BIOVALENTIA: Biological Research Journal
Vol. 10 No. 2 (2024)
DOI: https:// 10.24233/biov.10.2.2024.441
ISSN Online: 2477-1392
Pages: 98-106

Weed Community Changes Due To Herbicide Treatment In Mature Oil Palm Plantations

Azharudin Apriansa[1,3*], Yakup[2], Susilawati[2], Dwi Asmono[3], Ruli Wandri[3]

[1]*Crop Sciences Graduate Program, Faculty of Agriculture, Universitas Sriwijaya, Jl. Padang Selasa 524, Palembang 30139, Indonesia & PT. Sampoerna Agro, Tbk, Jl. Basuki Rahmat 788, Palembang 20127, Indonesia*
[2]*Department of Crop Science, Faculty of Agriculture, Universitas Sriwijaya, Jl. Padang Selasa No. 524, Palembang 30139, Indonesia*
[3]*PT. Sampoerna Agro, Tbk, Jl. Basuki Rahmat 788, Palembang 20127, Indonesia.*

*Corresponding author
E-mail address: Azharudin.apraiansa@gmail.com (Azharudin Apriansa).
Peer review under responsibility of Biology Department Sriwijaya University

Abstract: *Stenochlaena palustris*, commonly known as pakisan weed, poses significant challenges in oil palm plantations due to its highly invasive nature, which can lead to reduced agricultural productivity. Management of this weed is critical, as effective control measures can inhibit its dominance and promote the proliferation of alternative weed species, thereby enhancing biodiversity within the ecosystem. This study aimed to 1) assess the effectiveness of the herbicide ammonium glufosinate, in combination with an adjuvant, for controlling S. *palustris* in oil palm plantations, and 2) investigate the subsequent alterations in the weed community structure following herbicide application. We employed a randomised group design (RAK), incorporating the herbicide with added adjuvants. Results showed a clear change from S. *palustris* to *Asystasia* sp. as the dominant species. Treatments K and H had the most *Asystasia* sp., while treatment L had the least. Furthermore, we clearly compared treatments L, K, and S to the control treatment, emphasizing the emergence of diverse species within the treatment plots. However, low levels of diversity and evenness suggest a stressed weed community, indicating that the herbicide application can disrupt existing ecological balances. This study emphasizes the importance of assessing herbicide impacts not only on targeted weed species but also on broader community dynamics, revealing a significant research gap in understanding the long-term ecological consequences of herbicide use in oil palm plantations.
Keywords: Ammonium glufosinat; adjuvant; succession; distribution; richness

Received: 21 Agusts 2024, Accepted: 18 October 2024, publish: 4 November 2024

1. INTRODUCTION

Weed invasion in oil palm plantations is a significant challenge that can hinder oil palm plants' growth and productivity [1]. Identified weeds like *Stenochlaena palustris*, *Imperata cylindrica* [2] FEE, C. and *Asystasia* sp.as [3] significant weeds for oil palm. Weeds compete with oil palms for important resources such as water, nutrients, spaces, and sunlight [4].

This competition can lead to reduced growth and productivity of oil palms, which in turn affects the overall yield of palm oil [5]. The application of herbicides is a common method to maximize crop yield and prevent weed dominance by suppressing the growth of weed populations [6]. Unwanted (weeds) compete for the same resources, such as space, water [7], light [8], and nutrients [9].

One of the weeds that is difficult to control is *Stenochlaena palustris*, which is classified as thick and rigid (*coriaceous*) with a waxy leaf surface that can reduce the ability of herbicides to enter the plant [10]. The efficacy of a herbicide is assessed by its optimal or anticipated inhibitory impact on the development of target weeds. Effectiveness is one of the important factors to determine the right herbicide for weed management. Key factors in assessing the efficacy of weed management include the weed mortality rate and growth inhibition, exemplified by biomass reduction and regrowth potential [11]. It is essential to identify the weed species, which can help to select an effective herbicide for weed control.

