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Effect of Different Weed Management Practices on growth and yield in Potato at Khumaltar, Lalitpur, Nepal

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ABSTRACT

Potato (*Solanum tuberosum* L.) is the fifth most important crops in the world in terms of production with an estimate of 375 million metric tons. In Nepal, potato ranks second in terms of production and sixth in terms of area coverage. Potato production is affected by weed infestation. Weeds compete with crops for nutrients, water and other resources, which eventually reduce the crop yield. The critical period of crop-weed competition for potato is 25-40 days from planting depending on the climatic-zone and planting seasons. The most common method of weed control in Nepal is manual method, while herbicides are uses in less areas. Weeds are considered as the major problem in conventional and organic farming, due to lower yields by weeds and higher costs of labor for weed control. Mulching is one of the best and safest practice for effective weed management in potato due to which micro-climate manipulation is developed. Metribuzin is widely used herbicides in potato that controls a range of broadleaf weed species and suppresses many grassy weeds. To study the performance of different weed management practices in potato ten treatments were set up viz., three herbicides (pendimethalin@ 1.0 kg a.i ha^{-1}, metribuzin@ 0.5 kg a.i ha^{-1} and atrazine @ 0.25 kg a.i ha^{-1}) constituting seven treatments, one mulching with rice straw, one treatment with two manual hoeing, and another treatment with no any weed management practices as control.The treatments were laid out in RCB design with 4 replications. The potato variety *Janak Dev* was planted on 12th Feb 2021 and 23rd Jan 2022 with tuber rate of 4.1 $t.ha^{-1}$ with row spacing of 60 cm and plant to plant 20 cm in a plot size of 4 x 3 meter in flat bed. Growth parameters such as plant height, plant fresh and dry biomass were recorded. Data on weed density, weed dry biomass, and tuber yield were taken.The economics of the different treatments were calculated. Among the treatments metribuzin@ 0.25 kg a.i ha^{-1} as pre-emergence proved effective in controlling weeds showing highest weed control efficiency (200.7 %) and tuber yield (32.79 t ha^{-1}) . However, the treatment rice straw mulch @ 6 t ha^{-1} produced the highest tuber yield (38.31 t ha^{-1}), 73.4 % increased yield over control, weed control efficiency(147.1%), economic benefit (NRS 13,40,850), benefit cost ratio (4.93).The treatment rice straw mulch @ 6 t ha^{-1} showed superiority among the different weeds management practices.

Keywords: Critical- period, metribuzin, micro-climate, mulch, yield

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INTRODUCTION

Potato (*Solanum tuberosum,* Family: Solanaceae), the fifth most important food crop in the world after rice, wheat, maize, and sugar crops in terms of production, with an estimation of 375 million metric tons (FAO 2023). It is one of the major commercial food crops in Nepal. According to MoALD (2023), area and production of potatoes is 198,256 ha and 3,410,829 metric tons, rank second in terms of production and sixth in terms of area coverage in Nepal. Potato production is predominantly located in the mid-hills (41.5% of the total area), in the plains (38.5%) and 20% in the mountains (MoALD 2018). It is cultivated and consumed as vegetables in lowland and mid-hill, however, it serves as a crucial staple food crop in the high-altitude regions (Kafle and Shah, 2012). The potato tuber contains 70-80% water, 20.6% carbohydrate, 2.1% protein, 0.3% fat, 1.1% crude fiber, and 0.9% ash (Gemmechu 2017).

Weeds are plants that are not desired as they compete with crops for essential resources such as nutrients and water, which can ultimately reduce the crop yields (Finch et al 2014 and Kumar et al 2017).Weed hampers growth and take moisture and nutrients from soil at early stage of potato like others crops. The average yield loss due to weed interference in the US was 44% (Ganie et al 2023). Weeds belong to different families: poaceae, amaranthaceae, fabaceae, and asteraceae. The prominent weed species found in potatoes can be grouped into two categories: broad-leaf and narrow-leaf weeds. *Amaranthus retroflexus, Chenopodium album, Hydrocotyle javanica, Plantango major, Potentilla kleiniana, Oxalis griffithi, Polygonum alatum, and Solanum khasiana* are broad leaf weeds, while *Cyperus rotundus, Spergula arvensis, Cyperus cyperoides, Arundinella nepalensis, Arundinella khasiana, Digitaria adscendes, Imperata cylindrica, Commellina diffusa, Arthraxon sp. Bracharia reptans, Caspillipedium assimile, Paspalum orbiculare,* and other *Cyperus sp.* are narrow leaf weeds found in potato fields (Yadav et al 2021). Khan et al (2008) found *Chenopodium album and Amaranthus viridis* weeds dominant among the weed species. Bhullar et al (2015) reported purple nutsedge (*Cyperus rotundus*) a challenging weed in potato cultivation in northwest India and the hardest to manage compared to other weed species with high density of over 20 plants per square meter.

