1. Number of leaves per potato plant were counted and potato leaves fresh biomass and weeds dry biomass were recorded during both years.

Differences among the treatments for number of leaves plant⁻¹ were found significant statistically during both the years. In 2003-04, maximum leaves (35.67 plant⁻¹) were noted in plots sprayed with 'Sencor' which were statistically at par with 30.67 and 29.00 leaves plant⁻¹ produced in herbicide treatments 'Dual gold' and 'Galaxy', respectively. Hand weeded plots also enhanced plant growth by producing 26.67 leaves plant⁻¹ as compared to 17.33 leaves plant⁻¹ counted in un-weeded plots throughout growing season. Since number of leaves produced in plots with no weed control was minimum the fresh leaves biomass was also minimum in these plots. Weedy check

plots resulted in only 38 g of leaves biomass which was significantly lower than the biomass produced in all other weed control treatments (Table-1).

While looking into the weed growth, it was observed that weed control strategies significantly controlled all weeds in potato crop against the weedy check. Maximum number of leaves (45.00 plant^{-1}) were counted in plots sprayed with 'Dual Gold' during the second year that was statistically similar to 41.33 plant^{-1} produced in 'Sencor'. Treatment spraying with 'Galaxy' and controlling weeds manually resulted in statistically similar number of leaves plant^{-1} (35.33 and 32.67), respectively. The lowest number of leaves (18) were counted in weedy check (Table-1).

Similarly fresh leaves biomass was also minimum ($56.00 \text{ g plant}^{-1}$) during the second year in un-weeded plots. While maximum leaves biomass was recorded in plots sprayed with 'Dual Gold' i.e. 167 g plant^{-1} . Rest of the three treatments resulted in similar leaves biomass of 138 g, 133 g, and 128 g plant^{-1} produced in hand weeded plots and those sprayed with 'Sencor' and 'Galaxy', respectively (Table-1).

Higher number of leaves and dry biomass in herbicide treated plots might be the result of their phytotoxicity on weeds. On the other hand, leafy plants are supposed to have more yield as more photosynthates were available to be partitioned into tubers. However, the yield inhibiting by Oust herbicide in potato has been reported by Kessler (2009). Decreasing weed population results in increased plant growth as supported by Susilowirjono (1976), Hawton (1977), Hashim *et al.* (2003) and Jan *et al.* (2004) who observed that as weed fresh and dry bio-mass decreases potato plant growth improves.

Table-1. Number of leaves and fresh leaves biomass plant^{-1} as influenced by weed management techniques in potato.

Treatments	Number of leaves plant^{-1}		Fresh leaves biomass plant^{-1} (g)	
	2004	2005	2004	2005
Sencor 70WP	35.67 a	41.33 a	111.0 a	133.0 b
Galaxy 450EC	29.00 ab	35.33 b	72.0 ab	128.0 b
Dual Gold 960EC	31.67 ab	45.00 a	94.0 a	167.0 a
Hand Weeding	26.67 b	32.67 b	75.0 ab	138.0 b
Weedy check	17.33 c	18.00 c	38.0 b	56.0 c
LSD _{0.05}	8.254	5.116	43.02	0.018

Means followed by different letter(s) are significant at 5% level of probability.

Data for the dry weed biomass revealed that minimum weeds (0.095 t ha^{-1}) were observed in plots weeded manually during the growing season that was very close to the mass (0.097 t ha^{-1}) recorded in plots sprayed with 'Sencor'. The plots treated with 'Galaxy' and 'Dual Gold' had 0.186 and 0.117 t ha^{-1} of weeds dry biomass (Table-2).

Weeds dry biomass calculated during the second year had similar pattern as found during the first year. All the weed control strategies had significant affect in controlling weeds efficiently. Although differences among the four weed control strategies were found non-significant, minimum dry bio-mass of weeds (0.118 t ha^{-1}) was recorded in plots sprayed with 'Sencor'. 'Dual Gold' resulted in 0.178 t ha^{-1} of weeds dry biomass followed by 0.155 and 0.145 t ha^{-1} recorded in plots sprayed with 'Galaxy' and the plots weeded manually. Weedy check plots produced 2.243 t ha^{-1} of weeds dry biomass.

The weed control efficiency due to various herbicidal treatments was quite acceptable. The herbicidal control efficiency was comparable with the hand weeding which their worth to control the prevailing weed flora in potato crop. Therese findings are in agreement with the previous work of Susilowirjono (1976), Hawton (1977), Hashim *et al.* (2003) and Jan *et al.* (2004) who observed that weed fresh and dry biomass decreases due to herbicidal application in potato crop.