Ammonium glufosinate is a post-emergence herbicide that can control broad-spectrum weeds, including difficult-to-control weeds such as *S. palustris.* The utilization of surfactants is a factor that influences the efficacy of herbicides. Studies indicate that surfactants enhance the infiltration of herbicides into foliar tissue, hence augmenting the absorption and efficacy of herbicides in weed management [12]. Ammonium glufosinate undergoes limited translocation after uptake, primarily remaining in the treated leaves. This study to determine the effectiveness of ammonium glufosinate with additional adjuvants in controlling *S. palustris* weeds in oil palm plantations, and to understand the changes in weed community structure following herbicide application.

2. MATERIALS AND METHODS

Description of research location

This experiment was conducted in the oil palm plantation of PT Sampoerna Agro, Ogan Komering Ilir (OKI) District (3º36′18.3″S- 3º36′25.7″S- 105º01′27.1″E-105º01′59.1″E) South Sumatra. OKI Regency is an area that has a Wet Tropical climate (Type B) with a dry season ranging from May to October, while the rainy season ranges from November to April. Daily air temperatures range from a low of 21°C at night to a high of 36°C during the day. Daily air humidity ranges from 69% to 98%. Located between 9 - 16 meters above sea level, it has a flat - undulating landform, with a land slope of 0 - 8%. Seasonal deviations usually occur once every five years, in the form of a dry season that is longer than the rainy season, with an average rainfall of less than 1,900 mm per year with an average rainy day of 60 days per year [12]. The soil at the research site is typic *kandiudults*, soil pH is < 4.5 - 5.5, and soil organic carbon content is < 1 - > 5 %. The research location was sought in an area dominated by S. *palustris* weed with more than 90% cover.

Research design

The research was conducted for four months, from June to September 2023. The design used was group randomised design (RAK). Weed control with ammonium glufosinate herbicide at a dose of 500grams of active ingredient per hectare. Treatment with the addition of different adjuvants consisting of four active ingredients namely *Polyether Modified Trisiloxane, Polyoxyalkylene alkyl ethers, Alkylphenol Ethoxylates Succinicester Sulfonic Acid Sodium, Alcohol Polyglycol Ether* and herbicide control without adjuvant. Each adjuvant was dosed at a concentration of 0.2%. Treatments were applied with a back sprayer with a volume of 200 litres/ha and using a deflector nozzle equipped with a 1.5 bar pressure regulator.

Measurement and sampling

Weed observations were made by recording the number of weed species and individuals and documenting the weeds recorded for identification purposes.

Vegetation analysis

Vegetation analysis was carried out by observing weeds using a 0.5 x 0.5 m quadrat [14] weeds were counted based on the number of species present in the quadrat plot. Furthermore, data analysis was carried out to determine the dominance (SDR) of weeds and Phytosociological Parameters [15]. Vegetation analysis values were obtained from observation data of initial vegetation analysis and 60 days after application (DAA). Plant species were identified at species level where possible and some species, including *S. palustris*, were identified at genus level [16].

The variables estimated are density (De), frequency (F), dominance (Do), important value index (IVI), similarity index (SI) [14][17], and summed dominance ratio (SDR) with the following formula:

Density (De)

$$De = \frac{Number\ of\ individual\ species}{Number\ of\ plots}$$

$$rDe = \frac{De\ of\ a\ species}{De\ all\ species} 100\%$$

Frequency (Fe)

$$Fe = \frac{Number\ of\ plots\ of\ a\ type\ species}{Number\ of\ plots}$$

$$rFe = \frac{Fe\ of\ a\ species}{Fe\ all\ species} x\ 100\%$$

Important value index of a species (IVI)

IVI= rDe+rFe+rDo

Summed Dominance Ratio (SDR)

SDR= IVI /3

Similarity index (SI)

Similarity index (SI) is widely used in weed science as it allows comparisons between species composition in different plots, treatments, or areas [14].

$$SI = \left(\frac{2a}{b+c}\right) x100\%$$

Where: a = the same number of species in two areas; b and c = the total number of species in two compared areas. The value of b is represented by area or plot 1, and c is represented by area or plot 2.

