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Efficacy of Various Biopesticides against Red Ant (*Dorylus orientalis* Westwood) in Potato Field

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ABSTRACT

Red ant (Dorylus orientalis Westwood) is the most destructive insect pest of potato tubers in the field in Nepal. A field experiment was conducted at Bhatkada, Dadeldhura district, Nepal in 2020 to determine the efficacy of various biopesticides and chemical insecticide on red ants. The plot size in this experiment was 106.7 m^2. Five treatments viz. Chlorpyriphos 20% EC (2 mL L^{-1} water), Banmaara (2 kg plot^{-1}), Cow urine (2 L 6 L^{-1} water plot^{-1}), Agave (25 g tuber^{-1}) and Control (no treatment) were evaluated in randomized complete block design with four replications. The data on plant height and the number of leaves were taken at 45, 60, and 75 days after planting (DAP). The data on slightly and severely infested tubers were taken after harvesting of potato. The results showed that Chlorpyriphos treated plots gave the lowest values of traits viz numbers of slightly infested tuber (91,500 ha^{-1}), severely infested tubers (12,500 ha^{-1}), weights of slight infested tubers (7,700 kg ha^{-1}) and severely infested tuber (1,130 kg ha^{-1}). Among the botanical pesticides, Agave treated plots provided the second lowest values of numbers of slightly infested tuber (145,500 ha^{-1}), severely infested tubers (37,400 ha^{-1}), weights of slight infested tubers (13,400 kg ha^{-1}) and severely infested tuber (3,110 kg ha^{-1}). The results showed that the Agave treatment provided the highest marketable yield (50,900 kg ha^{-1}). Thus, Chlorpyriphos and Agave could be used to efficiently protect potato tubers from red ant in potato field.

Keywords:
Botanical Pesticides; Chemical Pesticide; Red Ant; Dorylus orientalis; Potato

1. Introduction

Potato (*Solanum tuberosum*) belongs to the family Solanaceae which is used as one of the most important foods for many people in the world. It is one of the most important vegetables as well as cash crop in Nepal. In Nepal, potato ranks 5th in term of area and in terms of production, potato ranks 2nd after rice (Upadhyay and Timilsina, 2020). They are rich in carbohydrates, protein, and vitamin C, making them a very good source of energy. Therefore, potatoes can be an important factor in improving the nutritional status and overall health of rural populations in developing countries (Bhatta et al., 2018). According to the recent statistics (MoALD, 2019), the potato production is 3,112,947 tones and productivity is 16.04 t ha^{-1}, which is greater than the previous years. However, the observed production and productivity are relatively lower than their potential. The major constraint for low productivity of potatoes especially in mid-hills and high hills is due to insect pest infestations. In potatoes, more than 40 insects have been found to be associated (NPRP, 2008). Amongst them, the red ant (*Dorylus orientalis* Westwood) is a major pest that attacks the potato in Mid-hills and high hills of Nepal (Sharma et al., 2019). According to the survey, in Nepal red ant is reported as a serious problem in the hilly areas of Dadeldhura district (Joshi, 2019). During the winter season, just after tuber formation, the red ant attacks potato crop and its infestation continues up to harvesting of potato unless any management approach is taken (Dash, 2013). Potato tubers are damaged and those tubers exhibit minute holes (2-3 mm diameter) and soft peels that are cleaned out (Bhattacharyya et al., 2014). The pest comes into sight or become noticeable during December and remains active until April, causing more than 10% of the damage in (irrigated) potato crops. High temperatures and dry weather favor the population build-up (Dash et al. , 2013). Since the damage of *D. orientalis* is emerging as major constraint for the success of potato crop, effective bio-rational measures of pest management are essential to suppress pests and market intact per fresh potatoes (Bhatta, 2018).

The discovery and adoption of synthetic pesticides as a quick and effective technique for managing agricultural pests and diseases resulted from increased need for food to feed the world's ever-growing population. Overuse of synthetic pesticides, on the other hand, is prohibited because of the dangers they pose to human health, the environment, and the development of resistant insect and pathogen strains (Lengai et al., 2020). The efficacy, biodegradability, diverse modes of action, low toxicity, and availability of source materials are all factors that contribute to the importance of botanical pesticides (Neeraj et al., 2017). The biorational measures for pest management are very useful to reduce pests and minimize waiting period to harvest and market fresh vegetables. Owing to the increasing threats of red ant infestation on potato crop, this study was carried out to evaluate the efficacy of different biopesticides and insecticide on red ant.

