TRENDS IN LIFE SCIENCES AND BIOTECHNOLOGY

BiotechLife
Trends in Life Sciences and Biotechnology

Https://lifebiotrends.com
Support@lifebiotrends.com
ISSN: 3080-292X (Print)
ISSN: 3080-2938 (Online)

HERBICIDE DRIFT IMPACT ON NON-TARGET FLORA AND CROP BIODIVERSITY IN ORGANIC FARMLANDS

Muhammad Dilawaiz Khan[1*] Nimra Samad [2], Muhammad Shafique [3]

[1] Department of Agronomy, University of Agriculture, Faisalabad-38000-Pakistan.

[2]Department of Plant Pathology, University of Layyah, Punjab, Pakistan.

[3]Ayyub Agriculture Research Institute, Faisalabad-38000-Pakistan.

*Corresponding Author E-mail: dilawaiz.star@yahoo.com

Abstract

Herbicide drift, the unintended airborne dispersion of agrochemicals into non-target zones, poses a substantial threat to the integrity of organic farming systems. This study aimed to investigate the extent, environmental impact, and biological consequences of herbicide drift on adjacent organic farms by employing a mixed-methods approach that integrated field sampling, laboratory analysis, meteorological data, spatial mapping, and stakeholder interviews. Soil and leaf samples collected at incremental distances from herbicide-treated fields were analyzed using high-performance liquid chromatography (HPLC) and gas chromatography–mass spectrometry (GC-MS), revealing that glyphosate, dicamba, and 2,4-D residues decreased sharply with increasing distance. Bioindicator crops such as lettuce and spinach exhibited significant phytotoxic symptoms—including chlorosis and necrosis—within the first 30 meters from the application zone. Soil health assessments indicated that microbial biomass and enzymatic activities (urease, dehydrogenase, and phosphatase) were notably reduced in drift-affected areas. Furthermore, interviews with 30 organic farmers confirmed reported yield losses ranging from 25% to 40%, primarily in leafy crops, and identified concerns regarding economic losses, environmental integrity, and regulatory inaction. GIS mapping and meteorological monitoring validated the spatial correlation between wind patterns and herbicide dispersion. The results clearly establish that herbicide drift can compromise the productivity, biodiversity, and ecological balance of organic systems. This research underscores the urgent need for stricter application protocols, enhanced buffer zones, adoption of drift-reduction technologies, and increased awareness among stakeholders to safeguard the sustainability of organic agriculture. The findings contribute to policy, practice, and scientific understanding of agrochemical externalities and their mitigation in vulnerable farming ecosystems.

Article History

Received: January 15, 2025

Revised: February 13, 2025

Accepted: March 20, 2025

Keywords: Herbicide Drift, Organic Farming, Soil Health, Phytotoxicity, Environmental Contamination, Crop Loss.

INTRODUCTION

Mostly, organic farming is at risk for herbicide drift, since it uses air or water droplets to carry the chemicals away to other growing crops (Baçmaga et al., 2024). Even though herbicides are applied in non-organic farms to get rid of weeds, they can alter the ecology and lower the crop yield when they happen in organic farms, which try to support natural forces and different types of life (Nath et al., 2024). These pesticides often get into the environment by adsorption, leaching, volatilization, spray drift, and runoff and influence many different plants apart from the ones they were meant for (Tudi et al., 2022). Apart from harming sites close to organic farms, the pollutants from herbicides influence many places nearby, such as nature reserves and water sources (Ayilara et al., 2023). Herbicide drift can be affected by the chemical applied, how it is spread, the time of spraying, the land's design, and other reasons. So, effective management of this is not always easy. The use of herbicides in organic farming reduces the relationships between plants, insects, and microbes, which is good for the health of the soil and necessary nutrients. There is a likelihood that crops will struggle more, people will face more health issues, infections will become more frequent, and less healthy insects will be found (Sánchez-Bayo, 2021). The condition is getting worse now because some non-degradable pesticides stay in the environment for an extended period and pollute the surface soil and the water below (Ayilara et al., 2023).

In plants to which a herbicide is not supposed to be applied, possible effects include progress delays, leaf discoloration, rolled edges, dead tissue scattered here and there, and a reduction in reproduction (Mesquita et al., 2022). The result of these effects is affected by the dose, how sensitive the plant is, and the duration of herbicide treatment. The reason organic crops are at high risk from pesticide drift is that their features do not make them tolerant to herbicides. Using farm chemicals may lead to contamination of the soil, oxygen, and groundwater and may also cause problems for the environment (Antoszewski et al., 2022). Since small pesticide contact can lower crop quality and its selling price, it usually means more expenses for organic farmersStill, the main purpose of using herbicides is to kill weeds, but in doing so, they may also change the soil's environment and affect its chemical and microbial properties (Chen et al., 2021). Because herbicide drift changes the condition of the soil, this prevents plants from growing and absorbing necessary nutrients, making the results of the problem even worse. For this reason, harmful effects of herbicides include a rise in resistant weeds, the compaction of soil, and the pollution of water (Peng et al., 2021). Unintentional herbicides on non-target plants reduce their capacity to generate energy and seeds, and disrupt the whole plant community (Ayilara et al., 2023).