Species Diversity Index

Assessment of weed diversity, species richness (S), Shannon's Exponential index [17], and Pielou's evenness index were calculated for each plot. Species richness (S) is the total number of weed species. The Exponential Shannon Index (H') was estimated as follows:

$$H' = \exp\left[-\sum_{i=1} pi\ Ln(pi)\right]$$

Where H' is the exponential Shannon Index, pi is the relative abundance of species i in the community, and Ln is the natural logarithm.

The Pielou Evenness Index (E) (Pielou EC) is calculated as follows [18] (Pielou EC):

$$E = \left[\frac{H'}{lnS}\right]$$

Where E is Pielou's Evenness Index, H' is the Shannon-Wiener diversity index (which measures species diversity) and lnS is the maximum possible value of H' (if every species is equally present).

Weed dominance index

Weed dominance index values were obtained from initial weed vegetation analysis data and 60 days after application. Weed dominance index values were analyzed using Simpson's Index [19]:

$$D = \frac{\sum n\ (n-1)}{N\ (N-1)}$$

Where D is Simpson's Diversity Index, n is the number of organisms belonging to species i, and N is the total number of organisms.

Analisis data

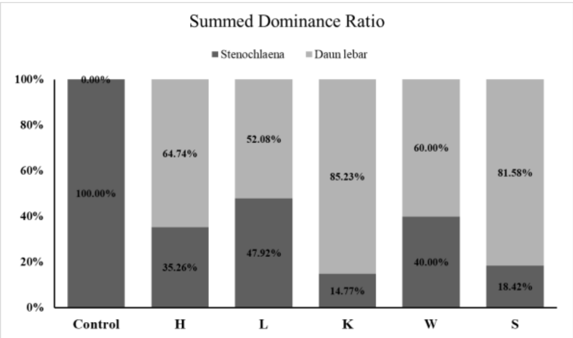
ANOVA analysis of variance and post hoc test for Randomized Complete Block Design (RCBD) was conducted to find significant differences among each herbicide and control for both experiments. Differences among treatment means were grouped based on Duncan's test with a probability level of 0.05. Analyses were conducted using R Studio (statistical analysis system) software, version 2022.07.1 Build 554.

3. RESULTS AND DISCUSSION

Initial vegetation analysis and weed species population shifts

The experimental plots were inhabited by two weed species, namely *S. palustris* weed and *Asystasia* sp., indicating a low weed mixture in this study. The dominance ratio (SDR) value of *Asystasia* sp. was highest and recorded as the most dominant species in all treatments after application. In the control, *S. palustris* weed was dominant and did not change its pre-treatment condition.

Figure 1. *Effect of herbicide application on weed composition and dominance*



Based on the percentage of and *S. palustris* and *Asystasia* sp. treatment K with a percentage of *S. palustris* 14.77%, *Asystasia* sp 85.23% and treatment S with a percentage of *S. palustris* 18.42%, *Asystasia* sp 81.58% is the best treatment because it has a combination of a low percentage of *S. palustris* and high *Asystasia* sp.

Prior to treatment application in the experimental area, the dominant weed species was *S. palustris*. At 16 MST, changes in weed composition occurred. This is due to the contact and systemic characteristics of the ammonium glufosinate herbicide. Weed sections that are immediately impacted will exhibit indications of chlorosis, subsequently leading to death. The abundance of weed seeds in the soil is also one of the important factors and determinants of a weed species' existence, survival, and dominance in an ecosystem. The abundance of weed seeds is influenced by various factors such as land management [20] [21] and herbicide application in crop cultivation practices [22] [23] [24] [25]. The abundance of weed seeds will continue to grow over time and the seeds can germinate if environmental factors such as water and oxygen are sufficiently available. All treatments showed the same pattern of dominance shift from *S. palustris* to *Asystasia* sp