Table-2. Weeds dry biomass and weed density as influenced by weed management techniques in potato.

Treatments	Weeds dry biomass (t ha^{-1})		Weed density (m^{-2})		Weed control efficiency (%)	
	2004	2005	2004	2005	2004	2005
Sencor 70WP	0.097 b	0.118 b	8.33 b	11.00 b	91.92	94.74
Galaxy 450EC	0.186 b	0.155 b	15.00 b	13.67 b	84.50	93.09
Dual Gold 960EC	0.117 b	0.178 b	9.00 b	13.00 b	90.25	92.06
Hand Weeding	0.095 b	0.145 b	8.00 b	10.61 b	92.08	93.53
Weedy check	1.20 a	2.24 a	61.00 a	91.00 a	--	--
LSD _{0.05}	0.961	0.535	7.992	7.578	--	--

Means followed by different letter(s) are significant at 5% level of probability.

Number of potato tubers (plot^{-1})

Data recorded during the first year of study illustrated that controlling weeds either manually or using herbicides significantly increased the number of large sized tubers (Table-3). Plots sprayed with the herbicide 'Sencor' resulted in maximum number of large-sized tubers

(38.90%) followed by plots with manual weeding which produced statistically similar number of large-sized tubers (37.33%) and Dual Gold treatment 33.88% tubers of larger size. While plots left unweeded resulted in minimum number of large-sized tuber (22.03%). Similar trend was observed for medium sized tubers where weedy check plot had minimum number of medium sized tubers (12.09%) of the total tubers produced. While looking into the figures presented for tubers of small size it was observed that controlling weed by hand or using herbicides resulted in the least number of small sized tubers. All the four treatments produced statistically similar results against weedy check.

Almost similar trend was observed during the second year of study. Data collected during 2005 are presented in Table-3. All the plots weeded manually or chemically resulted in higher percentage of large-sized tubers. Sencor and hand weeding resulted in maximum number of larger tubers i.e. 36.20% and 36.02%, respectively followed by Galaxy (34.92%) and Dual Gold with 33.88% of tubers. Least number of large-sized tubers (20.03%) was recorded in weedy check. The production of medium sized tubers was affected significantly by weed control practices. Significantly smallest percentage of medium sized tubers (10.75%) was recorded in weedy check plots having maximum weeds population. Although differences among the other four treatments was non-significant statistically, however hand weeded plots produced maximum percentage of medium sized tubers (19.02%) followed by the weedicide treatment Galaxy (18.63%). While plots, sprayed with Dual Gold resulted in 18.47% and Sencor, 18.24% tubers of medium size (Table-3).

Data recorded for small-sized tubers during the second year showed the same pattern as it was observed in the first year. Unweeded plots (weedy check) produced maximum number of smaller tubers (67.62%) which were significantly higher than the smaller tubers produced by all other treatments (Table-3). Since weeds compete for resources with the main crop, thus affecting it adversely. Significantly more tubers of the smaller size in the weedy check are an obvious evidence of such competition. Jilani *et al.* (2007) reported that competition for nutrients, water and sunlight is responsible for the production of fewer number of onion bulbs in weedy check plots. Statistically similar numbers of large and medium sized tubers recorded in all herbicide treatments and hand weeded shows that herbicides are a good substitute for cultural weed control or manual weeding. Most of the previous work has shown almost similar results. Jan *et al.* (2004) reported that letting the weeds grow in the potato

field increased the number of smaller sized tuber and reduced the marketable yield.

Table-3. Large, medium and small tubers per plot (%) as influenced by weed management techniques in potato.

Treatments	Large (%)		Medium (%)		Small (%)	
	2004	2005	2004	2005	2004	2005
Sencor 70WP	38.90 a	36.20 a	20.23 a	18.24 a	40.86 b	45.00 b
Galaxy 450EC	30.42 ab	34.92 a	18.10 a	18.63 a	51.48 b	46.67 b
Dual Gold 960EC	33.88 a	33.35 a	19.31 a	18.47 a	46.80 b	47.80 b
Hand Weeding	37.33 a	36.02 a	19.92 a	19.02 a	42.75 b	44.75 b
Weedy check	22.03 b	21.96 b	12.09 b	10.75 b	65.95 a	67.62 a
LSD _{0.05}	10.20	4.563	4.357	2.867	12.45	8.981

Means followed by different letter(s) are significant at 5% level of probability.

