E-ISSN: 2788-8428
P-ISSN: 2788-8436
ZEL 2024; 4(2): 47-53
www.zoologicaljournal.com
Received: 17-05-2024
Accepted: 21-06-2024

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Efficacy of bio pesticides on growth, yield and red ant damage to potato

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DOI: https://dx.doi.org/10.22271/letters.2024.v4.i2a.105

Abstract
Growing incidence of red ants causing damage to tubers has been a major problem among potato farmers in Doti. A field experiment was carried out at farmer's field in Budar, Jorayal Rural Municipality-2, Doti during March-June, 2023 to study the performance of locally available botanical pesticides on red ant infestation to potato tubers and compare it with chemical control. Five treatments namely Eupatorium (Banmara) (T_1), Jholmol (T_2), Agave americana (Ketuke) (T_3), chlorpyriphos 50% EC + cypermethrin 5% EC (T_4), control (T_5) were arranged in a randomized complete block design and replicated four times. A significantly higher marketable yield (t ha^{-1}) was observed in all treatments except control (T_5) (7.42±1.46 tonnes); the highest marketable weight was observed in chlorpyriphos 50% EC + cypermethrin 5% EC (T_4) (16.07±1.46 tonnes) being at par with Jholmol (T_2) (15.57±1.46 tonnes), Eupatorium (Banmara) (T_1) (15.37±1.46 tonnes) and Agave americana (Ketuke) (T_3) (13.13±1.46 tonnes). Results also exhibited that the application of Jholmol (T_2) (4.75%), Eupatorium (Banmara) (T_1) (9.64%), Agave americana (Ketuke) (T_3) (15.70%) were statistically at par with chlorpyriphos 50% EC + cypermethrin 5% EC (T_4) (0%) in terms of loss percentage of tubers due to red ants whereas control (T_5) had the highest loss percentage of 46.33%. However, B: C ratio was the highest from Eupatorium (Banmara) (T_1) and the lowest from chlorpyriphos 50%EC + cypermethrin 5% EC (T_4). This study suggests that there are statistically significant botanical alternatives (especially Eupatorium (Banmara) to chemical pesticides and proposes further study into the performance of botanicals.

Keywords: Banmara, botanicals, jholmol, ketuke, red ant

Introduction
Potato, one of the key food consumed in Nepalese kitchen across all geographical regions, is grown at altitude ranging from 100 meter above sea level to 4000 masl in Nepal. In the year 2021, potato was grown in 198788 ha with the production of 3,325,231 mt. Agriculture contributed 23.95% to country's Gross Domestic Product out of which potato alone made contribution of 5.52% to Agriculture Gross Domestic Product (MoALD 2022) [19]. Despite higher production and productivity of this crop, domestic production is insufficient to meet the increasing demand of potatoes for consumption and industrial purpose in Nepal. Unavailability of quality seed and fertilizers, improper method of planting, higher incidence of insect-pests and lack of post-harvest technologies have been identified as the major problems associated with low production of potato (Bajracharya & Sapkota 2017) [2] in the mid hills of Nepal. Out of the various insect species associated with potato crop in Nepal, red ant (*Dorylus orientalis westwood*) is one of the important soil pests in mid hills and high hills of Nepal (Gc *et al*. 1997; Bhatta *et al*. 2018) [8, 1] damaging a wide range of crops belonging to solanaceae and cruciferae family in Nepal (Joshi 1998) [11]. They consume roots of many plants, causing them to wilt and die (Jackson 2021) [10].
Red ant is reported to damage 70-90% of potato tubers at harvest Kishore *et al*. (1990) [15] and can reduce the yield up to 35-40% as reported by Konar *et al*. (2013) [16]. The infestation is exacerbated by dry weather and high temperature during the growing season (Kishore *et al*. 1990) [15]. So, farmers growing vegetables at small scale in such conditions have been using musty and putrid things like cattle urine, mustard oilseed cake, jholmol in their kitchen garden; and malodorous botanicals like Ketuki (*Agave Americana*), Banmara (*Eupatorium*), Neem (*Azadiracta*), and Titepati (*Artemisia*) for controlling pests. These botanicals are also known to have phenolic compounds and terpenes capable of repelling many insects (Rizwan *et al*. 2012; Kafle & Shih, 2013) [22, 13]. But on the other hand, commercial farmers are using different pesticides like Malathion, Chlorpyriphos, Dursban for reducing the extent of

damage and improving the quality and yield of marketable tubers.