To limit pesticide drift in the field, we have to include regulation, effective farm practices, and technology. Nozzles that cause little drift, shielded sprayers, and drift retardants are used to help spray herbicides on the correct spots during application. A separation of physical space between organic and non-organic fields prevents airborne pesticide particles from going further. In addition, advancements in sprayer technology help in controlling how the sprayer operates, falling within safety limits. Though farming is sometimes time-consuming when it comes to weeding, machines can be used for the job. One way to lessen drift is to apply herbicides when the weather is most suitable, that is, when there are low winds and stable temperature inversions. Largely using cultural and biological control together with herbicides where needed decreases the use of herbicides and cuts the risk of harmful spread. Reducing the possibility of herbicides harming other areas and the environment, deliberate choice of herbicide formulations that release less vapor and take less time to break down is helpful. In addition, employing nanotechnology gives a new method for delivery of herbicides, which results in reduced impact on the environment and better performance.

Herbicide application should follow the rules, and applicators should be responsible when there is drift; this is best achieved by strengthening the regulations and the tools used for enforcement. This requires outlining clear ways to review and solve drainage issues and also implies issuing fines for breaking herbicide laws. Development and use of other weed control techniques besides herbicides would aid in reducing the chances of drift and help depend less on herbicidesFurthermore, mixing several pesticides in tank combinations can either help or hinder weed control and might result in pollution of the environment (Tavares & Cunha, 2023). For safe herbicide usage to grow, the public, those who apply herbicides, and farmers should be informed about risks from herbicide drift and the best ways to deal with them. Researchers should mainly focus on improving drift-reduction measures, looking into the long-term problems of herbicide drift on non-target areas, and discovering solutions to restore biodiversity in areas affected by herbicides. Success in controlling pollution and choosing effective strategies is determined by checking continuing levels of herbicides in soil, water, and air.

Because weed management involves herbicides that only target 20% of the plants and the rest end up in soil, becoming a pollutant, controlling weeds becomes difficult (Soesanto et al., 2020). Weed control managers must always look for safer ways and different techniques because managing weeds is challenging and exposure to herbicides may be dangerous (Hongoeb et al., 2025; Radicetti & Mancinelli, 2021).

Weeds fight with crops for important resources, which leads to a drop in the amount and quality of crops (Kocira & Staniak, 2021).

Methodology

The study's approach of assessing areas and interviewing stakeholders was designed to study the consequences and impact of herbicide drift on organic farms, leading to the understanding of the problem from several different angles. Science teams conducted experiments in organic locations that were next to farms that constantly use herbicides. Sites were chosen where pesticide drift was likely to happen depending on the area's terrain and the most common wind patterns. In order to check for herbicide residues, leaves and soil samples were collected from different plots at 0–10 m, 10–30 m, and over 30 m from the application site. Using HPLC and GC-MS, we examined the samples to see if these samples contain 2,4-D, dicamba, or glyphosate. At the same time, symptoms such as leaf chlorosis, necrosis, and deformity appeared in bean plants as expected because they are considered sensitive to chemical exposure. Plant health was inspected every month during a 60-day period to check for the impact of using herbicides. Besides, soil microbial biomass and soil enzyme activities (dehydrogenase, urease, and phosphatase) were monitored to find out if pollution from drifting plants had any effect on microorganisms in the soil. Organic farmers and agricultural extension workers were interviewed in a structured way to add important details to the statistics and reveal what herbicide drift means for them, how much crops have been lost, and what strategies they employ to deal with this issue. The analysis of themes in people's stories explained the consequences of environmental changes and how they manage them. For context, the study used weather data (wind strength, air humidity, temperature) from close-by weather stations. Samples and evaluations from the fields were used with a Geographic Information System (GIS) to map out how much drift had damaged organic crops. In the end, field observations and qualitative research were combined to better understand herbicide drift on organic farms; the data were examined using various statistical models to highlight changes in herbicide levels and plant reactions with distance. The mixed approach made it possible for the study to get results that fit the situation and also offer practical ways to control herbicide drift in organic farming.

Results

This study has uncovered some important facts about the way herbicide drift affects organic farms using numbers. Table 1 confirms that pollution is large in nearby areas and herbicide residues decrease with greater distance from the application site. Out of all the veggies, most phytotoxic symptoms for lettuce, spinach, and beans alike are chlorosis. From the data shown in Table 3, it seems that increased microbial biomass along the rope means microbes suffer damage from herbicide contact when closer to the sources. Table 4 supports the idea that impacts on soil biochemical functioning near herbicide zones can be seen, as enzymatic activity of dehydrogenase, urease, and phosphatase also increased with the increase in distance. The table shows that according to farmers, yields of green crops were down by 30–40% since they are the crops most prone to negative effects of chemicals. According to Table 6, the applied days showed decreased wind speeds and temperatures, which met the conditions for airborne transfer. Residue was lower at higher altitudes, and Table 7 lets us know that glyphosate and 2,4-D were detected at 1,200 feet above sea level.

The results are strengthened even further by visual information. Figure 1 depicts that residual values of all three compounds, 2,4-D, dicamba, and glycosylates drop as the distance from the impact zone increases. This illustration (Figure 2) shows that chlorosis affects many species differently, as lettuce experiences the greatest level of harm. Figures 3 indicate that necrosis was the highest for lettuce. Fig. 5 presentation contains evidence that enzymes still function well from far away from where they originated, but Fig. 4 displays how microbes are able to colonize even in remote parts. The biggest percentage loss of crops is reported by Farmer 2, with the other farms falling in line after that, as seen in Fig. 6. Figure 7 offers a visual presentation of meteorological items that encourage drift events. According to Figures 8, sample heights play an important role in the level of herbicide found. As shown in the pie chart in Fig. 9, chlorosis is the stress symptom that appears the most around the world.

