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ANTI-DRIFT TECHNOLOGY: MARKET, FORMULATION, APPLYING METHODS

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Abstract

Drifting is a global issue worldwide and consists in the application of crop protection products or other sprayed materials away from the target area, leading to substance loss, possible damage to nearby crops and plants and pollution of local surface waters. Without the use of anti-drift agents, drift-reducing nozzles or other drift-reducing techniques, spraying fertilizers, herbicides and pesticides in general would be ineffective. Thus, crop protection effect is reduced and waste, which can result in lower incomes for farmers and higher costs for food consumers. Concrete solutions to reduce drifting and waste of crop protection products are necessary and require focus on specific particularities. The present research should increase the interest for multifaced solutions to reduce drifting. In this light the purpose of this review considers the most important data and relevant literature on this topic in order to offer significant insights and to identify knowledge gaps within literature. Thus, short- and long-term solutions refer to proper identification of the best agents that can be used for anti-drift technology. Without the use of anti-drift agents, drift-reducing nozzles or other drift-reducing techniques, spraying fertilizers, herbicides and pesticides in general would be ineffective. The anti-drift market is at a very early stage due to the lack of user education and lack of high-quality research.

Key words: *crop protection, drift, formulation, product, solution*

INTRODUCTION

Nowadays climate changes have become significant issue worldwide threatening agriculture across the planet, creating concern about the health of plants, animals and people and the ability to provide food for billions of people [19][24][25].

Despite the genetic and biotechnological progress, machinery revolution, improved cropping technologies, agricultural systems are affected by climate change through changes in temperatures, precipitation and extreme weather events, impacting directly crops production and availability and indirectly the biotic constrainers of crops, such as weeds, pests and pathogens and their relationship with plants [10][11][22][30]. Beside the impact of abiotic constrainers (heat, soil salinity, soil acidity, lodging, snow, hail, variable humidity, natural disasters) and social events (pandemics, markets, income variability and stability, consumption, globalization of food production), controlling biotic constrainers plays one of the most important roles on the crops yield, availability and stability of food [3][5][7][8][23].Thus, climate change together with human-induced changes is expected to increase the spread of pathogens, pests and invasive species in areas where they have not been relevant before, bringing new challenges for crop management, especially in using crop protection products, in order to face yield losses and avoid alteration of natural landscape vegetation [12].

In this context, drift effect is an increasingly important concern of the agricultural industry because even if small droplets of plant protection products (commonly defined as less than 150 microns in diameter) traditionally provide better crop coverage, they are also more prone to drift. Large droplets (commonly thought to be larger than 400 microns in diameter) tend to resist drifting, but are prone to jumping off crop surfaces, leading to reduced coverage and efficiency. The optimal size range for minimizing drift and maximizing efficiency is generally considered to be 200-400 microns [17][18]. Also, a great challenge is to find a functional balance between controlling drift and preserving the effectiveness and coverage of pesticides applied to crops. One of the aspects considered to be of great benefit in achieving this balance is the use of anti-slip or anti-drift products. By using anti-drift agents, the aim is to reduce the level of pollution, to increase the consumption of fertilizers and biostimulants with foliar or on soil application, and to increase the production of agricultural and horticultural crops.

Without the use of anti-drift agents, drift-reducing nozzles or other drift-reducing techniques, spraying fertilizers, herbicides and pesticides in general would be ineffective, primarily because there could be inadequate treatment of land and growing areas intended for treatment, and, the resulting spray, if transported beyond the intended treatment area, can have negative effects on crops, land and water courses [14][15][32].

Also, by reducing drift, more food could be made accessible for consumption without an increased demand for higher yields.

MATERIALS AND METHODS

In order to provide a comprehensive overview of the current state of knowledge on the article topic, the current study research included and synthesized pertinent literature that was indexed in international databases, using a qualitative informational approach based on books, scientific articles, news articles, reports, and websites [29].

The goal of this paper is to provide significant insights based on the article's topic and to identify knowledge gaps in the literature. To achieve this goal, systematic, semi-systematic, and integrative research approaches were used to compare current literature, papers, studies, reports, and statistics [21][26]. Additionally, the text mining approach, a well-known text analysis methodology used to draw connections and knowledge from a vast number of textual sources, was applied.

This review highlights the status and views of anti-drift technology, identifies their current issues, and suggests appropriate solutions.

The following sections outline how the books, articles, studies, and reports consulted for this review were grouped.

RESULTS AND DISCUSSIONS

Anti-Drift products-Formulations/Market

Controlling drift can provide more stable and secure yields with less crop protection product loss, even though biotechnology and gene editing have the potential to increase yield and breed cultivars with beneficial traits like drought and heat resistance, pest and disease resistance, and improved nutraceutical properties [4].