Insect pests develop resistance to certain insecticides over time (Georghiou 1986) [7], which may compel the growers in increasing the dose of chemical biocides to sustain crop production. Increasing use of chemicals and pesticides for improving production and productivity of major food crops may pose serious threats (Busvine 1980) [5] to both human and soil health. So, this research intends to find the effect of locally available botanicals and bio pesticides in managing red ants for improving both the quality and yield of potato tubers.

Materials and Methods

Site description: The experiment was conducted in farmer's field at Jorayal-2, Doti district, Province-7, Nepal from March-June, 2023. Located at 27º20" N latitude and 77º49" longitude and 1358 masl in the humid sub-tropical zone, the site had sandy loam soil. During the experimental period, the maximum temperature reached 32.44 °C during the month of June whereas minimum temperature reached up to 13.9^0 on 21st March. The relative humidity ranged from 88.81 to 39.6% and the site received a total precipitation of 242.71mm during the growing period (NASA 2023)

Table 1: Treatment details

S. No.	Treatments	Indication (Labeling)	Doses	Methods of application
1.	*Eupatorium* (Banmara)	T_1	0.5 kg/m^2	Used by cutting it into pieces and placed between tubers during planting.
2.	Jholmol	T_2	Concentration of 1:4 with water	Used 45 days after planting (DAP), the process was repeated for 4 times at 15 days interval.
3.	*Agave americana* (Ketuke)	T_3	0.5 kg/m^2	Used by cutting it into pieces and placed between tubers during planting.
4.	Chlorpyriphos 50% EC + cypermethrin 5% EC	T_4	2ml/liter water	Used by drenching of soil 45 DAP. The process was repeated for 4 times at 15 days interval.
5.	Control	T_5	-	All the other condition was same with no any treatment for control of red ant performed.

Experimental setup

The experiment was conducted in Randomized Complete Block Design (RCBD) with four replications and five treatments. The treatments consisted of different botanicals and pesticides to control red ant infestation as shown in Table 1. The experimental field was 157.5 m^2 (15 m × 10.5 m). There were altogether 20 plots and each plot receiving a treatment had the dimension of 2.4 m × 2 m. The Cardinal variety of potato was sown on 6th March 2023. Planting was done on ridges made 60cm apart in each plot. Plant to plant distance was 25 cm in each row. There were 4 rows with 8 plants in each row.

Observations

Phenology: Days to 1st sprouting was recorded by counting the number of days from the date of planting to the appearance of 1st sprout measuring about 2mm. Percentage sprouting was recorded by dividing the number of sprouted tubers by the total number of tubers in each treatment. Days to 50% flowering was recorded when 50% of the plant population in each plot produced flowers Days to physiological maturity was recorded as days from emergence to maturity when the haulms of 50% of the plant population per plot have showed sign of senescence or turn yellowish. Data pertaining phenology were recorded on the basis of visual observation.

Growth parameters

Plant height and Number of stems per hill were recorded at 45, 60, 75, 90 days after planting (DAP). Ten plants were tagged randomly from each plot as a sample plants and their height was measured and number of stems were counted. Data collected from these sample plants was used to amplify the data in standard hectare scale.

Yield parameters

Yield of haulm was recorded 10 days prior to harvesting using digital weighing balance and sack. During harvesting, yield of red ant damaged tuber, yield of non-damaged tuber, total yield from the randomly selected sample plants. Untouched potato tubers without any holes were categorized as marketable tubers or non-damaged tubers whereas tubers having holes made by red ants were categorized as red ant damaged tubers. Average was computed for each plot using values of randomly sampled 10 plants. Loss percentage was calculated by dividing red ant damaged tubers with total yield multiplied by 100.

Data analysis

Data was systematically arranged on the basis of various observed parameters into MS-Excel and further subjected to analysis of variance. EXCEL AND R-studio 4.3.1 were used for the data analysis. All the data analyzed were put to DMRT for mean comparison by selecting 5% level of significance.