2. Materials and Methods

2.1 Site description

The research experiment was carried out at Bhatkada, Dadeldhura district, Nepal whose geographical location is 29º26″ N latitude and 80º12″ to 80º47″ longitude in the humid sub-tropical zone with an elevation of 1745 m above sea level during the year of 2019/2020.

2.2 Climatic data

Weekly average temperature relative humidity and rainfall during cropping season at Bhatkada, Dadeldhura was given in Figure 1. Data regarding meteorological parameters of experimentation site viz. Relative humidity, precipitation, maximum and minimum temperature was taken from the regional department of hydrology and meteorological station, Dadeldhura during the cropping period. According to the Figure 1, the average maximum temperature was observed 25.8°C which ranged from 17.8°C to 31.8°C whereas the average minimum temperature was observed 12.5°C which ranged from 6.2°C to 19°C. The average rainfall of 4.8 mm with total of 86.7 mm rainfall was observed in the experimentation field. These all parameters indicated that the area was fit for the potato production.

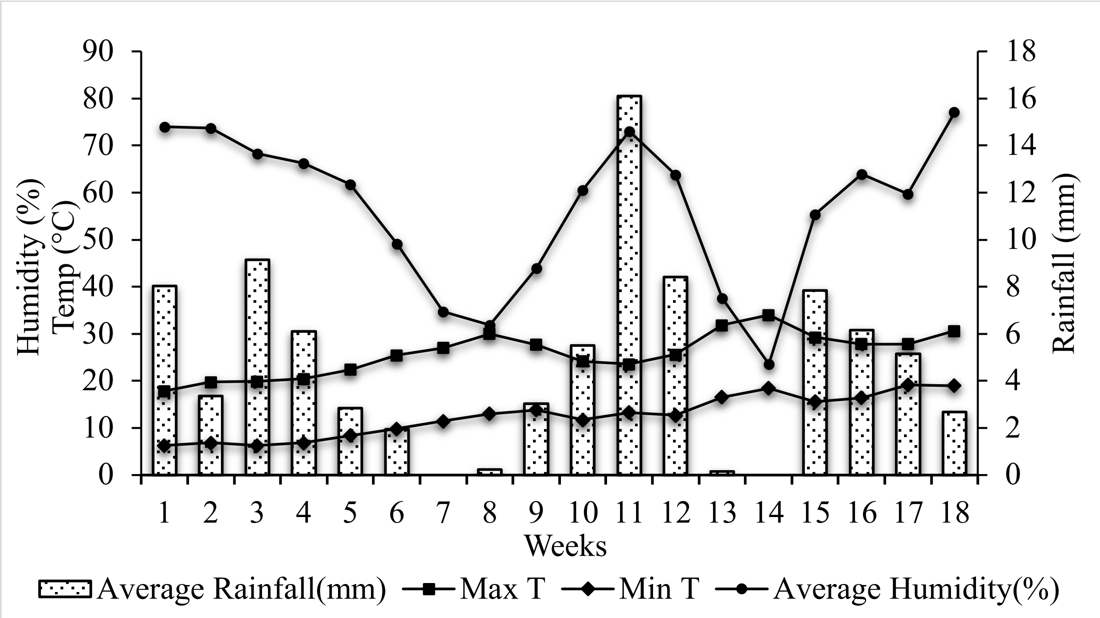

Figure 1. Weekly average temperatures, relative humidity, and rainfall during cropping season at Bhatkada, Dadeldhura.

2.3 Plant materials

The Desiree variety of potato was used for the experimental study. This variety was received from National Potato Research Program, Khumaltar, Lalitpur, Nepal. The reason behind using this variety is it is abundantly available and mostly used and preferred by the farmers in the region.