Relative Tuber weight (%)

Percent weight of large, medium and small tubers is presented in Table-4. Since weed control plots, either through herbicides or hand weeding, produced higher percentage of large and medium sized tubers these plots also resulted in higher tuber weight during the year 2004. The plots remained un-weeded produced the lowest weight of large-sized tubers as compared to other treatments. Weedy check plots produced tubers of 52.67% weight of total weight produced. Maximum weight of large tubers (69.75%) was recorded in plots sprayed with 'Sencor' followed by hand-weeded plots (66.57%) and herbicide treatment 'Galaxy' with 65.48% weight of large tubers. Dual Gold was also found effective and resulted in higher percentage of large-sized tubers with 64.58% weight of total weight.

Medium sized tubers, although, not affected significantly but weedy check produced minimum tubers' weight during the first year of study. Looking into the results obtained for the weight of small sized tubers it was observed that presence of weeds in un-weeded plots significantly increased the number of smaller tubers and hence the highest weight of small sized tubers. Weedy check plot with 33.11% weight of smaller tubers had significantly higher than the weight of smaller tubers recorded in all other treatments.

Significantly minimum percentage of the large tubers' weight (53.32%) was recorded in plots which were left un-weeded in year-2

(Table-4). While maximum percentage of large tubers' weight (69.42%) was obtained in 'Galaxy' which was statistically similar to plots sprayed with 'Sencor' i.e. 68.52%. Medium sized bulbs were also affected significantly by weed control. Leaving the plots un-weeded reduced the weight of medium sized tubers (12.76%). The highest and statistically similar percentage of medium tubers' weight was recorded in plots sprayed with 'Dual Gold' and 'Galaxy' (18.20% and 17.85%), respectively. Manually weeded plots and plots sprayed with 'Sencor' produced similar results statistically giving 16.31% and 16.17% weight of medium sized tubers, respectively. It was observed during the second year of study that un-controlled plots produced maximum percentage of smaller tubers' weight (33.92%) as compared to all other treatments. Minimum weight of small tubers (12.73%) was recorded in plots sprayed with 'Galaxy'. Controlling weeds by 'Dual Gold' and 'Sencor' and hand weeding resulted in statistically similar results by giving 17.85%, 17.13% and 15.31% smaller tubers' weight of the total weight produced. Since the percentage of small sized tubers was higher in the un-weeded plots therefore the weight of small sized tuber also maximum in the same plots. Significantly higher weight of large and medium sized tubers in all weed control plots than weedy check demonstrated the phenomena of accumulation of all nutrients, water and sunlight into organic matter in tubers whereas weed present in weedy check took a significant toll and shared the resources which eventually resulted in less weight of the large and medium sized tubers. The findings are well supported by Hashim *et al.* (2003).

Table-4. Relative Weight of large, medium and small tubers (%) as influenced by weed management techniques in potato.

Treatments	Large		Medium		Small	
	2004	2005	2004	2005	2004	2005
Sencor (70WP)	69.75 a	68.52 a	17.07 ^{NS}	16.17 ab	13.17 b	15.31 bc
Galaxy (450EC)	65.48 a	69.42 a	19.18	17.85 a	15.35 b	12.73 c
Dual Gold (960EC)	64.58 a	64.67 b	18.90	18.20 a	16.52 b	17.13 bc
Hand Weeding	66.57 a	65.84 ab	16.84	16.31 ab	16.57 b	17.85 b
Weedy check	52.67 b	53.32 c	14.16	12.76 b	33.11 a	33.92 a
LSD _{0.05}	7.058	3.776	--	4.599	6.632	4.892

Means followed by different letter(s) are significant at 5% level of probability.

NS= non-significant

Tuber yield (t ha⁻¹)