All over the world the objectives of any spraying applied in agriculture are to balance production, effectiveness of spraying and prevention of drift generated by the application of pesticides to protect the environment. Frequently, anti-drift products are incorporated into pre-packaged pesticide products and are referred to as “built-in” or “in-formulation” adjuvants. Anti-drift adjuvants reduce the risk of drift and maximize performance by binding ultra-small particles into larger droplets after spraying, which are less exposed to drift.

Tests have indicated that in some cases, anti-drift agents have reduced the drift effect by between 50-80% [6][17][31].

Currently available products used to reduce the drift phenomenon can be classified as: emulsions, thickeners, agents that cause particle formation and foaming agents.

Emulsions are viscous, white, miscible with water, having a creamy consistency like a mayonnaise (Table 1). These emulsions, formulated especially in the case of herbicides, are widely used to reduce drift. In the case of emulsions, small water droplets are dispersed in a homogeneous oily phase. In contrast, the most common emulsions form dispersed, non-homogeneous oily particles in the water. Most phenoxyacetic herbicides are in the form of highly volatile esters, oil-soluble amines or soluble acids. The drift effect is not entirely eliminated and some small drops are produced during spraying.

Table 1. Adjuvant products

Petroleum spray oils (1-3% emulsifier)	Petroleum spray oil plus surfactant (5% emulsifier)	Petroleum spray oil concentrates (>15% emulsifier)	Vegetable oils (emulsified)	Vegetable oils (Esterified and emulsified)
Ad-Here™ [970 mL/L]	Bolster [838 g/L]	Adjuvator [582 g/L]	Biotrol Oil	Activoil
Broadcoat [846 g/L]	D-C-Trate [839 g/L]	Agridex [730 g/L]	Chemag Extend	Adigor
Empower [861 g/L]	D-C-Tron Cotton [827 g/L]	Amplify [432 g/L]	Chemtrol	Bolster
SACOA AntiEvap [859 g/L]	Rulvapron [838 g/L]	Auster Spraying Oil [582 g/L]	Codacide	Dasher
SACOA CottOil [859 g/L]	Trump™ [830 g/L]	AW Power Tek [432 g/L]	Ecotrol	Effectivoil
		Bonza [411 g/L]	Endorse	Fastup
		Canopy [792 g/L]	Envoy (blend with buffer and surfactants)	Glysarin 704
		D-C-Trate Advance [653 g/l]	Intact	Hasten
		Enhance [598 g/L]	Miller Exist	Impel
		Genboost {426 g/L]	Nexus Spray Adjuvant	Inflirtrator
		Hot-Up [190 g/L]	Nuturf Driftex	Kwickin
		Hotwire [598 g/L]	ProCanOil Spray Oli	Phase Dispersant Penetrant
		Hustle [598 g/L]	Protect oil	Plantocrop
		In-bound [653 g/L]	Rutec Control Oil	Promax
		Magnify [426 g/L]	Sacoa Xseed	Pronto
		PCT Reactor [582 g/L]	Simplot oilon	Protec Plus
		Powersurge [598 g/L]	Smart Crop Spray Oil	Racer Ultra
		Propel [432 g/L]	Spalding canola oil spray oil conc.	Rapid Oil
		Supercharge [411 g/L]	Praytech oil	Rocket
		T-oil [432 g/L]	Stoler Natur Oil	Swift
		Tribute [666 g/L]	Supa Stik	Synertrol Excel
		TurboOil [426 g/L]	Synertrol	Trio Sterycon oil 700
		Uptake [582 g/L]	Xtend Plant Oil	4-Farmers Speedy
		Vibral [432 g/L]		
		Voltage [432 g/L]		
		Yakka [426 g/L]		
Oil adjuvants groped in the various categories in the Table may not be necessary identical in their composition or performance. Differences in the qualities of the feedstock used (e.g. hydrocarbon chain length); types of emulsifiers used and combination with other minor ingredients for example can give rise to differences in performance. Where pesticide labels specify a particular brand of adjuvant for use, it is wise to establish equivalency of similar products before substituting an alternative branded product.				

Source: Adjuvants – Oils, surfactants and other additives for farm chemicals – revised 2012 edition [2].

Using conventional sprayers, the percentage of small drops produced when using emulsions is affected by factors such as nozzle type, hole size, nozzle orientation during spraying, all of which influence the quality of spraying.