Economic analysis

Cost of cultivation, gross return, net return, benefit cost ratio were calculated for economic analysis. Cost of cultivation was calculated by adding all the inputs that were used during the course of cultivation. Gross return was calculated by multiplying the marketable yield with the existing market price of potato. Net returns for each plot was calculated by deducting the cost of cultivation from the gross return obtained whereas Benefit cost ratio (B: C ratio) was calculated by dividing the gross return with the cost of cultivation.

Results

Phenology: The treatments had no significant influence on days to 1st sprouting and 75% sprouting but significant effect on days to 50% flowering were observed as shown in Table 2. The average days to 1st sprouting and 75% sprouting was 23.6 and 38 days respectively. The observed days to 50% flowering revealed early flowering in Jholmol (62.25 days) and Chlorpyriphos 50% EC+ Cypermethrin 5%

EC (62.50 days) treated plots as compared to other treatments. Flowering was and maturity were significantly delayed with the application of *Eupatorium* (Banmara) and *Agave americana* (Ketuke) in potatoes. Similarly, the plot which were not treated with any botanicals also showed delayed flowering i.e.64.25 days. The result showed that tubers from Jholmol and Chlorpyriphos 50% EC+ Cypermethrin 5% EC applied plots matured 2 days earlier than *Agave americana* (Ketuke) treated potatoes.

Table 2: Phenology of potato as affected by chemical pesticides and bio pesticides

Treatments	Sprouting		Days to 50% flowering	Days to 50% maturity
	Days to 1st sprouting	Days to 75% sprouting		
Eupatorium (Banmara)	23	36.5	64^{b}	90.75^{ab}
Jholmol	23	39.5	62.25^{a}	90.25^{a}
Agave americana (Ketuke)	23.75	37.25	64.75^{b}	92.25^{c}
Chlorpyriphos 50% EC+ Cypermethrin 5% EC	23.75	36.5	62.50^{a}	90.25^{a}
Control	24.5	40.25	64.25^{b}	91.75^{bc}
SEm (±)	0.627	2.58	0.39	0.34
CD	1.93	7.97	1.21	1.05
F-test	ns	Ns	**	**
CV%	5.31	13.62	1.24	0.75
Grand Mean	23.6	38	63.55	91.05

Note: NS: Non-significance, **significant difference at 0.01 level of significance, CV: Coefficient of variance, SEm (±): Standard error of mean, treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance, CD: Critical Difference.

Plant height

Plant height increased throughout the crop growth period, with the value of 10.88 cm at 45 DAP and reached up to 30.12 cm at 90 DAP as observed in Table 3. The plant height was significantly influenced by the application of various botanicals and chemical treatments at 60 DAP but was not significantly influenced at other observation time. However, at 60 DAP, the maximum plant height was observed in the treatment Chlorpyriphos 50% EC+ Cypermethrin 5% EC (19.82 cm) which was slightly superior to the treatment Jholmol (17.85 cm). It revealed 23.48% increase in plant height with the chemical insecticides as compared to the Control. But, the treatments *Eupatorium* (Banmara), Control and *Agave americana* (Ketuke) were statistically at par in yielding plant height at 60 DAP but were inferior to Jholmol and chemical pesticides. The treatment *Agave americana* (Ketuke) had the shortest plant height of only 27.22 cm among all the treatments, as observed 90 days after planting.

Table 3: Plant height (cm) of potato as affected by chemical pesticides and bio pesticides

Treatments	Plant height (cm)			
	45 DAP	60 DAP	75 DAP	90 DAP
Eupatorium (Banmara)	10.97	16.17^{b}	27.85	28.57
Jholmol	10.95	17.85^{ab}	30.02	30.85
Agave americana (Ketuke)	10.62	14.75^{b}	26.12	27.22
Chlorpyriphos 50% EC+ Cypermethrin 5% EC	11	19.82^{a}	33.8	34.3
Control	10.87	16.05^{b}	28.9	29.65
SEm (±)	0.35	1.02	1.81	1.74
CD	1.07	3.16	5.57	5.36
F-test	Ns	*	Ns	ns
CV%	6.43	12.13	12.33	11.56
Grand Mean	10.88	16.93	29.34	30.12

Note: NS: Non-significance, * significant difference at 0.05 level of significance, CV: Coefficient of variance, SEm (±): Standard error of mean, treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance, CD: Critical Difference.