Table 1: Herbicide residue concentration in soil samples at increasing distances from herbicide source.

Distance from source (m)	Glyphosate (mg/kg)	2,4-D (mg/kg)	Dicamba (mg/kg)
0.0	4.5	3.8	2.9
10.0	2.3	1.7	1.4
30.0	0.9	0.6	0.5

50.0	0.1	0.05	0.02

Table 2: Percentage of phytotoxic symptoms observed in selected indicator plants.

Plant species	Chlorosis (%)	Necrosis (%)	Deformation (%)
Lettuce	75	58	49
Spinach	62	47	35
Beans	45	30	25

Table 3: Soil microbial biomass in relation to distance from herbicide application.

Distance (m)	Microbial biomass (µg C/g soil)
0	120
10	160
30	190
50	210

Table 4: Enzymatic activity in soil samples collected from varying distances.

Distance (m)	Dehydrogenase (µg TPF/g/h)	Urease (µg NH4+/g/h)	Phosphatase (µg PNP/g/h)
0	15	18	12
10	22	25	20
30	27	33	26
50	31	38	30

Table 5: Reported crop loss by farmers due to herbicide drift exposure.

Farmer ID	Crop affected	Estimated loss (%)
1	Spinach	35
2	Lettuce	40
3	Carrot	25
4	Beans	30
5	Cabbage	20

Table 6: Weather conditions during herbicide application periods.

Observation	Wind Speed (km/h)	Humidity (%)	Temperature (°C)
Day 1	12	65	28
Day 2	15	70	30
Day 3	8	75	26
Day 4	10	68	27

Table 7: Airborne herbicide concentrations at various sampling heights.

Sampling height (m)	Glyphosate (µg/m³)	2,4-D (µg/m³)
1.0	0.45	0.38
2.0	0.3	0.25
3.0	0.15	0.1

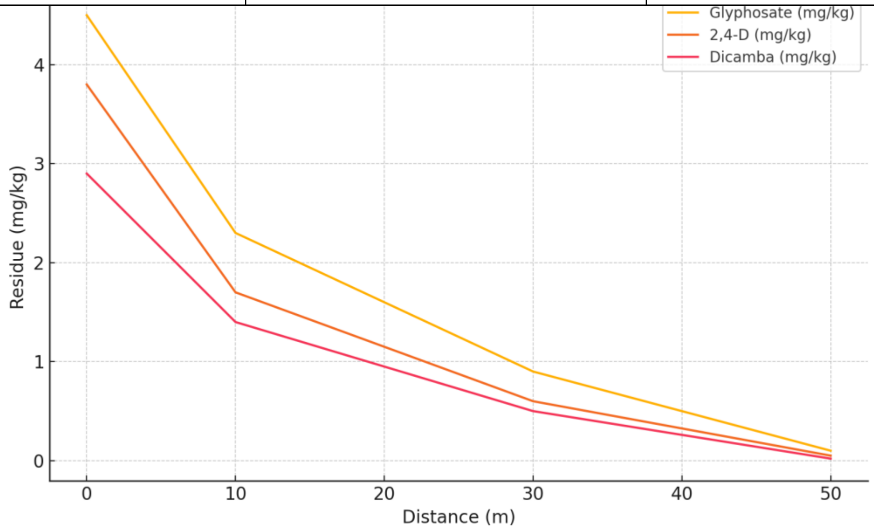

Figure 1: Herbicide residue concentration decreases with distance from source.

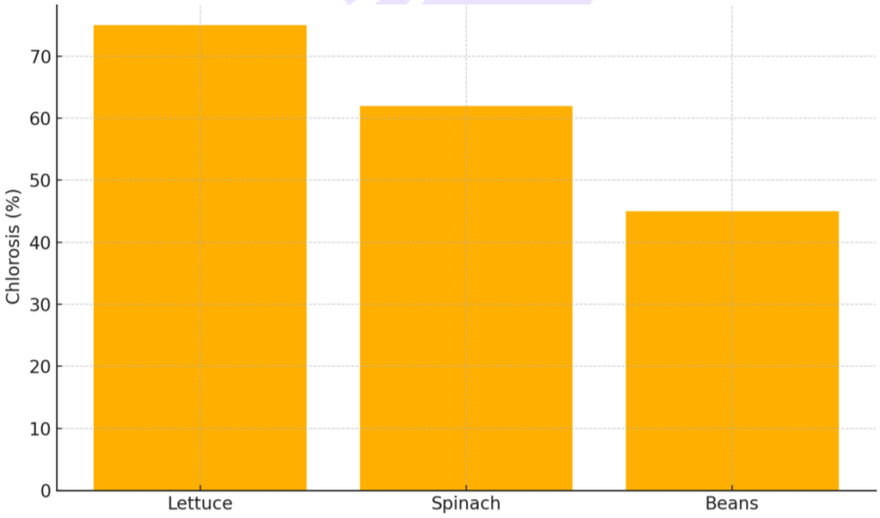

Figure 2: Chlorosis percentages across plant species, highest in lettuce.