The viscosity of the emulsion also affects the degree of control of the drift phenomenon. Thin emulsions produce much smaller droplets, likely to be exposed to drift during spraying. The viscosity of the emulsions depends on the water/oil ratio and the size of the stirring drops. Some formulations of emulsions become more viscous as they are stirred and pumped, and the number of small drops increases. In the field, viscosity can be adjusted by varying the water/oil ratio as more oil is added. The emulsion becomes thinner and more fluid.

Thickeners are synthetic polymers that are soluble in water. They increase the viscosity of the water fraction of the spray solution, thus increasing the size of the drops during spraying. Many thickeners act as adhesives, increasing the adhesion of the sprayed substance to the leaves and stems of plants and reducing the slip from them during spraying.

Polymers used as anti-drift control agents are the most common type of adjuvants and work by increasing the size of drops during spraying. Adjuvants used as anti-drift agents aim to increase the coarse fraction of the spray mixture while reducing the fine fraction.

Most of the anti-drift agents mentioned in the literature are based on polymers of high molecular weight and possessing good viscosity. Commonly, polyacrylamide (PAM), polyethylene eoxides (PEO), polyvinylpyrrolidone (PVP) have been used over time as anti-drift agents [20][28]. Even at a high dilution, usually at 100-100 ppm, these polymers are effective in delaying the breakage of the spray mixture and reducing the formation of isolated droplets [16][20].

In any case, the current formulations of anti-drift agents have a limited effect on reducing drift for a number of reasons, most commonly known as physical degradation by shear. This type of polymer degradation leads to a significant decrease in the viscosity of the mixture resulting in a decreased control of the distribution of drops during spraying. To minimize this, polymers with an intrinsic viscosity of between 6 and 15 DL/g. should be used.

It is generally accepted that the polymers that provide the best control of drift are either non-ion polymers (e.g. homopolymer acrylamide) or have a relatively low anionic content (e.g. 5 to 30 wt.%) and have high intrinsic viscosity, above 6 DL/g.

Such polymers tend to form viscous mixtures with water at low concentrations. Normally, in practice, the emulsion or powder should be mixed with water directly into the tank of the sprayer to form an aqueous polymer solution.

Results from a study conducted at USDA-ARS Texas showed that the type of polymer significantly influences the size of the droplets that form in the sprayer mixture [13]. For example, polyvinyl and polyacrylamide are much more effective than alkyepoxides or copolymers in increasing the diameter of particles and reducing the volume of the spray solution composed of small particles.

[9] experimented with several chemical formulations such as emulsifiable synthetic resins, plant polymers, synthetic latex or fluid organosilicon, phosphatidyllcholine and propionic acid, sodium dodecylbenzenesulfonate and carboxymethylcellulose, nonylphenoxy polyethanol and ethoxylnonylphenol. The results showed that the group of mineral oils and anti-drift agents determined better control of drifting than surfactants and water.

Guar gum and its derivatives have been used in aqueous mixtures as an excellent anti-drift agent without presenting the disadvantages of polymers. The ability of guar gum to alter the rheology of liquids and increase their adhesion is important in increasing the effectiveness of foliar splashes. The water-guar gum mixture not only possesses desirable characteristics as an anti-drift agent, but maintains these characteristics for a long time during spraying conditions and is resistant to mechanical shear and degradation effect. In any case, the gums do not shear as easily as the polymer chain, and some types of polymers (polyethylene oxide) shear even faster than other polymers (polyacrylamide) when passing through the spray pump.

On international markets there are products (Atplus™ DRT-EPS, Atplus™ DRT-100, 41-A©, Control™) mentioned to have an anti-drift effect suitable both for mixing in the tank of the sprayer and directly incorporated in the plant protection products used, proving good performance in several types of nozzles used.

Recently, [27] tested the anti-drift potential of folic acid and zinc nitrate in a supramolecular hydrogel formulation biocompatible with the herbicide dicamba in a low-volume mixture. This hydrogel containing non-organic solvents has shown biocompatibility and biodegradation due to its natural compounds. The main way this hydrogel reduces the drift phenomenon is by increasing the size of the droplets and this is due to the three-dimensional structure of this gel. This study showed a new strategy to diminish the drift effect and use hydrogels in agriculture.

According to the Agricultural adjuvants market report (2020), the global adjuvant market is estimated to reach $4,4 billion in 2026, recording an annual growth rate of 6.1% between 2020 and 2026 [1].

Currently, the adjuvant market is relatively small in the global pesticide segment. However, the adjuvant market has seen significant growth due to the increasing need to control harmful organisms in agriculture, especially in developed countries. The targeting of research funds by companies to develop such anti-drift products and anti-foaming agents will lead to the growth of the adjuvant market in the next 7 years In addition, with the increase in the use of drones for pesticide application, companies will focus on obtaining compliant drone application adjuvants.