Number of stems per hill

The final number of stems were almost the same as observed one week after sprouting. Average number of stems per hill of potato plant was recorded to be 2.79. The analysis on observed number of stems per hill showed no significant influence of different botanicals and chemicals in the later stages of plant growth as shown in Table 4. This implies that there was no sprouting from the tubers at later stages of crop growth. Among the three shoots in each eye of the tuber, the most developed one germinates first Jukneviˇcienė *et al*. (2011) [12] which justifies that there is no growth of sprouts from the eye at later stages of plant growth, which is observed in our study even with the application of pesticides at different time periods.

Table 4: Number of stems per hill of potato of potato as affected by chemical pesticides and bio pesticides

Treatments	Number of stems per hill			
	45 DAP	60 DAP	75 DAP	90 DAP
Eupatorium (Banmara)	2.85	2.92	2.92	2.92
Jholmol	2.2	2.37	2.37	2.37
Agave americana (Ketuke)	2.95	2.95	3.02	3.02
Chlorpyriphos 50% EC+ Cypermethrin 5% EC	2.75	2.8	2.8	2.8
Control	2.72	2.75	2.82	2.82
SEm (±)	0.22	0.25	0.26	0.26
CD	0.69	0.79	0.80	0.80
F-test	ns	Ns	Ns	Ns
CV%	16.8	18.64	18.83	18.83
Grand Mean	2.69	2.76	2.79	2.79

Note: NS: Non-significance, CV: Coefficient of variance, SEm (±): Standard error of mean, treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance, CD: Critical Difference.

Yield of marketable tubers

Non damaged tubers which can be marketed easily were recorded as marketable tubers. All the treatments were quite effective in controlling the red ant infestation in potatoes, as observed in Table 5 from the yield of non-damaged tubers. The weight of marketable (non-damaged) tubers was found to be significantly higher in all the treatments than the control plots, where no any botanicals or pesticides were added. The highest marketable yield of 16.06 t ha^{-1} was obtained from application of Chlorpyriphos 50% EC+ Cypermethrin 5% EC followed by Jholmol (15.57 t ha^{-1}), *Eupatorium* (Banmara) (15.37 t ha^{-1}) and *Agave americana* (Ketuke) (13.12 t ha^{-1}) respectively. The lowest marketable tuber yield i.e. non damaged tuber was found in Control with the value 7.42 t ha^{-1}. Our results revealed that that the combination of chemical insecticides decreased the infestation and increased the non-damaged tuber yield by 3.14% as compared to Jholmol. Similarly, 109.83% increase in marketable tuber yield was obtained from Jholmol as compared to control. In the same way, 18.62% increase non-damaged tuber was obtained in Jholmol as compared to *Agave Americana*.

Yield of red ant damaged tuber

Results showed significant effect of all the treatments on yield of red ant damaged tubers (non-marketable tuber yield) as observed in Table 5. The mean yield of red ant damaged tuber was found to be 2.24 t ha^{-1}.

It showed that Jholmol as well as all the botanicals used were statistically at par with the Chlorpyriphos 50% EC+ Cypermethrin 5% EC in checking red ant infestation in potatoes. The highest damage by red ant was observed in the control plot followed by *Agave americana* The most effective treatment in controlling red ant was Chlorpyriphos 50% EC+ Cypermethrin 5% EC, which had zero infestation. It means chemical method was highly effective in controlling the infestation in potato followed by Jholmol, which was also quite effective in controlling the red ant infestation. Jholmol applied potatoes showed 88.19% less damaged tubers yield than un amended Control. After Jholmol, *Eupatorium* (Banmara) served as a good alternative in controlling red ant infestation showing 74.68% decrement as compared to control. The treatment *Agave americana* was also found to control the red ant infestation in potato with the value of damaged tuber being 2.38 t ha^{-1}, which was quite lower as compared to 6.44 t ha^{-1} in the Control.