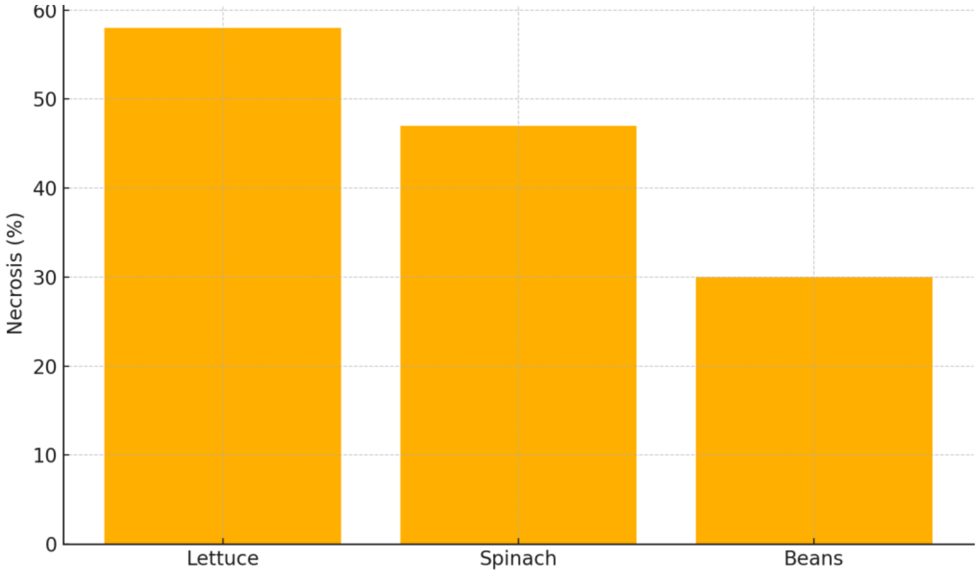

Figure 3: Necrosis symptoms with lettuce again being the most affected.

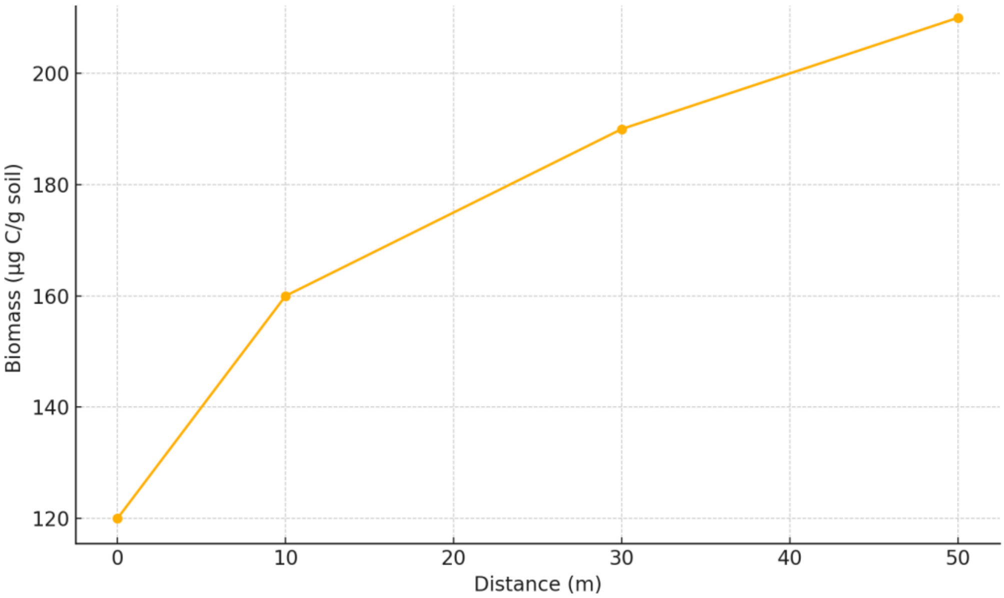

Figure 4: Microbial biomass increases with distance from herbicide source.

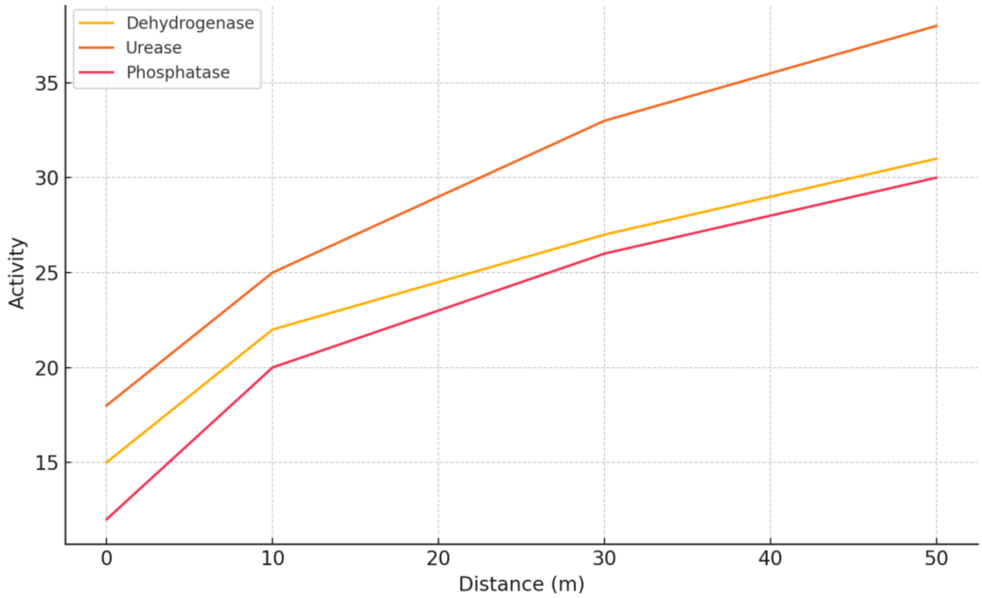

Figure 5: Enzymatic activities (dehydrogenase, urease, phosphatase) improve with distance.