2.4 Experimental setup

This experiment was conducted in Randomized Complete Block Design (RCBD) with four replications. The plot size was 106.7 m^2 (19.4 m × 5.5 m). Each replication consists of five treatments each measuring an area of 3.6 m × 1 m. The Desiree variety of potato was sown on 19th February 2020. Crop geometry was maintained at 20 cm (Plant to Plant distance) × 60 cm (Row to Row distance). Each plot has 6 rows with 5 plants per row. The details of treatments were given in Table 1.

2.5 Method of treatment application

Harvesting time of every crop depends upon the respective cultivar. The variety we used was Desiree so its maturity day is around 80-90 days. Potato from the experimental field was harvested after 90 days of plantation.

Table 1. Treatment details for the experiment

No.	Treatments	Indication (Labeling)	Doses	Methods of application
1.	Chlorpyriphos 20% EC	T1	2 mL L^{-1} water	Soil drenching, and fumigation using plastic covers to prevent the vaporization of chemical.
2.	Banmaara (*Eupatorium adenophora*)	T2	2 kg $plot^{-1}$	Broadcasting the 1-night shed dried leaves.
3.	Cow urine	T3	2 L 6 L^{-1} water $plot^{-1}$	Soil drenching and fumigation using plastic covers to prevent the vaporization of Cow-urine.
4.	Agave (*Agave americana*)	T4	25 g $tuber^{-1}$ (Number of agave pieces is equal to number of seed tubers)	Placement method was used. Each piece of agave (weighing about 25 g) was placed alongside the potato tubers. 30 tubers were planted per plot and 30 pieces of agave were used.
5.	Control (Water only)	T5	-	-

2.6 Data recording

Plant height and number of leaves were measured after 45, 60 and 75 days after planting (DAP). Plant height measured with a meter tape. Five plants were tagged randomly from each plot as a sample plants and their height were measured. Number of leaves per plant were counted and then average were computed. The number of tubers was recorded during harvesting from each plot. After then, average was computed for further analysis.

Weight of tubers per plant was also recorded from each plot. Previously uprooted sample plants to record the number of tubers per plant were taken to weighing device and the weight was taken. All the weights of tubers were taken and entry was made for average calculation as well as for the average weight of tubers per plot.

During harvesting, number of intact tubers, slightly and severely infested tubers per plot were recorded from the randomly selected sample plants. Tuber categorization for the identification of damaging nature of red ant was based on the number of holes that red ant makes on tuber as given on Table 2 (Bhatta, 2018). All the tubers previously collected for recording the nature of tuber damage were re-collected and weight was also taken.

Table 2. Tuber Categorization

Type	Tuber category	Definition
Tuber damage	Intact (a)	Clear tuber without any damage
	Slightly infested (b)	Tubers having 1 or 2 shallow holes
	Severely infested (c)	Tubers having more than 2 deep holes
Tuber yield	Marketable yield (a+b)	Intact yield + Slightly infested tubers
		Severely infested tubers
	Non-marketable yield (c)	

Source: Joshi, 1998

2.7 Data Analysis

Data analysis was carried out using GenStat version 18 (VSN International, 2015). Analysis of variance was used to determine statistically significant differences between means. Mean comparison of each treatment was made by applying the Fisher LSD test ($p \leq 0.05$).

3. Results and Discussion

3.1 Results

3.1.1 Plant height

The height of the plant observed at 45, 60 and 75 days after planting were shown in the Table 3. The average height of potato plant at 45, 60 and 75 DAP were 18.02 cm, 35.22 cm and 60.118 cm respectively. The plant height was significantly influenced by the application of various botanicals and chemical treatments at 45 and 60 DAP but was not significantly influenced at 75 DAP. At 45 DAP, the maximum average plant height was observed in Banmaara treated plots which was statistically at par with cow urine (19.415 cm) and agave (21.14 cm) treated plots. Chlorpyriphos treated plots ranked the second in terms of height at 45 DAP (16.17 cm) whereas plant height was the minimum (12.15 cm) under the control plot as shown in Table 3. At 60 DAP, the maximum average plant height was observed again in Banmaara treated plots (40.16 cm) which was statistically at par with Cow urine (36.315 cm) and Agave (37.330 cm) treated plots. The cow urine and Agave treated plots were also statistically similar with Chlorpyriphos treated plot (33.15 cm) whereas the minimum plant (29.17cm) was observed again under the control plots which was also statistically par with Chlorpyriphos treated plots. At 75 DAP; the plant height was not significantly influenced by the application of insecticidal treatments.