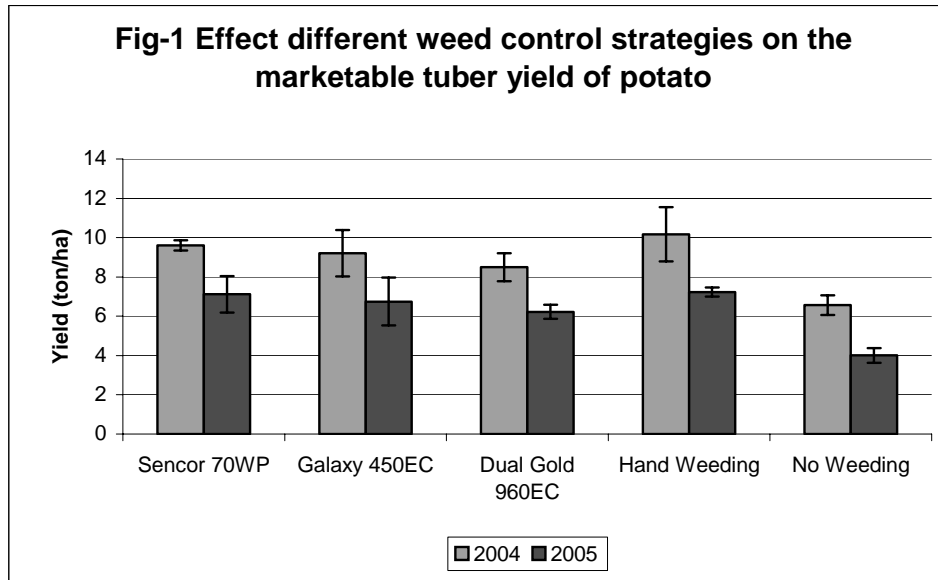
Total tubers' marketable yield is presented in Table-5. It was observed during the first year that differences among the treatments for marketable yield were significant statistically. The highest marketable yield of 10.17 t ha⁻¹ was recorded in manually weeded plots followed by the plots sprayed with 'Sencor' and 'Galaxy' giving 9.61 and 9.21 t ha⁻¹. Spraying 'Dual Gold' also had higher marketable yield of 8.50 t ha⁻¹. Allowing the weeds to grow for a full crop season significantly reduced the marketable yield to only 6.57 t ha⁻¹ (Fig-1).

Results obtained for the second (Table-5) year were almost similar as found in first year. The marketable yield in plots with no weed control was 4.01 t ha⁻¹ as compared to other treatments. Maximum marketable yield of 7.24 t ha⁻¹ was obtained in plots which were hand weeded followed by plots sprayed with 'Sencor' that produced 7.12 t ha⁻¹. Spraying 'Galaxy' and 'Dual Gold' resulted in 6.75 and 6.23 t ha⁻¹ marketable yield. However, differences among the first four treatment for marketable yield were found non significant statistically.

Table-5. Total marketable yield (t ha⁻¹) as influenced by weed management techniques in potato.

Treatments	Total marketable yield (t ha ⁻¹)		% increase over check	
	2004	2005	2004	2005
Sencor 70WP	9.61 ab	7.12 a	46.27	77.56
Galaxy 450EC	9.21 ab	6.75 a	40.18	68.33
Dual Gold 960EC	8.50 b	6.23 a	29.38	55.36
Hand Weeding	10.17 a	7.24 a	54.79	80.55
Weedy check	6.57 c	4.01 b	--	--
LSD _{0.05}	1.605	1.329	--	--

Means followed by different letter(s) are significant at 5% level of probability.



Percent increase calculated for all treatments over weedy check for both years is presented in Table-5. Percent increase in treated and weedy check ranged from 29% to 54% in 2004 and 55% to 80% in 2005, respectively.

Although herbicides tested (Sencor and Galaxy) produced statistically at par tuber yield to that of hand weeding followed by Dual gold, but the percent increase shows 8.5% more yield in hand weeded plots than Sencor treated plots. Hand weeding or cultural weed control involves excavation and digging of soil, which favors the tuber growth and development and might have resulted in higher yield in the hand weeded plots. Zollinger (2008) stated that besides removing weeds, cultural control by making ridge or hill helps protect tuber from sunburn (tuber greening), frosts, excessive rainfall or irrigation and reduces the amount of soil to be moved at harvest. On the other hand, Kessler (2009) reported low levels of herbicides, which did not result in obvious damage to the potato plants above ground, negatively affected their underground growth, reducing yields. Although no phytotoxicity has been reported or observed with herbicides tested but it could not be ruled out that yield might have been affected due to some growth inhibiting action of herbicides as no increase in yield was observed even in the absence of weeds right from the start of the crop growing period, whereas in hand weeding treatments crop had weed

competition for the first 45 days of growth. However, further studies in future on such aspects may bridge this gap.

The economic analysis of the data given in Table-6 indicates that the overall net income was greater in hand weeding treatment. During 2003-04, the highest variable cost (Rs.6975 ha⁻¹) was also recorded in hand weeding. The herbicide Dual gold (Rs.1545 ha⁻¹) followed the above treatment. The variable cost was lower in Sencor treatment, which also had higher benefit cost ratio (0.93). During the same year, the net benefit of Rs.42725 ha⁻¹ was the highest under hand weeding, closely followed by Sencor (Rs.39949 ha⁻¹). The net income (Rs.54229 ha⁻¹) and benefit cost ratio (1.20) was the highest in Sencor treatment, closely followed by hand weeding (Rs.53693 ha⁻¹) owing to a greater yield in 2004-05.