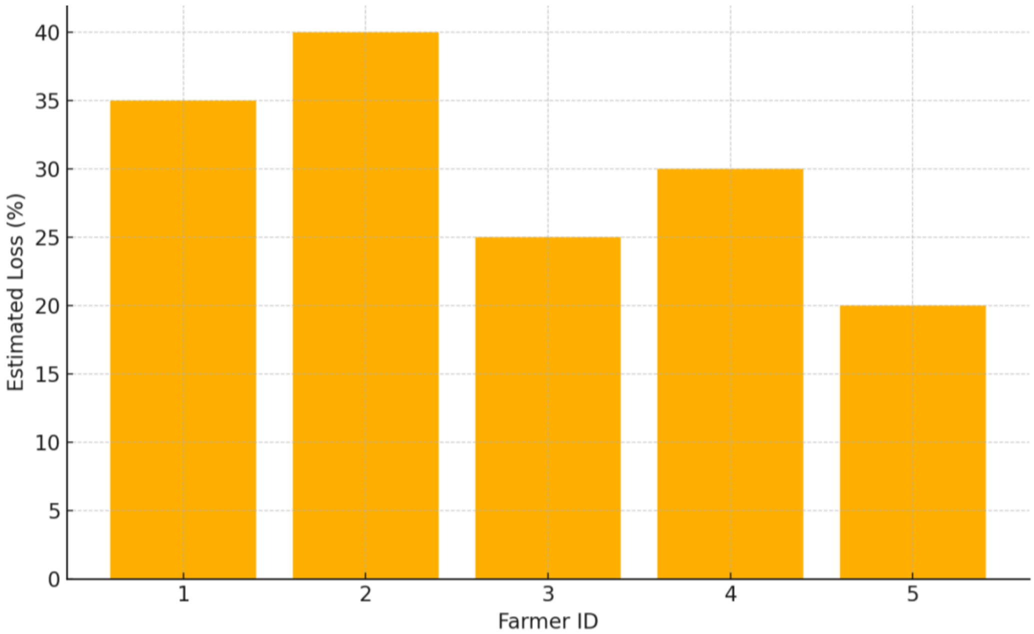

Figure 6: Reported crop losses by individual farmers near drift zones.

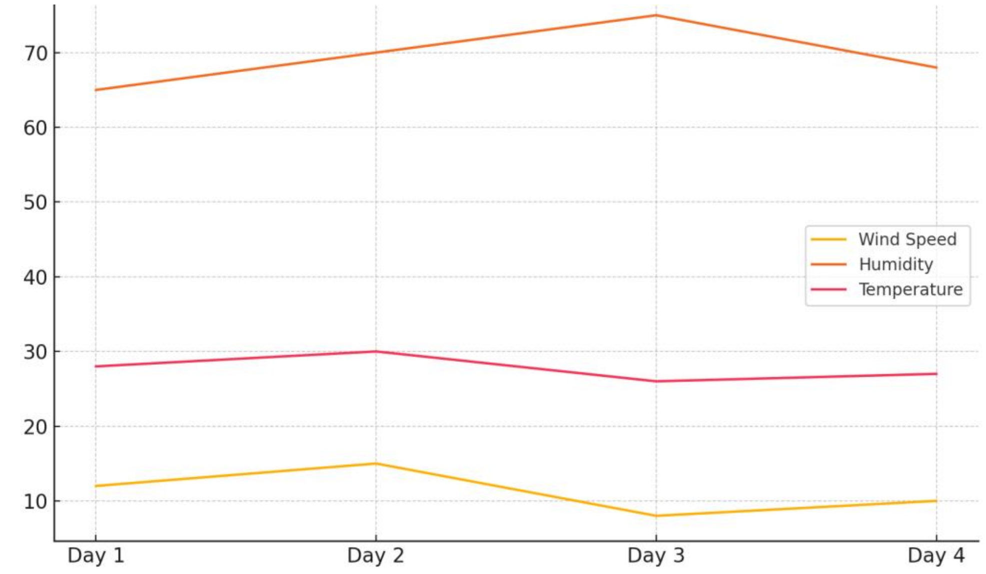

Figure 7: Weather conditions during application days support herbicide drift.