Table 3. Effect of different pesticides on plant height of potato at Bhatkada, Dadeldhura in 2020

Pesticides	Plant height (cm)		
	45 DAP	**60 DAP**	**75 DAP**
Chlorpyriphos	16.17[b]	33.155[bc]	58.63
Banmaara	21.25[a]	40.160[a]	66.21
Cow Urine	19.415[a]	36.315[ab]	60.45
Agave	21.14[a]	37.330[ab]	60.10
Control	12.15[c]	29.170[c]	55.20
Grand Mean	18.024	35.226	60.118
SEm (±)	0.73	1.46	2.51
F-test	**	**	ns
LSD (0.05)	2.24	4.51	ns
CV%	8.074	8.31	8.36

** Significant difference at 0.01 level of significance, ns: Non significant, LSD: Least Significant Difference, CV: Coefficient of variation, SEm±: Standard error of mean. Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ according to LSD test

3.1.2. Number of leaves

Number of leaves per plant was found significantly higher in plant having insecticidal property than in control plots (Table 4). At 45 DAP, the highest number of leaves was found in Banmaara treated plots (78) which was statistically at par with Agave (77). However, the number of leaves in Banmaara and Agave was found statistically at par with Cow urine (58) which was found statistically similar with Chlorpyriphos treated plots. The minimum number of leaves was found under control plots (34). At 60 DAP, the number of leaves was found highest in Banmaara treated plots (459) which was statistically at par with Agave (256) and Cow urine (236). Similarly, number of leaves under chlorpyriphos (201) was also found statistically at par with Cow urine and Agave while the number of leaves was found lowest in Control plots (132). At 75 DAP, the highest number of leaves was found again in Banmaara treated plots (459). The minimum number of leaves was found under Control (229) plots in which no insecticidal plant and chemical treatment was applied. Cow urine ranked second (364) in terms of number of leaves which was statistically at par with Agave (362) and Chlorpyriphos (360).

Table 4. Effect of different pesticides on number of leaves of potato at Bhatkada, Dadeldhura in 2020

Pesticides	Number of leaves ($plant^{-1}$)		
	45 DAP	60 DAP	75 DAP
Chlorpyriphos	39.65^{bc}	201.75	360.0^{b}
Banmaara	78.35^{a}	294.95	459.80^{a}
Cow Urine	58.70^{ab}	236.15	364.45^{b}
Agave	77.45^{a}	256.45	362.0^{b}
Control	34.35^{c}	132.95	229.45^{c}
Grand Mean	57.7	224.45	355.14
SEm (±)	6.87	20.99	30.08
F-test	**	ns	**
LSD (0.05)	21.19	64.68	92.68
CV%	23.84	18.70	16.94

**Significant difference at 0.01 level of significance, ns: Non significant, LSD: Least Significant Difference, CV: Coefficient of variation, SEm±: Standard error of mean. Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ according to LSD test

3.1.3 Number and weight of slightly infested tubers

Number and weight of slightly infested tubers was given in Table 5. In Chlorpyriphos treated plots, the lowest number of slightly infested tuber (91,500 ha^{-1}) and lowest weight of slightly infested tuber (7,700 kg ha^{-1}) were found. Agave showed the second least infestation number of slightly infested tubers (145,500 ha^{-1}) and second least weight of slightly infested tubers (13,400 kg ha^{-1}).

Table 5. Effect of different pesticides on number and weight of slightly infested tubers of potato at Bhatkada, Dadeldhura in 2020

Pesticides	Slightly infested tubers (ha^{-1})	
	Number of slightly infested tubers	Weight of slightly infested tubers (kg ha^{-1})
Chlorpyriphos	$91{,}500^{d}$	$7{,}700^{d}$
Banmaara	$166{,}500^{bc}$	$14{,}900^{bc}$
Cow Urine	$199{,}500^{b}$	$19{,}000^{b}$
Agave	$145{,}500^{c}$	$13{,}400^{c}$
Control	$253{,}700^{a}$	$24{,}500^{a}$
Grand Mean	171,300	15,900
SEm (±)	14,230	6,300
F-test	**	**
LSD (0.05)	43,850	4,360
CV%	16.50	17.75