Total tuber yield

The total yield of tuber as observed from the result (Table 5) revealed no significant influence of insecticides (marketable + red ant damaged). However, the maximum tuber yield was obtained from the treatment *Eupatorium* (Banmara) amounting 17 t ha^{-1} which was 5.85% and 22.56% higher than that obtained from the treatment Chlorpyriphos 50% EC+ Cypermethrin 5% EC and Control respectively.

Table 5: Quality and yield of potato as affected by chemical pesticides and bio pesticides

Treatments	Damaged tubers (t ha^{-1})	Marketable tubers (t ha^{-1})	Total yield (t ha^{-1})	Loss percentage	Weight of haulm (t ha^{-1})
Eupatorium (Banmara)	1.63[a]	15.37[a]	17.00	9.64[a]	8.26
Jholmol	0.76[a]	15.57[a]	16.32	4.75[a]	9.17
Agave americana (Ketuke)	2.38[a]	13.12[a]	15.51	15.70[a]	6.90
Chlorpyriphos 50% EC+ Cypermethrin 5% EC	0[a]	16.06[a]	16.06	0[a]	8.14
Control	6.44[b]	7.42[b]	13.87	46.33[b]	8.10
SEm (±)	1.16	1.46	1.03	7.86	0.73
CD	3.59	4.50	3.16	24.23	2.52
F-test	*	**	Ns	**	Ns
CV%	103.89	21.62	13.03	102.86	18.01
Grand Mean	2.24	13.51	15.75	15.28	8.11

Note: NS: Non-significance, * significant difference at 0.05 level of significance, **significant difference at 0.01 level of significance, CV: Coefficient of variance, SEm (±): Standard error of mean, treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance, CD: Critical Difference.

Loss percentage

The loss percentage was found to be significantly higher in Control (46.33%) followed by Agave Americana (15.7%), Eupatorium (9.64%) and Jholmol (4.75%). There was no loss from the Chlorpyriphos 50% EC+ Cypermethrin 5% EC applied plot, as is evident from the Table 5.

Loss percentage was statistically similar in all the treatments except for the Control

Weight of haulm

The weight of haulm revealed no significant influence of insecticidal treatments. The average haulm weight was found to be 8.11 t ha^{-1}. Jholmol yielded the haulm weight of 9.17 t ha^{-1}, which was also the highest among all the treatments. Similarly, *Agave americana* (Ketuke) yielded the lowest with the value of 6.9 t ha^{-1}. Similar weight of haulm from all the treatments implies no significant effect of treatments on haulm. This might be due to less variance in height and number of stems causing similar accumulation of above ground biomass in all treatments.

Economic analysis

Average cost of cultivation recorded was NRs. 3,35,433.4/ha. The treatment Control exhibited the lowest cost of cultivation followed by *Eupatorium* (Banmara). Both *Eupatorium* and *Agave americana* (Ketuke) had similar cost of production, as both were collected in similar amount from the nearby forests. The highest cost of cultivation was recorded in Chlorpyriphos 50% EC+ Cypermethrin 5% EC as shown in Figure 2. Gross return was calculated by multiplying the marketable yield with the existing market price of potato which was NRs. 40,000/t at the time of harvest. The average gross return was recorded to be NRs. 5,40,438.4. Chlorpyriphos 50% EC+ Cypermethrin 5% EC treated plots exhibited the highest gross return without any loss percentage from the total tuber yield. The lowest gross return was obtained from the Control due to higher amount of damaged tuber and low tuber yield.