All herbicide treatments can suppress S. *palustris* weed growth with low abundance values of 8–33% (table 1). While the abundance of *Asystasia* sp. weed was highest in treatment K by 92% and H by 79%, the lowest abundance was in treatment L by 33% in addition to the control. Thus, changes in community composition occur due to changes in species density in each population. Species whose populations develop following a progressive pattern, *Asystasia* sp., are species that seem to be suitable for the environmental conditions of the research site and are able to adapt to less favourable environmental conditions. Invasiveness has been considered the prominent trait of Asystasia, whereas it is only a negative aspect of this plant due to its high adaptability and resilience to almost any environmental conditions (Tanjung, L et al., 2023)

Table 1 *Relative abundance of dominant weeds in the experimental area*

Treatment	*S. palustris*	*Asystasia* sp.
Control	1.00 ± 0.00 a	0.00 ± 0.00 b
H	0.21 ± 0.01 b	0.79 ± 0.01 a
L	0.33 ± 0.33 ab	0.33 ± 0.33 ab
K	0.08 ± 0.08 b	0.92 ± 0.08 a
W	0.24 ± 0.17 b	0.42 ± 0.24 ab
S	0.33 ± 0.33 ab	0.67 ± 0.33 ab

Similarity index (SI)

The similarity index between the different herbicide treatment plots (Table 2), which indicates the similarity of species in the weed community. Sorenson similarity index values of 0.00% to 100.00% indicated that there was similar variability among weed species across all herbicide treatments.

Table 2 *Similarity index of weed species according to Sorenson among different herbicide treatments*

Treatments	Control	H	L	K	W	S
Control	-	66.7%	0.0%	0.0%	66.7%	0.0%
H	66.7%	-	66.7%	66.7%	50.0%	66.7%
L	0.0%	66.7%	-	100.0%	66.7%	100.0%
K	0.0%	66.7%	100.0%	-	66.7%	100.0%
W	66.7%	50.0%	66.7%	66.7%	-	66.7%
S	0.0%	66.7%	100.0%	100.0%	66.7%	-

The similarity index between the control, L, K, and S treatments recorded the lowest value of 0%, indicating that the weed species invasion of the plots changed. The 66.67% similarity between the control treatment and H and W showed close weed species similarity.

The similarity index is commonly used in weed science to facilitate comparisons of species composition across different treatment plots [12]. The similarity index is a numerical scale that ranges from 0 to 100%. A higher number on the scale indicates a better degree of uniformity in species distribution within a given area or plot. When all species are present in equal abundance within a sample plot, the IS value will be 100% [26]. However, the calculation of the similarity index (SI) only considers the presence or absence of species, ignoring their density and dominance. This may result in SI values that do not accurately reflect compositional similarity among the areas studied [12] Kuva MA.

Diversity Index

The value of the species diversity index is a measure that shows the variety of plant species in a community. The results of vegetation analysis show that the diversity index value (H') of weeds is low <1 (table 3). From the value of the Shannon-Wiener diversity index (H), the Pielou evenness index (J) can be calculated.

Table 3. *Effect of herbicides on weed diversity and evenness indices*

Treatments	Weed Diversity	Weed Density
	Index (H')	Index (J)
Control	0.5196	0.750
H	0.5074	0.732
L	0.1391	0.201
K	0.2954	0.426
W	0.6269	0.904
S	0.2036	0.294

According to the table's results, there was significant variation in the weed diversity index (H') and weed density index (J) among the various treatments. In the control treatment, the diversity index (H' = 0.5196) and weed density (J = 0.750) indicated that the weed community was at a moderate level, without any herbicide intervention. The diversity index (H' = 0.5074) and density (J = 0.732) went down a little in treatment H. This means that this treatment didn't have a big effect on the structure of the weed community; species diversity stayed pretty much the same.

Treatment L, on the other hand, greatly reduced the number and variety of weeds (H' = 0.1391) and their density (J = 0.201), showing that it was very good at controlling weed species. This created a simpler community dominated by species that were stronger against the treatment. Similar results were seen with the S treatment, which saw big drops in diversity (H' = 0.2036) and density (J = 0.294), showing that it worked to make the weed community simpler.