**Significant difference at 0.01 level of significance, LSD: Least Significant Difference, CV: Coefficient of variation, SEm±: Standard error of mean. Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ according to LSD test

3.1.4 Number and weight of severely infested tubers

Number and weight of severely infested tubers were given in Table 6. In Chlorpyriphos treated plots, the lowest number of severely infested tuber (12,500 ha^{-1}) and lowest weight of severely infested tuber (1,130 kg ha^{-1}) were found. Agave showed the second least infestation number of severely infested tubers (37,400 ha^{-1}) and the second least weight of severely infested tubers (3,110 kg ha^{1}).

Table 6. Effect of different pesticides on number and weight of severely infested tubers of potato at Bhatkada, Dadeldhura in 2020

Pesticides	Severely infested tubers (ha^{-1})	
	Number of severely infested tubers	**Weight of severely infested tubers (kg ha^{-1})**
Chlorpyriphos	12,500^{d}	1,130^{e}
Banmaara	54,100^{c}	4,750^{c}
Cow Urine	83,300^{b}	6,930^{b}
Agave	37,400^{c}	3,110^{d}
Control	158,300^{a}	12,960^{a}
Grand Mean	69,100	5,780
SEm (±)	6,930	490
F-test	**	**
LSD (0.05)	21,300	1,510
CV%	20	16.97

** Significant difference at 0.01 level of significance, LSD: Least Significant Difference, CV: Coefficient of variation, SEm±: Standard error of mean. Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ according to LSD test

3.1.5. Number and weight of intact potato tubers

Number and weight of intact tubers was given in Table 7. In Chlorpyriphos treated plots, the highest number of intact tuber (893,700 ha^{-1}) and the highest weight of intact tuber (37,600 kg ha^{-1}) were found. Banmara showed the second highest number of intact tubers (783,300 ha^{-1}) and the second highest weight of intact tubers (37,400 kg ha^{-1}). Similarly, Agave showed the third highest number of intact tubers (754,100 ha^{-1}) and third highest weight of intact tubers (25,000 kg ha^{-1}).

Table 7. Effect of different pesticides on number and weight of intact potato tubers at Bhatkada, Dadeldhura in 2020

Pesticides	Number and weight of intact tuber (ha^{-1})	
	Number of intact tubers	Weight of intact tubers (kg ha^{-1})
Chlorpyriphos	893,700[a]	37,600[a]
Banmaara	783,300[ab]	37,400[a]
Cow Urine	508,300[b]	35,300[ab]
Agave	754,100[ab]	25,000[ab]
Control	470,800[b]	8,700[b]
Grand Mean	682,000	28,800
SEm (±)	69,900	4,100
F-test	**	**
LSD (0.05)	215,500	12,700
CV%	20.51	28.58

** Significant difference at 0.01 level of significance, LSD: Least Significant Difference, CV: Coefficient of variation, SEm±: Standard error of mean. Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ according to LSD test

3.1.6 Weight of marketable yield

Marketable weight is the weight which excludes the weight of severely infested tuber i.e., it comprises the weight of intact and slightly infested tuber (Bhatta, 2018). Weight of marketable yield was given in Table 8.

Table 8. Effect of different pesticides on weight of marketable tubers at Bhatkada, Dadeldhura in 2020

Treatment	Weight of marketable tubers (kg ha^{-1})
Chlorpyriphos	45,300[ab]
Banmaara	50,200[a]
Cow Urine	44,000[ab]
Agave	50,900[a]
Control	33,300[b]
Grand Mean	44,800
SEm (±)	4,500
F-test	Ns
CV%	20.20

ns: Non significant, CV: Coefficient of variation, SEm±: Standard error of mean. Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ according to LSD test

In Agave treated plots, the highest weight of marketable tuber (50,900 kg ha^{-1}) was found. Banmara showed the second highest weight of marketable tubers (50,200 kg ha^{-1}). Similarly, Chlorpyriphos showed the third highest weight of marketable tubers (45,300 kg ha^{-1}) no significant difference was found in marketable weight per yield by the application of insecticidal treatments.