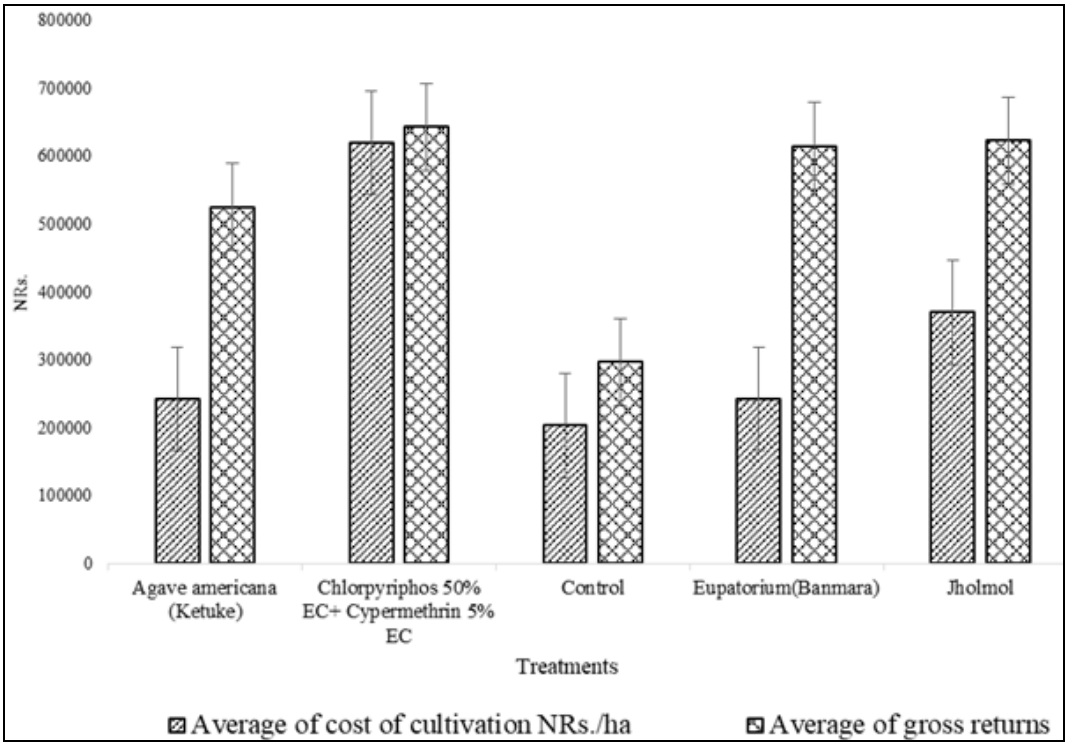

Fig 2: Cost of cultivation vs gross return

The net return value was calculated by subtracting the cost of cultivation from gross return. Average net return amounted NRs. 205020. The highest net return was obtained from *Eupatorium* (Banmara) and *Agave americana* (Ketuke) and the lowest from Chlorpyriphos 50% EC+ Cypermethrin 5%. The reason behind the lowest net return from this chemical insecticide was the higher cost of for purchase though the marketable yield was high. The treatments *Eupatorium* (Banmara) and *Agave americana* (Ketuke) provided the highest B: C ratio of more than 2.17, whereas Chlorpyriphos 50% EC+ Cypermethrin 5% EC (1.04) treated plots had the lowest B: C ratio as shown in Table 6. It revealed that the use of botanicals was economic in controlling red ant infestation as compared to Jholmol and chemical based insecticides in the mid hills like Doti.

Table 6: Benefit cost ratio of potato as affected by chemical pesticides and bio pesticides

Treatments	B: C ratio
Eupatorium (Banmara)	2.54
Jholmol	1.68
*Agave americana (*Ketuke*)*	2.17
Chlorpyriphos 50% EC+ Cypermethrin 5% EC	1.03
Control	1.46

Discussion

Application of bio pesticides, chemical pesticides showed significant improvement in growth, yield and quality of potatoes as compared to un amended control. Despite the time of application of different pesticides, no significant difference in days to sprouting were observed. Application of Chlorpyriphos 50% EC+ Cypermethrin 5% EC and Jholmol induced early flowering and maturity in the potato as compared to *Eupatorium* and *Agave Americana.* Maturity delayed in *Agave americana* (Ketuke), which might have released the nutrients slowly at later stages of the plant growth due to slow decomposition in soil. Jholmol might have supported for early flowering as it also functions as bio-fertilizer as well as bio-pesticide (Bhusal & Udas 2020) [4]. Higher concentration of chlorpyriphos after few spray might have slowed down the metabolism, resulting in quick maturity of potato. Mu *et al*. (2022) [20] reported slowdown of protein content, shoot biomass in rice plant at higher concentration of Chlorpyrifos who also had reported increased in chlorophyll content at low and medium concentration of Chlorpyriphos which might have increased the plant height of potato. In contradictory to our findings, Bhattarai *et al*. (2022) [3] reported the highest plant height in *Agave* which was statistically at par with Banmaara and cow urine. Application of same botanicals can have different effects under different soil and variety.