Interestingly, treatment W showed the highest diversity index (H' = 0.6269) and higher weed density (J = 0.904) than the other treatments, indicating that this treatment may have created more favourable conditions for the growth of diverse weed species. Treatment K showed a moderate decrease in diversity (H' = 0.2954) and density (J = 0.426), indicating the dominance of species more tolerant to the treatment.

Overall, these data show that the different treatments produced varying effects on weed community structure. Treatments L and S proved to be the most effective in suppressing weed diversity and density, whereas treatment W appeared to increase weed community diversity, indicating a potential change in species composition due to the herbicide intervention used.

However, it is important to note that despite the differences in diversity levels, all treatments showed relatively low diversity values. This may indicate that other factors, such as environmental conditions or other farming practices, also play a role in determining weed diversity. As shown in this study, the type and frequency of herbicide use can greatly affect weed diversity. Effective herbicides can reduce the number of weed species, while less effective applications can allow more species to persist.

Weed dominance index

An ecosystem uses the dominance index (D) to measure species diversity and the balance of the number of individuals in each species.

Table 4. *Effect of herbicides on weed dominance index*

Treatments	Weed Dominance Index (D)
Control	0.663
H	0.674
L	0.939
K	0.841
W	0.565
S	0.902

Based on the displayed data, the weed dominance index (D) showed significant variation among the various treatments. The dominance index (D) describes the degree of dominance of a particular species in a community; higher values indicate dominance by one or more specific species. In the control treatment, the dominance index of 0.663 reflected a relatively balanced weed community, with moderate dominance by certain species but still species diversity within the community.

Treatment H showed a slight increase in dominance with an index of 0.674, which was close to the control value. This suggests that this treatment did not significantly alter the dominance structure in the weed community, thus still maintaining a similar diversity to the control. In contrast, treatment L showed a significant increase in dominance index (0.939), indicating strong dominance by one or a few species that may be more resistant to the treatment. Treatment S exhibited a similar condition, displaying a high dominance value of 0.902, suggesting a decrease in species diversity and an increase in dominance among the surviving species.

Treatment K showed a lower dominance value compared to L and S, but remained quite high with an index of 0.841. This suggests that a few specific species still dominated the weed community in this treatment, despite a slight increase in diversity compared to treatments L and S. In contrast, treatment W produced the lowest dominance index of 0.565, indicating that this treatment promoted a more diverse weed community, with a more even distribution of species and without strong dominance by any particular species.

Overall, these data indicate that the L and S treatments significantly reduced weed community diversity by increasing the dominance of certain species, while the W treatment tended to promote a more balanced and diverse community with lower dominance.

4. CONCLUSION

The shift in weed abundance in this study occurred due to differences in species responses to ammonium glufosinate herbicide application. Results showed that after treatment, S. *palustris* species experienced a significant decrease in abundance, while *Asystasia* sp. showed an increase in dominance. This suggests that *Asystasia* sp. effectively adjusts to the modified environment resulting from herbicide treatment. The effectiveness of herbicides in controlling weeds was evident from the analysis of diversity and dominance indices. Herbicide treatments showed a decrease in diversity index (H') below 1, with treatments L and S recording the lowest values, indicating a reduction in the number of weed species. Treatment W, on the other hand, showed the highest diversity index, reflecting conditions that are more favorable to the growth of diverse weed species. As a result, herbicide application directly affects weed community structure and species diversity. For the future, it is necessary to implement a more sustainable weed management strategy using an integrative approach. This includes rotating the use of different herbicides to prevent resistance development, as well as the introduction of mechanical and biological weed control techniques. While some treatments were successful in suppressing the abundance of certain weeds, analyses revealed the need for wise management to maintain ecosystem balance and prevent the dominance of undesirable species. Further research in this area is also important to develop more environmentally friendly and effective methods.

5. CONFLICT OF INTEREST

The authors declare that they are not aware of any competing financial interests or personal relationships that are likely to influence the work reported in this paper.

6. ACKNOWLEDGEMENTS

All authors would like to thank PT Bina Sawit Makmur and PT Sampoerna Agro Tbk for funding this research in Fiscal Year 2023.