3.2 Discussion

Because of its biodegradable nature after application, capacity to alter the behavior of target pests and favourable safety profile, it is hoped that plant-based pesticides play a significant role in achieving yield in potato. Taller plants and more number of leaves were observed in Banmaara treated plots because after the application of Banmaara, it acted as compost inside the soil and provided nutrients including Carbon: Nitrogen ratio (14.2) and the compost formed provided 2.0% Nitrogen, 0.02% Phosphorus and 1.2% Potassium (Lallianrawna et al., 2013). Banmaara, when incorporated in the experimental field showed the reduced number of slightly and severely infested tuber by 34.42% and 65.78% respectively than that of control plots. Meanwhile the Banmaara treated plots had weight of slightly and severely infested tuber reduced by 39.34% and 63.30% respectively in comparison to control plots. According to the research done by Devkota (2004), Banmaara had major identified constituents as Monoterpenes and Sesquiterpenes such as Cymene, Metha-1,8-diene, Camphor, Caryophyllene, a-thujene, Borneol etc. Among the different constituents, caryophyllene, esp. β-caryophyllene was found to be possible repellent for red ant (Kafle and Shih, 2013).

Banmaara had 39.89% more number and 76.59% more weight of intact tubers than in control. The average number of slightly infested tuber in agave treated plots were found 42.62% less than in control plots per plant while average weight of slightly infested tubers was found to be 45.17% lesser than in control plots. Number of severely infested tubers were found 76.3% lesser and weight was also found to be 75.89% lesser than in control plots per plant. Total phenolic contents (10.541–39.35 GAE, mg 100 g^{-1}) and total flavonoid contents (43.35–304.8 CE, mg 100 g^{-1}) were found in appreciable amount in *Agave.* Mono-2-ethylhexyl phthalate (11.37%), 1,2-benzene dicarboxylic acid (6.33%), *n*-docosane (6.30%), and eicosane (6.02%) were found to be major constituent in *Agave americana* which might be responsible for its repelling property (Rizwan et al., 2012).

Cow urine treated plots showed 21.31% lesser number of slightly infested tubers and 22.39% lesser weight of slightly infested tubers than that of control plots per plant. The number and weight of severely infested tubers was found reduced by 47.36% and 46.52% respectively than in control plots. Cow urine was used as an insecticide based on the experience of local farmers and some researches which has been evident to lower the red ant infestations by some percentage (Mohanty et al., 2014).

Chlorpyriphos treated plots had 63.93% less slightly infested tuber than that of control plots and the weight of slightly infested tuber was found 68.82% less than that of control plots. The response of chlorpyriphos had been significant in case of severe infestation. Chlorpyriphos treated plots had about 92.10% lesser number of severely infested tubers than in control plots and the weight was found to be 91.19% less severe than in control plots. Since the applied chemical was composed of 50% Chlorpyriphos and 5% Cypermethrin, their mode of action inhibits the breakdown of a neurotransmitter called acetylcholine (ACh) when insects, especially red ants are exposed to it. Marketable yield of Agave was 34.51% higher than control while it was 33.57% higher in Banmaara. Chlorpyriphos treated plots had production 26.46% more than control plots while cow urine treated plots had marketable yield 24.26% more than control however it was the lowest among the treatments.

4. Conclusion

The use of chemical pesticide was found better than botanical pesticides for the control of red ant in potato field. The results of this study indicate that biopesticides can be successfully included in the integrated pest management programs designed for controlling the red ant in potato field. Among the botanical pesticides, the use of Agave was found the most effective since its application reduced the number and weight of infested tubers of potato. Thus, Agave was found effective in managing this pest, can be suggested as eco-friendly management technique in integrated management of the pest.

References

Bhatta, M., R.B. Thapa, M.R. Pokharel and M.D. Sharma. (2018). Biorational Management of Red Ant (*Dorylus Orientalis* Westwood) of Potato in Taplejung, Nepal. *Journal of The Plant Protection Society*, 5: 194–202. DOI: https://doi.org/10.3126/jpps.v5i0.47131

Bhattacharyya, B., U. Bhuyan and D. Pujari. (2014). Management of Red Ant, *Dorylus Orientalis* Westwood (Hymenoptera: Formicidae) in Potato. *Journal of Entomological Research*, 38(4): 265–267.