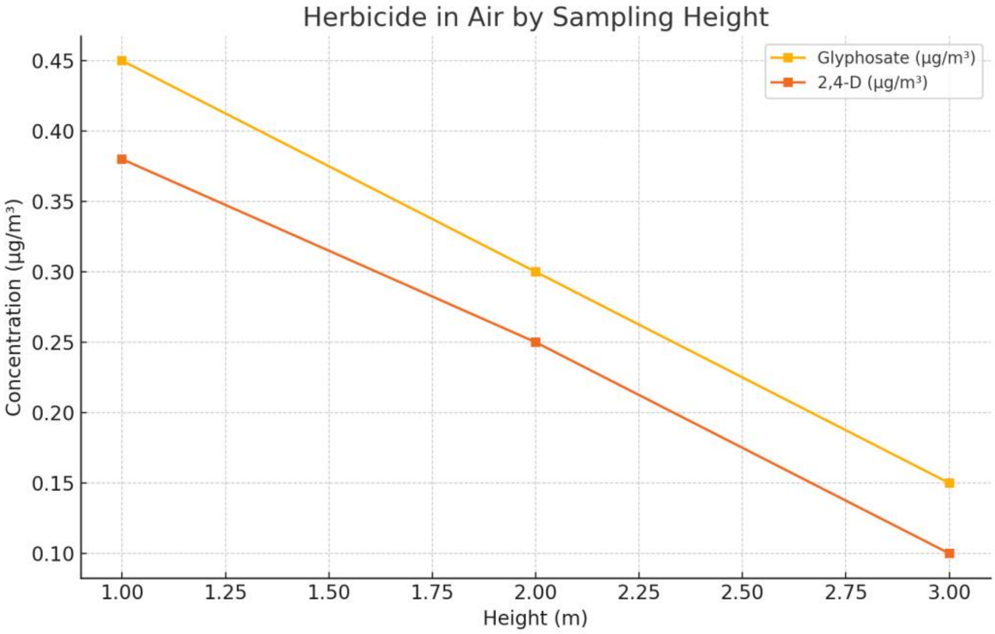

Figure 8: Airborne herbicide levels decline with higher sampling heights.

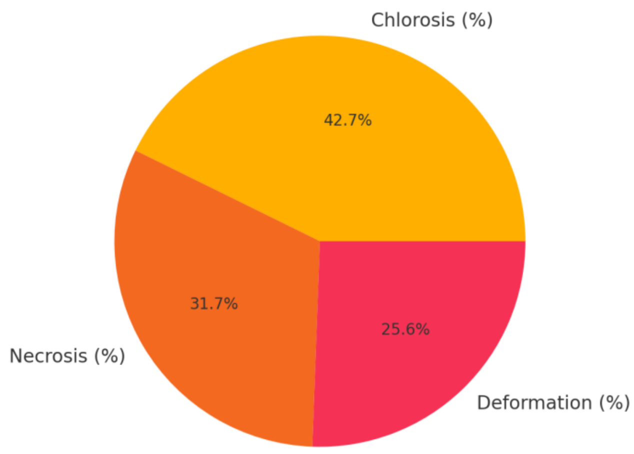

Figure 9: Distribution of phytotoxic symptoms, dominated by chlorosis.

DISCUSSION

Pesticide drift control is crucial because all the studies have confirmed that drifting herbicides negatively impact both the way organic farming is carried out and its business success. Even though chemical fungicides assist in defeating plant diseases, about 90% end up in the environment and are harmful to the surroundings. Since glyphosate is often used heavily in some situations, it may make male plants unable to reproduce. Utilizing herbicides for many years from the mid-twentieth century has caused issues where people and the environment are put at hazard (Üstüner et al., 2020). Thus, pollution may go through runoff into water sources or be spread by drift across the environment (e.g., Mrs. Kumar et al., 2020). Since glyphosate can stay in the soil for several months, there has been doubt regarding its long-term effects on the soil and plants that may take it in (Soares et al., 2021). Some studies on animal models have revealed that glyphosate can be linked with challenges in having children, developing, the health of DNA, how the brain works, and reproduction (Chianese et al., 2023).

Since herbicide drift blurs the dividing line between organic and conventional farming, it increases the number of environmental problems and results in losses for the organic sector (Parven etal., 2024). It is clear from the research that small amounts of pesticides are harmful to the plants, affect the soil and its bacteria, and cut back on organic farming's harvest. Watching organic farming is important because more hazards could harm it; thus, attempts should be made to lessen those dangers. Other plants near sensitive lettuce and spinach suffer because of pesticide drift, and this leads to visible chlorosis and necrosis (Suvorov & Stancu, 2021). As a result of these damages, crops become smaller and are prone to facing many diseases (Crouzet et al., 2020). As reported by Gomes et al., changes to a plant's photosynthesis and diet usually result in greater limits on its growth. Consequently, the use of pesticides could affect all of the nutrients, disease prevention, and soil health since soil bacteria help with these matters. Lowering the levels of microbes and their enzymes in the soil results in a change that makes it tougher for nature's balance and plant feed to be supported. It has been determined by studies that using herbicides can decrease the amount of soil microbes, so affecting the way cellulose and lignin are broken down in the environment (Oluyemi, 2020). If herbicide insecticides are applied to these microflowers, their makeup can alter, and this may influence the way microscopic nitrogen fixers function (Nandanwar et al., 2020). Another aspect to think about is that herbicide remains in soil and water can cause significant changes to urease, dehydrogenase, and phosphatase in the soil (Brar, 2020). The difficulties of organic farmers because of pesticide drift highlight the financial damages from these chemicals. If production falls and it becomes costlier to enforce protective rules or pollution lowers the value of the market, organic farming may be seriously affected. It was found that wind speed and temperature are very important in helping to spread pesticides after their application.