Competition from weeds significantly limits the optimum growth, resulting in decreased quantity, size of tubers, and the economic in potato (Singh et al 1984, Nelson and Thoreson 1981). Weeds also work as volunteer plants which help in spread of diseases and pests in potatoes (Pandey 2000). The reduction in yield reported up to 71% when no weed control measures were applied (Tolman et al 1986). There are various weed management strategies, such as cultural practices, mechanical methods, chemical methods, and integrative approaches (Jabran et al 2023). The critical period of weed control in potato is 20 to 66 days after emergence under irrigated conditions (Monteiro et al 2011). The optimal period for controlling weeds in potato crops usually varies depending on factors such as region, climatic conditions, soil type, nutrient status, composition of weed species and density. Potato faces competition from major weeds families like Poaceae, Amaranthaceae, Fabaceae, and Asteraceae (Sayari et al 2022).

Herbicides eliminate weeds by interrupting their biochemical processes, and their growth (Singh et al 2020, Antonio et al 2016, Singh et al 2007). Herbicide like pendimethalin as pre-emergence has been used for weed control in potato (Tomar et al 2008). The pre-emergence herbicide Metribuzin at 0.75 kg ha^{-1} and at reduced rate were effective in controlling broadleaf weeds in potatoes reducing the weed density by 90% and 9-16.5% increase in tuber yield (Abdallah et al 2021, Singh et al 2001, Singh et al 2007, Siblani and Haidar 2017). Metribuzin also as early post emergence application at 0.7 kg ha^{-1} was more efficient to suppress broadleaf weed species and grasses (Sayari and Jaouad 2022). Atrazine has also been found effective in controlling broadleaf weeds when applied at a rate of 1 kg ha^{-1} to 1.25 kg ha^{-1}, and resulted in comparable tuber yields of 23.6 t ha^{-1} with other herbicides, (Prasad and Singh 1995, Sharma et al 2004, Sharma and Sandhu 1985).

The safest method for controlling weeds in potato is mulching. It increases crop yields, reduce water loss by minimizing the evaporation from the soil, and controlling weed growth (Sims et al 2018). Organic mulching, such as cereal straw, leaves, and bark mulch, can enhance soil properties including its physical, chemical, and biological characteristics (Grassbaugh et al 2004, Genger et al 2018, El-Metwally et al 2019, Hussain and Luqman 2022, Khan et al 2022, Shafiq and Kaur 2021, Wang et al 2009, Waheed et al 2023). Thickness of the mulch must be 5-10 cm to prevent light interception for weed growth (Lal 1990). Studies have shown mulching had significant impacts on cost of cultivation, gross return, net financial returns, and benefit-to-cost ratios of potato crop (Yadav et al 2018, Deka et al 2021).

Due to the severe weed problem in potato which caused huge costs and reduce yield, the field experiments were carried out to find out the best weed management practices in terms of yield and economics.

Materials and Methods

Experimental site

Field experiment was conducted at the National Agronomy Research Centre, Nepal Agricultural Research Council, Khumaltar Nepal (latitude 27° 40' N, longitude 85 °20' E, and altitude 1360 m. amsl.) during 2021 and 2022. The soil of the experimental plots was loam with pH of 5.6, organic carbon 1.3 %, total nitrogen 3600 kg ha^{-1}, available P_2O_5 558 kg ha^{-1} and available potassium 212 kg ha^{-1}.

Experimental design, treatment details and cultural practices

The experiment was laid out in a randomized complete block design with 4 replications. Of the 10 treatments, 3 herbicidal treatments (pendimethalin, metribuzin, and atrazine), one mulching treatment with rice straw, one

treatment with two manual hoeing, and another treatment with no any weed management as control.