The analysis further revealed that herbicide treatment 'Sencor' is labor and cost-effective which subsequently produced higher net return. The comparable net income of herbicides with hand weeding offers an option for the use of herbicides as an alternative management tool.

Table-6. Economic analysis (benefit cost ratio) as influenced by weed management techniques in potato.

2003-04	Variable cost Rs.ha⁻¹	Common cost ha⁻¹	Total cost Rs.ha⁻¹	Total income Rs. ha⁻¹	Net income Rs. ha⁻¹	BCR
Sencor	1051	41800	42851	82800	39949	0.93
Galaxy	1174.5	41800	42974.5	81675	38700.5	0.90
Dual Gold	1545	41800	43345	76500	33155	0.76
Hand Weeding	6975	41800	48775	91500	42725	0.88
Weedy Check	0	41800	41800	73125	31325	0.75
2004-05						
Sencor	1091	44200	45291	99520	54229	1.20
Galaxy	1214.5	44200	45414.5	91600	46185.5	1.02
Dual Gold	1585	44200	45785	88960	43175	0.94
Hand Weeding	6507	44200	50707	104400	53693	1.06
Weedy Check	0	44200	44200	71680	27480	0.62

CONCLUSIONS

The findings of the present research reveal that weed management practices improved the growth and yield of potato as compared to weedy check. In weedy check plots, there was an intense competition between crop plants and weeds for soil and climatic resources. As regards weeding techniques, growth of weeds in the treated plots resulted in low weed density and dry weed biomass as compared to weedy check where weeds were left unchecked. Overall, the total marketable yield was noticeably higher in conventional hand weeding as compared to weedy check. Therefore, it can be concluded that the use of herbicides also offers a good alternative in case of skilled labour scarcity for potato production.

REFERENCES CITED

- Hashim, S., K. B. Marwat and G. Hassan. 2003. Chemical weed control efficiency in potato (*Solanum tuberosum* L.) under agro-climatic conditions of Peshawar, Pakistan. Pak. J. Weed Sci. Res., 9 (1-2): 105-110.
- Hawton, D. 1977. Weed control in potatoes on the Athernton Tableland, Queensland. Australian J. Exper. Agric. Animal Husb., 17 (8): 832-836.
- Jaiswal, V.P. and S.S. Lal. 1996a. Efficacy of cultural and chemical weed control methods in potato. J. Indian Potato Assoc., 23 (1-2): 20-25.
- Jaiswal, V.P. and S.S. Lal. 1996b. Efficacy of cultural and chemical weed-control methods in potato (*Solanum tuberosum*). Indian J. Agron., 41 (3): 454-456.
- Jan, H., A. Muhammad and A. Ali. 2004. Studies on weed control in potato in Pakhal plains of Mansehra. Pak. J. Weed Sci. Res., 10 (3-4): 157-160.
- Jilani, M.S., M. Ramzan and K. Waseem. 2007. Impact of weed management practices on growth and yield of some local genotypes of onion. Pak. J. Weed Sci. Res., 13 (3-4): 191-198.
- Kessler, B. 2009. Study shows herbicides can affect potato yields. available online at <http://www.greenrightnow.com/wabc/2009/01/08/study-shows-herbicides-can-affect-potato-yields/>.

- Knezevic, M., M. Durkic and D. Samota. 1995. Chemical and mechanical weed control in potatoes. *Fragmenta Phytomedica et Herbologica*, 23 (2): 61-67.
- Sahota, T. S. and P. M. Govindakrishnan. 1982. Critical period of crop competition in potato. *Bangladesh Hort.*, 10: 15-18.
- Susilowirjono, S. 1976. The effect of weeds on the growth and yield of potatoes (*S. tuberosum* L.). *Bull. Penelitian Hort.*, 4 (2): 15-23.
- Thakral, K. K., M. L. Pandita, S. C. Khurana and G. Kalloo. 1988. Efficacy of cultural and chemical weed control methods in potato. *J. Indian Potato Assoc.*, 15 (3-4): 148-152.
- Zollinger, R. K. 2008. North Dakota Weed Control Guide. North Dakota State University. W-253, January 2008.