Devkota, H.P., N. Jamarkattel, K. Masuda, S. Yahara and P. Basnet. (2004). Chemical Constituents of Banmara. In the Proceeding of National Conference on Science and Technnology, Kathmandu, Nepal, pp: 169-170.

Dash, C.K., K. Hassan, M.E.A. Pramanik, M.H. Rashid and A.R. Choudhury. (2013). Development of Management Strategies Against Red Ant (*Dorylus orientalis*, Westwood) of Potato. *Universal Journal of Plant Science*, 1(3): 74-77. DOI: http://dx.doi.org/10.13189/ujps.2013.010303

Joshi, S.L. (1998). Ecology and management of the red ant, *Dorylus orientalis* Westwood in Nepal. Doctoral Thesis. Imperical College of Science, Technology and Medicine, University of London; pp.193-201.

Kafle, L. and C.J. Shih. (2013). Toxicity and Repellency of Compounds From Clove (*Syzygium aromaticum*) to Red Imported Fire Ants *Solenopsis invicta* (Hymenoptera: Formicidae). *J Econnomic Entomology*, 106(1): 131-5. DOI: 10.1603/ec12230. doi: https://doi.org/10.1603/ec12230

Lallianrawna, S., R. Muthukumaran, V. Ralte, G. Gurusubramanian and N.S. Kumar. (2013). Determination of total phenolic content, total flavonoid content and total antioxidant capacity of Ageratina adenophora (Spreng.) King and H. Rob. *Science vision*, 13(4):149-56.

Lengai, G.M., J.W. Muthomi and E.R. Mbega. (2020). Phytochemical Activity and Role of Botanical Pesticides in Pest Management for Sustainable Agricultural Crop Production. *Scientific African*, 7: e00239. DOI: https://doi.org/10.1016/j.sciaf.2019.e00239

MoALD. (2019). Statistical Information on Nepalese Agriculture. Ministry of Agriculture and Livestock Development (MoALD), Singh Durbar, Kathmandu, Nepal.

Mohanty, I., M.R. Senapati, D. Jena and S. Palai. (2014). Diversified Uses of Cow Urine. *International Journal of Pharmacy and Pharmaceutical Sciences*, 6(3): 20-22.

Neeraj, G.S., A. Kumar, S. Ram and V. Kumar. (2017). Evaluation of Nematicidal Activity of Ethanolic Extracts of Medicinal Plants to Meloidogyne Incognita (Kofoid and White) Chitwood Under Lab Conditions. *International Journal of Pure and Applied Bioscience*, 5(1): 827-831. DOI: http://dx.doi.org/10.18782/23207051.2525

NPRP. (2015). Annual Report, National Potato Research Programme (NPRP), Khumaltar, Lalitpur, Nepal.

Rizwan, K., M. Zubair, N. Rasool, M. Riaz, M. Zia-Ul-Haq and V. DeFeo. (2012). Phytochemical and Biological Studies of Agave Attenuata. *International J. of Mol. Sci.*, 13(5): 6440-6451. DOI: https://doi.org/10.3390/ijms13056440

Sharma, P.N., R.C. Adhikari, B.B. Khatri and K.P. Upadhyay. (2019). Evaluation for Released and Promising Genotypes of Potato against Red Ant. *Journal of Nepal Agricultural Research Council*, 5: 81-87. DOI: https://doi.org/10.3126/jnarc.v5i1.23812

Upadhyay, K.P. and A.P. Timilsina. (2020). Bung: A Traditional Practice of Potato Cultivation in Eastern Hills of Nepal. *Journal of Agriculture and Natural Resources*, 3(1): 38-50. DOI: https://doi.org/10.3126/janr.v3i1.27004

Upadhyay, K.P., N.B. Dhami, P.N. Sharma, J.D. Neupane and J. Shrestha. (2020). Growth and Yield Responses of Potato (*Solanum tuberosum* L.) to Biochar. *Agraarteadus*, 31(2):244-253. DOI: https://doi.org/10.15159/jas.20.18