The detail of the treatments is given in the Table 1. The cropping geometry was row spacing of 60 cm and plant to plant 20 cm. The experimental plot size was of 4 × 3 meter. The potato variety *Janak Dev* was obtained from the cold store of seed company at Panauti in Kavre and left for 10 days for sprouting in the Agronomy Centre. The tuber developed 4-7 sprout of 0.5 to 1 cm in length and planted on 12th Feb 2021 and 23rd Jan 2022 with tuber rate of 4.1 t ha^{-1}. The fertilizers was applied at the dose of 100:100:60 N: P: K kg ha^{-1}. Full dose of P and K and half dose of N was applied before planting and the half of nitrogen was top dressed at 30 days after planting (DAP). The planting of potato tuber was done in a flatbed after proper tillage. Irrigation was given on the fourth day after planting and the second after hoeing for weeding. The herbicides used as pre-emergence were applied on the second day after planting potato tuber and the post emergence were applied at 25 days after planting. Herbicides were applied using knapsack sprayer fitted with flat fan nozzle. For mulch treatment dry rice straw at the rate of 7.2 kg per plot was uniformly placed with thickness of 8 cm over the plot on the same day after potato planting.

Table 1. Treatments detail of the experiment

SN	Treatment	Notation
1	Pendimethalin @ 1.0 kg a.i ha^{-1} as pre-emergence (PE)	Pendi@1.0 kg a.i ha^{-1} as PE
2	Metribuzin @ 0.5 kg a.i ha^{-1} as pre-emergence	Metri@0.5 kg a.i ha^{-1} as PE
3	Atrazine@ 0.250 kg a.i ha^{-1} as pre-emergence	Atra @0.25 kg a.i ha^{-1} as PE
4	Atrazine @ 0.125 kg a.i ha^{-1} as pre-emergence	Atra @0.125 kg a.i ha^{-1} as PE
5	Metribuzin @ 0.250 kg a.i ha^{-1} as pre-emergence	Metri @0.25 kg a.i ha^{-1} as PE
6	Atrazine @ 0.250 kg a.i ha^{-1} as early post emergence @ 15- 25 DAS	Atra @ 0.25 kg a.i ha^{-1} as PO
7	Metribuzin @ 0.5 kg a.i ha^{-1} as early post emergence @ 15- 25 DAS	Metri @ 0.5 kg a.i ha^{-1} as PO
8	Straw mulch @ 6 t ha^{-1}	SM @ 6 t ha^{-1}
9	Weed free (2 manual hoeing at 25 DAS, and 60 DAS)	WF (2 MH)
10	No weeding(control)	NW (control)

Data collection

The weed data was recorded from the quadrant of 100 × 100 cm. Plant height was recorded from 10 tagged plants at vegetative stage (45 DAP) and reproductive stage (90 DAP). The crop biomass was taken at 45 DAP from two plants from second row and average was calculated .The crop was harvested on 5 June, 2021 and 16 May, 2022 manually loosening soil. The net harvested plot area was 7.2 m^2 and the tuber yield was converted into yield tones per hectare.

Statistical analysis

Data were analyzed using the Genstat statistical package 18th edition, with analysis of variance conducted for all variables and Duncan's multiple range test (DMRT) were used for mean separations at $p<0.05$.

RESULTS AND DISCUSSION

Plant height and biomass

The plant height at early vegetative stage (45 DAP) ranged from 29.4 to 33.9 cm with the highest plant measured in the treatment straw mulch and the lowest plant height in the no weeding (control) treatment (table 1).

The plant height was higher in all the treatments compared with control. However, the differences among the treatments mean were insignificant. The plant height at reproductive stage (90 DAP) ranged from 65.8 to 84.5 cm following similar trend with that of vegetative stage with the longest plant height in straw mulch treatment and shortest in the control. And the mean difference in plant height among the different treatments were statistically significant. Similar results of increased plant height due to rice straw mulching and reduced height was reported by Pulok et al (2016).

The plant fresh biomass at vegetative stage (45 DAP) ranged from 212.3 g to 563 g and dry biomass ranged from 50.1 g to 14.7 g. The highest plant fresh and dry weight was found in the treatment straw mulch and the lowest fresh and dry weight in the no weeding treatment (control). The mean difference of fresh and dry weight was significant.