REFERENCES

[1] Nduru, E. N. I., Lizmah, S. F., Subandar, I., Chairuddin, C., & Arisyi, M. A. (2023). Analisis vegetasi gulma pada perkebunan kelapa sawit (*Elaeis guineensis* jacq) di area afdeling i, Kebun Jaya Seujahtera, PT. ASN. Biofarm : *Jurnal Ilmiah Pertanian*, 19(1), 7. https://doi.org/10.31941/biofarm.v19i1.2529.

[2] FEE, C. (2022). The Climbing Swamp Fern, Stenochlaena palustris (Burm. F.) Bedd. (Blechnaceae) - A Noxious Weed in Oil Palm Estates and Its Management. *The Planter*. https://doi.org/10.56333/tp.2022.014.

[3] H. Satriawan and Z. Fuady, "Short communication: analysis of weed vegetation in immature and mature oil palm plantations", *Biodiversitas Journal of Biological Diversity*, vol. 20, no. 11, 2019. https://doi.org/10.13057/biodiv/d201123

[4] Sinlae, A. A. J., Alamsyah, D., Suhery, L., & Fatmayati, F. (2022). Classification of broadleaf weeds using a combination of k-nearest neighbor (knn) and principal component analysis (pca). *Sinkron*, 7(1), 93-100. https://doi.org/10.33395/sinkron.v7i1.11237.

[5] Swanzy, F. K. M., Sosu, E., & Danso, W. O. (2020). Perception of environmental effects of weedicide use in oil palm production by farmers in denkyembour district, ghana. *Asian Journal of Agricultural Extension, Economics & Amp; Sociology*, 1-7. https://doi.org/10.9734/ajaees/2019/v37i430291.

[6] Muin, A., Wirianata, H., & Nugraha, T. (2022). Glyphosate application and potential eleusine indica resistance in oil palm plantations. AJARCDE (*Asian Journal of Applied Research for Community Development and Empowerment*), 7 (1), 6-9. https://doi.org/10.29165/ajarcde.v7i1.188.

[7] Korav, S., Ram, V., Ray, L. I. P., Krishnappa, R., Singh, N. J., & Premaradhya, N. (2018). Weed Pressure on Growth and Yield of Groundnut (Arachis hypogaea L.) in Meghalaya, India. *International Journal of Current Microbiology and Applied Sciences*, 7(03), 2852–2858. https://doi.org/10.20546/ijcmas.2018.703.328.