It is evident from surface activity of 2,4-D and glyphosate that it is very important to follow proper application guidelines and have buffer zones. High levels of herbicides at altitudes prove that these chemicals can travel far and pollute wide areas. Since glyphosate is the top contaminant, herbicide pollution in soil is causing more questions (Krauss et al., 2020). The outcomes should be added to effective plans to keep herbicides away from organic farms. A buffer zone can be made, where it physically prevents migrating pesticides. Making green borders of trees, shrubs, or tall grasses along organic fields can greatly stop herbicides from reaching the plants.

CONCLUSION

Both data and opinions collected from various sources are used here to explore herbicide drift in organic farming at a new level. The research reveals that non-target plants, the health of the soil's microbes, and the production of crops in nearby organic fields can be badly impacted by herbicide drift, even at very low levels. It was found that the level of herbicide and related problems fell with greater distance from where the herbicide was applied. Despite lower microbial population and activity in the soil of open areas, the lettuce and spinach plants exhibited bad symptoms of chlorosis and necrosis. Both the farmers and the agencies expressed that there are financial losses, less produced crops, and a necessity to use preventative treatments. Focusing on the importance of how and when herbicides are applied, the climate and GIS proved that Distribution is easier under some climatic conditions. It is demonstrated that organic farming is unstable when harmony in nature is upset, which also confirms herbicide drift can be dangerous for the environment. To preserve organic farming, the study points out that it is important to enforce buffer zones, welcome advanced technologies, and put in methods of weed control that do not rely on pesticides. Food production also relies on tight monitoring of rules, providing farmers with more knowledge, and replacing use of harmful chemicals with better substitutes. In short, our study shows that unintentional contact with chemicals over a long period can weaken and threaten organic farming, and so, food security and the environmental condition. In the next steps, research could test enhanced application of sensors to spot and reduce drifting events instantly and analyze how mixtures of different herbicides may cause more problems than either one used alone.

REFERENCES

Antoszewski, M., Mierek-Adamska, A., & Dąbrowska, G. B. (2022). The Importance of Microorganisms for Sustainable Agriculture—A Review [Review of The Importance of Microorganisms for Sustainable Agriculture—A Review]. Metabolites, 12(11), 1100. Multidisciplinary Digital Publishing Institute.

Ayilara, M. S., Adeleke, B. S., Akinola, S. A., Fayose, C. A., Adeyemi, U. T., Gbadegesin, L. A., Omole, R. K., Johnson, R. M., Uthman, Q. O., & Babalola, O. O. (2023). Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides [Review of Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides]. Frontiers in Microbiology, 14. Frontiers Media.

Baćmaga, M., Wyszkowska, J., & Kucharski, J. (2024). Environmental Implication of Herbicide Use [Review of Environmental Implication of Herbicide Use]. Molecules, 29(24), 5965. Multidisciplinary Digital Publishing Institute.

Brar, A. S. (2020). Herbicide residue in soil, crop produce and in underground water: A review [Review of Herbicide residue in soil, crop produce and in underground water: A review]. International Journal of Chemical Studies, 8(6), 1173. AkiNik Publications.

Chen, J., Yang, W., Li, J., Anwar, S., Wang, K., Yang, Z., & Gao, Z. (2021). Effects of Herbicides on the Microbial Community and Urease Activity in the Rhizosphere Soil of Maize at Maturity Stage. Journal of Sensors, 2021(1).

Chianese, T., Cominale, R., Scudiero, R., & Rosati, L. (2023). Could Exposure to Glyphosate Pose a Risk to the Survival of Wild Animals? A Case Study on the Field Lizard Podarcis siculus [Review of Could Exposure to Glyphosate Pose a Risk to the Survival of Wild Animals? A Case Study on the Field Lizard Podarcis siculus]. Veterinary Sciences, 10(9), 583. Multidisciplinary Digital Publishing Institute.

Crouzet, J., Arias, A. A., Dhondt-Cordelier, S., Cordelier, S., Pršić, J., Hoff, G., Mazeyrat-Gourbeyre, F., Baillieul, F., Clément, C., Ongena, M., & Dorey, S. (2020). Biosurfactants in Plant Protection Against Diseases: Rhamnolipids and Lipopeptides Case Study [Review of Biosurfactants in Plant Protection Against Diseases: Rhamnolipids and Lipopeptides Case Study]. Frontiers in Bioengineering and Biotechnology, 8. Frontiers Media.

Gomes, H. de O., Menezes, J. M. C., Costa, J. G. M. da, Coutinho, H. D. M., Teixeira, R. N. P., & Nascimento, R. F. do. (2020). A socio-environmental perspective on pesticide use and food production. Ecotoxicology and Environmental Safety, 197, 110627.

Hongoeb, J., Tantimongcolwat, T., Ayimbila, F., Ruankham, W., & Phopin, K. (2025). Herbicide-related health risks: key mechanisms and a guide to mitigation strategies [Review of Herbicide-related health risks: key mechanisms and a guide to mitigation strategies]. Journal of Occupational Medicine and Toxicology, 20(1). BioMed Central.

Kocira, A., & Staniak, M. (2021). Weed Ecology and New Approaches for Management. Agriculture, 11(3), 262. https://doi.org/10.3390/agriculture11030262

Krauss, M., Berner, A., Perrochet, F., Frei, R., Niggli, U., & Mäder, P. (2020). Enhanced soil quality with reduced tillage and solid manures in organic farming – a synthesis of 15 years. Scientific Reports, 10(1).