Table 2. Effect of different treatments on plant height and biomass in potato at Khumaltar

Treatment	Plant height (cm)	Plant height (cm)	Fresh Plant BM	Dry Plant BM
Pendi@1.0 kg a.i ha^{-1} as PE	32.7	79.9	256.9	22.2
Metri @0.5 kg a.i ha^{-1} as PE	31.0	80.8	240.5	42.4
Atra @0.25 kg a.i ha^{-1} as PE	32.2	77.9	255.4	29.7
Atra @0.125 kg a.i ha^{-1} as PE	30.7	79.4	319.3	34.1
Metri @0.25 kg a.i ha^{-1} as PE	32.5	83.0	238.9	38.8
Atra @ 0.25 kg a.i ha^{-1} as PO	33.2	79.0	228.5	23.7
Metri @ 0.5 kg a.i ha^{-1} as PO	33.3	80.0	226.8	37.8
SM @ 6 t ha^{-1}	33.9	84.5	563.4	50.1
WF (2 MH)	29.6	67.5	282.2	24.0
NW (control)	29.4	65.8	212.3	14.7
P-value	0.12	0.07	<.001	<.001
LSD (0.05)	0.32	0.13	101.4	22.3
CV (%)	9.4	10.0	54.8	40.6
Grand mean	31.9	77.8	282	31.8

Effects of weed management practices on weed density, weed dry weight and weed species

The major weed species observed in the experimental plots were, *Alternanthera philoxeroides, Coronopus didymus, Chenopodium album, Anagallis arvensis, Phalaris minor, Capsella bursa-pastoris, Alopecurus aequalis, Spergula arvensis, Ageratum conyzoides, and Commelina bengalensis.* The weed density per meter square ranged from 13 to 207 with the lowest weed density recorded in the treatment metribuzin @ 0.250 kg ha^{-1} as pre-emergence and the highest weed density recorded in the treatment no weeding control. The difference in the mean weed density was statistically significant among the treatments. The weed dry weight ranged from 2.2 to 100 g from 0.5 m^2, the lowest weight dry weight was found in the treatment metribuzin @ 0.250 kg ha^{-1} as pre-emergence and the highest dry weight found in the treatment no weeding control. Similar result of low weed density and weed biomass by application of metribuzin as pre-emergence spray was also reported by Siblani and Haidar (2017).

Table 3. Lists of major weed species recorded in the experimental field

SN	Common Name	Scientific Name	Local Name
1	Water cress	*Coronopus didymus*	Chamsure jhar
2	Alligator weed	*Alternanthera philoxeroides*	Patpate
3	Lambs Quarters	*Chenopodium album*	Bethe
4	Scarlet pimpernel	*Anagallis arvensis*	Krishnanil
5	Canary grass	*Phalaris minor*	Ragate
6	Lady's purse/Shepherd's purse	*Capsella bursa-pastoris*	Chaulani
7	Short-awned -foxtail	*Alopecurus aequalis*	Leu
8	Corn spurry	*Spergula arvensis*	Thangne
9	Goat weed	*Ageratum conyzoides*	Gandhe
10	Day flower	*Commelina bengalensis*	Kane

Tuber yield

The tuber yield ranged from 22.09 t ha^{-1} to 38 t ha^{-1} with the highest tuber yield recorded in the treatment straw mulch@ 6 t ha^{-1} and the lowest yield in the treatment control. Straw mulch accelerated tuber yield compared to others practices due to better weed controlled and more favorable microclimatic conditions developed by rice straw mulching was reported by Hussain and Luqman (2022) and Waheed et al (2023). The second highest yield (32.79 t ha^{-1}) was recorded in the treatment metribuzin @ 0.25 kg a.i ha^{-1} as PE. The difference in the mean tuber yield was found to be significantly different. Singh et al (2007) and Siblani and Haidar (2017) found the use of reduced rates of metribuzin can effectively manage weeds and increased potato yields.

Yield increment over control

The yield increases in the different treatments over control treatment ranged from 9.3 to 73.4 %. The increase in the tuber yields was the highest in the treatment with straw mulch @ 6 t ha^{-1} and the least increase in yield over control was obtained in the Atrazine @ 0.250 kg ha^{-1} as early post emergence @ 15- 25 DAS.