Statistically, application of Jholmol, Eupatorium and *Agave americana* were equally effective in minimizing the loss due to red ant infestation as chemical pesticides. Though non-significant, loss percentage of tuber from application of Jholmol was lesser as compared to other treatments but higher than application of Chlorpyriphos 50% EC+ Cypermethrin 5% EC. These chemical pesticides have been reported to control pests by disrupting their nervous system, leading to paralysis and eventual death (Kumar 2020) [17], which might have controlled red ant infestation to the extreme end with no single damage to potato tuber in our study. Bhattarai *et al*. (2022) [3] in a research conducted in Bhatkada, Dadeldhura also reported highest marketable yield (non-damaged tubers) from Chlorpyrifos application over control which was also reported by Kishore *et al*. (1990) [15]. Similar to our findings, 46.41% loss in potato tuber yield was observed by Dash *et al*. (2013) [6] in the control plot, who also reported the lowest loss percentage from Dursban 20 EC. As compared to control, loss percentage was relatively lower in Jholmol and *Eupatorium.* This indicates prominent red ant repelling properties in these bio pesticides. As opposed to our findings, slightly better performance of *Agave americana* over *Eupatorium* on red ant damage to tubers was observed by Khanal *et al*. (2017) [14]. Red ant damaged tuber was nearly three times lower in Agave Americana as compared to control, revealing it to be one of the better alternative in controlling this pest. Control presented no hindrance against red ant making it most easy target for red ants to cause maximum damage on most tubers however the botanicals used repelled the red ant population and faced little damage compared to control. Lowest yield in control might be due to stress caused by red ants and no external treatments applied to provide nutrition for potato growth and yield, as is done in case of botanicals and Jholmol.

Apart from insecticidal effects, Banmara (*Eupatorium*) provides 2.0%, 0.02% and 1.2% nitrogen, phosphorus and potassium respectively to the soil after decomposition Lallianrawna *et al*. (2013) [18], which might be the reason of the highest tuber yield from *Eupatorium* applied plots over other treatments. After Banmara, Jholmol performed better in terms of total tuber yield as it contains animal urine which has more nitrogen than animal manure. Addition of nutrient into the soil besides pest repellent property in Jholmol ICIMOD (2016) [9] might have improved proper growth of potato and better yield. Similarly, the treatment Chlorpyriphos 50% EC+ Cypermethrin 5% EC was reported to have insecticidal effect, which might have improved the tuber yield as compared to control. Increased growth during the early growth stages and reduced stress of plants towards the external stimuli particularly red ant during the tuberization have improved the yield without single damage to tubers.

Economic analysis revealed higher profits from Eupatorium as compared to other bio-pesticides due to lower cost associated with its use and higher tuber yield. Though the marketable tuber yield was higher in Chlorpyriphos 50% EC+ Cypermethrin 5% EC, the cost for purchase and use is also the higher making it the less profitable as revealed by the benefit cost ratio. Similarly, the net returns were also higher in Agave and Jholmol as compared to the chemical pesticides. The research revealed the promising benefits from the use of locally available botanicals and Jholmol than going for the expensive inputs in red ant infested areas of Nepal.

Conclusion

This research suggests that there are statistically significant botanical alternatives especially *Eupatorium* (Banmara*)* and *Agave americana* (Ketuke) to chemical pesticides and proposes further study into the efficacy of botanicals. Application of Eupatorium, Jholmol, Agave Americana and Chlorpyriphos 50% EC+ Cypermethrin 5% EC were quite effective in controlling red ant infestation. Among the botanical pesticides, the use of *Eupatorium* (Banmara) was found to be the most effective since its application reduced the weight of infested tubers and provided the highest B: C ratio. Hence, it can be suggested as eco-friendly management technique for management of the red ant in potato.

Acknowledgements

The authors are thankful to the support provided by LI-BIRD and Faculty of Agriculture for conducting this research study. The authors would like to acknowledge the support received from Anisha Bohara for data collection and Rakshya Sharma for her generous support throughout the study period.

Conflict of Interest

The author(s) declared no potential conflict of interest with respect to the research, authorship and/or publication of this article.

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