Kumar, R., Sankhla, M. S., Kumar, R., & Sonone, S. S. (2020). Impact of Pesticide Toxicity in Aquatic Environment. Biointerface Research in Applied Chemistry, 11(3), 10131.

Liang, Y., Du, Y., Song, Y., Wang, S., Zhao, C., Feng, Z., Zuo, S., Yang, F., Xu, K., & Huo, Z. (2025). Dual stimuli-responsive prodrug co-delivery nanosystem of salicylic acid and bioavailable silicon for long-term immunity in plant. Journal of Nanobiotechnology, 23(1).

Mesquita, C. P. B. de, Solon, A. J., Barfield, A., Mastrangelo, C. F., Tubman, A. J., Vincent, K., Porazinska, D. L., Hufft, R. A., Shackelford, N., Suding, K. N., & Schmidt, S. K. (2022). Adverse impacts of Roundup on soil bacteria, soil chemistry and mycorrhizal fungi during restoration of a Colorado grassland. Applied Soil Ecology, 185, 104778.

Nandanwar, S. K., Yele, Y., Dixit, A., Góss-Souza, D., Singh, R. K., Shanware, A., & Kharbikar, L. L. (2020). Effects of Pesticides, Temperature, Light, and Chemical Constituents of Soil on Nitrogen Fixation. In IntechOpen eBooks. IntechOpen.

Nath, C. P., Singh, R. G., Choudhary, V. K., Datta, D., Nandan, R., & Singh, S. S. (2024). Challenges and Alternatives of Herbicide-Based Weed Management. Agronomy, 14(1), 126.

Oluyemi, B. M. (2021). Prolonged Usage of Herbicides Reduces Heterotrophic Aerobic Bacteria and Fungi Population and Alters Soil Physicochemical Parameters. Journal of Advances in Microbiology, 63.

Parven, A., Meftaul, I. M., Venkateswarlu, K., & Megharaj, M. (2024). Herbicides in modern sustainable agriculture: environmental fate, ecological implications, and human health concerns. International Journal of Environmental Science and Technology.

Paul, S. K., Mazumder, S., & Naidu, R. (2024). Herbicidal weed management practices: History and future prospects of nanotechnology in an eco-friendly crop production system. Heliyon, 10(5).

Peng, Y., Li, S. J., Yan, J., Tang, Y., Cheng, J. P., Gao, A. J., Yao, X., Ruan, J. J., & Xu, B. L. (2021). Research Progress on Phytopathogenic Fungi and Their Role as Biocontrol Agents [Review of Research Progress on Phytopathogenic Fungi and Their Role as Biocontrol Agents]. Frontiers in Microbiology, 12. Frontiers Media.

Qin, G., Zhao, N., Wang, W., Wang, M., Zhu, J., Yang, J., Lin, F., Huang, X., Zhang, Y., Min, L., Chen, G., & Kong, J. (2023). Glyphosate-Induced Abscisic Acid Accumulation Causes Male Sterility in Sea Island Cotton. Plants, 12(5), 1058.

Radicetti, E., & Mancinelli, R. (2021). Sustainable Weed Control in the Agro-Ecosystems. Sustainability, 13(15), 8639.

Sánchez-Bayo, F. (2021). Indirect Effect of Pesticides on Insects and Other Arthropods [Review of Indirect Effect of Pesticides on Insects and Other Arthropods]. Toxics, 9(8), 177. Multidisciplinary Digital Publishing Institute.

Scavo, A., & Mauromicale, G. (2020). Integrated Weed Management in Herbaceous Field Crops. Agronomy, 10(4), 466.

Soares, D., Silva, L., Duarte, S., Pena, A., & Pereira, A. M. P. T. (2021). Glyphosate Use, Toxicity and Occurrence in Food [Review of Glyphosate Use, Toxicity and Occurrence in Food]. Foods, 10(11), 2785. Multidisciplinary Digital Publishing Institute.

Soesanto, L., Mugiastuti, E., & Manan, A. (2020). The Potensial of Fusarium sp. and Chaetomium sp. as Biological Control Agents of Five Broad-Leaf

Weeds. Caraka Tani Journal of Sustainable Agriculture, 35(2), 299.

Suvorov, N., & Stancu, A. (2021). Environmental residues and contaminants. Western Balkan Journal of Agricultural Economics and Rural Development, 3(1), 51.

Tavares, R. M., & Cunha, J. P. A. R. da. (2023). Pesticide and Adjuvant Mixture Impacts on the Physical–Chemical Properties, Droplet Spectrum, and Absorption of Spray Applied in Soybean Crop. AgriEngineering, 5(1), 646.

Tudi, M., Li, H., Li, H., Wang, L., Lyu, J., Yang, L., Tong, S., Yu, Q., Ruan, H. D., Atabila, A., Phung, D., Sadler, R., & Connell, D. (2022). Exposure Routes and Health Risks Associated with Pesticide Application [Review of Exposure Routes and Health Risks Associated with Pesticide Application]. Toxics, 10(6), 335. Multidisciplinary Digital Publishing Institute.

Üstüner, T., M, A. S., & ALMHEMED, K. (2020). Effect of Herbicides on Living Organisms in The Ecosystem and Available Alternative Control Methods. International Journal of Scientific and Research Publications, 10(8), 622.