Table 4. Effect of different treatments on weed density, weed biomass, weed control efficiency (WCE) and tuber yield of potato at Khumaltar

Treatment	Weed/m^2	Weed dry wt.(g)	WCE (%)	Tuber Yield (t ha^{-1})	Increase yield (%) over control
Pendi@1.0 kg a.i^{-ha} as PE	85	28.4	165.9	30.39	37.6
Pendi@1.0 kg a.i ha^{-1} as PE	17	5.3	198.8	30.82	39.5
Metri @0.5 kg a.i ha^{-1} as PE	19	12.0	197.8	31.19	41.2
Atra @0.25 kg a.i ha^{-1} as PE	27	5.4	194.0	31.19	48.4
Atra @0.125 kg a.i ha^{-1} as PE	13	2.2	200.7	32.79	48.4
Metri @0.25 kg a.i ha^{-1} as PE	190	30.0	115.2	24.14	9.3
Atra @ 0.25 kg a.i ha^{-1} as PO	205	8.1	108.0	29.33	32.8
Metri @ 0.5 kg a.i ha^{-1} as PO	124	23.7	147.1	38.31	73.4
SM @ 6 t ha^{-1}	186	9.7	117.1	26.00	17.7
WF (2 MH)	207	100.0	----	22.09	
NW (control)	<.001	<.001		<.001	
LSD (<0.05)	59.92	18.6		5.6	
CV (%)	32.6	47		11.2	
Grand mean	107.3	22.5		29.53	

Economics

The variable costs incurred in the different treatments are presented in the table 5. The cost invested in weed management in the different treatments ranged from NRs 4,650 to NRs 53,440 with the highest costs in the two-hand hoeings (weed free) treatment and the lowest weed management cost in the atrazine @ 0.125 as PE. The costs for tillage, seed, and others practices used in the different treatments ranged from NRs 35,000 to NRs 2,60,000 with the lowest costs in the control treatment and NRs 2,60,000 in all others treatments. The total costs for the different treatments ranged from NRs 2,60,000 to NRs 3,13,440. The lowest total cost was found in the control treatment, whereas the highest cost in the treatment two manual hoeing.The benefits obtained from the different treatments ranged from NRs 7,73,150 to NRs 13,40,850 with the lowest in the control and the highest benefit found in two manual hoeings. The benefit cost ratio (returns per rupees invested) ranged from 2.90 to 4.93 with the lowest in the control and the highest in the mulching with rice straw @ 6 t ha^{-1}. The highest benefit from rice straw mulch was also reported by Waheed et al 2023 that mulching practices showed significant impact on economic parameters. Due to which the result of straw mulching, the cost of cultivation, benefit, and benefit cost ratio are significantly higher than the treatments with no mulching.

Table 5. Effect of different treatments on economic of different treatments in Potato at Khumaltar

Treatments	Cost for weed management	Tillage, seed, fertilizers and others management and harvest	Total costs of cultivation	Yield	Benefit	B:C
Pendi@1.0 kg a.i^{-ha} as PE	9000	260000	269000	30.39	1063650	3.95
Metri @0.5 kg $^{a.i\ ha-1}$ as PE	7500	260000	267500	30.82	1078700	4.03
Atra @0.25 kg $^{a.i\ ha-1}$ as PE	5300	260000	265300	31.19	1091650	4.11
Atra @0.125 kg $^{a.i\ ha-1}$ as PE	4650	260000	264650	31.19	1091650	4.12
Metri @0.25 kg $^{a.i\ ha-1}$ as PE	5750	260000	265750	32.79	1147650	4.32
Atra @ 0.25 kg a.i^{-ha} as PO	5300	260000	265300	24.14	844900	3.18
Metri @ 0.5 kg a.i^{-ha} as PO	7500	260000	267500	29.33	1026550	3.84
SM @ 6 t $^{-ha}$	12000	260000	272000	38.31	1340850	4.93
WF (2 MH)	53,440	260000	313440	28.00	980000	3.12
NW (control)	0	35000	260000	22.09	773150	2.90

(Note :80 manday @ of Rs. 668/manday for hand weeding, seed rate: 22.5 t ha^{-1}, price of seed Rs. 100 kg^{-1}, price of tuber sold @ Rs. 35 kg^{-1}), BC= benefit cost ratio, Yield= tuber yield t ha^{-1}

CONCLUSION

From the experiment, it can be concluded that among the various treatments employed for weed management in potato, mulching with rice straw @ 6 t ha^{-1} was found effective in controlling weeds with weed control efficiency of 147 %, the highest tuber yield of 38.31 t ha^{-1} and 73.4 % increased yield over control. This treatment also resulted in highest benefit of Rs.13,40,850 and highest benefit cost ratio of 4.93.

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AUTHORS' CONTRIBUTION

RK Bhattarai conceptualized, conducted and prepared the manuscript as a lead author while other authors assisted in field work and write-up.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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