[8] Guglielmini, A. C., Verdú, A. M. C., &

Satorre, E. H. (2017). Competitive ability of five common weed species in competition with soybean. *International Journal of Pest Management*, 63 (1), 30–36. https://doi.org/10.1080/09670874.2016.1213459.
[9] Thompson, C. R., Dille, J. A., & Peterson, D. E. (2019). Weed competition and management in sorghum. *Sorghum: State of the Art and Future Perspectives*, (17), 347–360. https://doi.org/10.2134/agronmonogr58.2014.0071.
[10] Pellissier, L., Wisz, M. S., Strandberg, B., & Damgaard, C. (2014). Herbicide and fertilizers promote analogous phylogenetic responses but opposite functional responses in plant communities. *Environmental Research Letters*, 9 (2). https://doi.org/10.1088/1748-9326/9/2/024016.
[11] Hasan, M., Ahmad-Hamdani, M. S., Rosli, A. M., & Hamdan, H. (2021). Bioherbicides: An eco-friendly tool for sustainable weed management. *Plants*, 10(6), 1–21. https://doi.org/10.3390/plants10061212.
[12] Kurniadie, D., Sumekar, Y., & Buana, I. (2017). Pengaruh berbagai jenis surfaktan pada herbisida glufosinat terhadap pengendalian gulma dan hasil tanaman jagung (zea mays l.) di jatinangor. *Kultivasi*, 16(2). https://doi.org/10.24198/kultivasi.v16i2.12211
[13] Badan Meteorologi, Klimatologi, dan Geofisika (BMKG), "Data Iklim Stasiun Klimatologi Kelas I Palembang Tahun 2016," BMKG, Palembang, Indonesia, 2016.
[14] Kuva MA, Salgado TP, Alves PLC (2021) Índices fitossociológicos aplicados na ciência e na gestãodas estratégias de controle de plantas daninhas. In: Martins AA, Murata AT (eds) Matologia: Estudo sobre plantas daninhas. *Jaboticabal*, Sao Paulo, pp 60–105.
[15] Souza de, W.M., Paiva, M.C.G., Zaidan, Ú.R., Mendes, K.F., de Freitas, F.C.L. (2022). Parameters of the Phytosociological Survey to Evaluate the Abundance, Distribution, and Diversity of the Weed Community. In: Mendes, K.F., Alberto da Silva, A. (eds) Applied Weed and Herbicide Science. *Springer*, Cham. https://doi.org/10.1007/978-3-031-01938-8_3.
[16] G.F. Chung, C.T. Lee, S.B. Chiu and K.H. Chee. Pictorial Guide to Common Weeds of Plantations and Their Control. Agricultural Crop Trust (ACT). 2017.
[17] Nkoa R, Owen MDK, Swanton CJ (2015) Weed abundance, distribution, diversity, and community analyses. *Weed Sci* 63:64–90. https://doi.org/10.1614/WS-D-13-00075.1.
[18] Pielou EC. An introduction to mathematical ecology. *An introduction to mathematical ecology*. 1969
[19] Khadka, CB, AL Hammet, A Singh, YP Timilsina, and MK Balla. 2016. Ecological parameters and diversity indices of marsh orchid (Dactylorhiza hatagirea D. Don) and its associates in Lete Village of Mustang District, Nepal. e *Journal of Applied Forest Ecology*. 4:29-39.
[20] Cabrera-Pérez, C., Royo-Esnal, A., & Recasens, J. (2022). Herbicidal effect of different alternative compounds to control Conyza bonariensis in vineyards. *Agronomy*, 12(4), 960. https://doi.org/10.3390/agronomy12040960.
[21] Pinke, G., Giczi, Z., Vona, V., Dunai, É., Vámos, O., Kulmány, I., Koltai, G., Varga, Z., Kalocsai, R., Botta-Dukát, Z., Czúcz, B., & Bede-Fazekas, Á. (2022). Weed composition in Hungarian Phacelia (Phacelia tanacetifolia Benth.) seed production: Could tine harrow take over chemical management? *Agronomy*, 12(4), 891. https://doi.org/10.3390/agronomy12040891.
[22] Comeau, P. G., & Fraser, E. C. (2018). Plant community diversity and tree growth following single and repeated glyphosate herbicide applications to a white spruce plantation. *Forests*, 9(3), 107. https://doi.org/doi:10.3390/f9030107
[23] Deligios, P. A., Carboni, G., Farci, R., Solinas, S., & Ledda, L. (2019). The

Influence of herbicide underdosage on the composition and diversity of weeds in oilseed rape (Brassica napus L. var. oleifera D.C.) Mediterranean Fields. *Sustainability*, 11(6), 1653. https://doi.org/10.3390/su11061653
[24] Gazola, T., Costa, R. N., Carbonari, C. A., & Velini, E. D. (2022). Dynamics of 2,4- D and dicamba applied to corn straw and their residual action in weeds. *Plants*, 11(20), 2800. https://doi.org/10.3390/plants11202800
[25] Idziak, R., & Woznica, Z. (2020). Efficacy of Reduced rates of soil-applied dimethenamid-p and pendimethalin mixture followed by postemergence herbicides in maize. *Agriculture*, 10(5), 163. https://doi.org/10.3390/agriculture10050163
[26] Winarso, G., Kamal, M., Rosid, M. S., Asriningrum, W., & Supriatna, J. (2020). Kajian pustaka asesmen status kondisi ekosistem mangrove. *Sriwijaya Bioscientia*, 1(2), 48-56. https://doi.org/10.24233/sribios.1.2.2020.200.