Technologies of application of anti-drift products

The factors that influence the drift are: weather conditions (wind speed and direction, ambient temperature and humidity), sprayer and application technology (type, parameters and position of nozzles, nozzle spacing, working pressure, dose per hectare, working speed) and other application parameters.

Spray disperses the liquid into small diameter droplets, the average diameter of the resulting droplets may be very different, from a few microns (μm) to 2-3 mm. Depending on the average size of the drops, the following forms (categories) of dispersion of the spray liquid are distinguished: Atomization, fine spraying, spraying and rain (artificial). Current use sprayers make drops with diameters between 50 μm and 1.5- 2 mm. The size of the drops used depends on the applied treatment and the sprayed product. Thus, for the work of fighting cryptogamic diseases are mainly used small-diameter drops, the application of fungicides is usually done by fine spraying. For the rest of the control products and depending on the toxicity of the product to the environment, it is recommended to perform drops of diameter between 150 and 600 μm.

When spraying, the compact jet of solution coming out of a limited space, the body of the nozzle or sprayer, is converted into a droplet by dispersing the liquid in open space in different directions at a speed capable of overcoming the internal cohesion forces of the dispersed liquid.

The hydraulic spraying process is only one of the technical possibilities used for spraying liquids. In spray pest control machines, several spraying procedures are used, which are distinguished by the way the liquid is trained at the speed necessary to annihilate the internal cohesion forces and propitious to disperse, as follows:

- hydraulic spraying, by passing the pressurized liquid through a small section hole and design in the open space;
- pneumatic spraying, here bringing the liquid to the speed required for dispersal is achieved by taking it over and transporting it in a high-speed air stream;
- centrifugal spraying, where both the speed and direction of dispersion is achieved by draining the liquid from a rotating disc at a high speed;
- "two medium" spraying is a combined process, resulting from the combination of hydraulic and pneumatic spraying.

For the characterization of the droplet spectrum in a nozzle jet, several reference sizes such as the mean volumetric diameter (VMD), which represents the limit size against which 50% of the total spray volume consists of droplets larger and smaller than VMD, respectively. Of importance for practice is another size denoted by Dv0.1 (median volume (10%)) volumetric diameter 10% - where 10% of the total spray volume is less than Dv0.1 expressed in μm. For fan or conical nozzles used in field crop treatments, the minimum allowable diameter Dv0.1 = 100 μm is considered, i.e. the value below which droplets can be easily carried by air currents (drift hazard). Also based on experimental data are given as optimal values of wind speed up to which spraying treatments can be applied, speeds between 2.0 and 6.5 km/h and maximum of about 9.0 - 15 km/h (3 - 5 m/s).

If losses of plant protection material due to evaporation and sublimation can be reduced by the use of suitably conditioned preparations, by the addition of organic solvents with a low degree of volatility or by the addition of adhesives to reduce the volatility of the applied product, losses due to drift can be reduced by using a spray process capable of reducing these losses. The most effective measure to reduce drift losses is the use of sprayers and nozzles with coarse droplet spectrum. With their help, at the same working flow and pressure, the amount of substance lost by drift when spraying with spray nozzles of anti-slip, impact or air injection type is much lower.

Compared to the amount of liquid lost when spraying with universal type nozzles (LU - Lechler Universal), losses due to drift when spraying with anti-slip nozzles (DG - drift guard) and impactful nozzles (TT - TurboTeejet) are only half. By using the air injection nozzles (ID - injector-duction, TD TurboDrop) the drift reduction is even greater, the loss value being half the corresponding value on the nozzles of type DG and TT, respectively a quarter of the drift produced by universal type nozzles.

The classification of sprayers according to the drift reduction capacity is made in three classes, expressed in drift reduction percentages: 90, 75 and 50%.

Lechler ID 120-04 POM (polyoxymethylene) and ID 120-04 C (ceramic material) air injection nozzles as well as spray systems AI 11004 VS nozzles were classified in the drift reduction class by 75%. Nozzles of type ID 120-03 POM, ID 120-03 C and AI 11003 VS are classified only in the 50% drift reduction class.

Regarding the use of the carrier air jet to reduce drift, it should be noted that this system allows to reduce drift only when spraying crops with abundant plant mass. In the case of pre-emergent sprays on unvegetated soil or in very small crops, an increase in the amount of fluid deviated from the treatment site (target) is observed.

Other measures may also contribute in addition to the abovementioned procedures for reducing drift.

Thus, when spraying potato crops, good results in reducing the drift were also obtained by using subfoliar sprinklers of the type Benest-Dropleg (Beneth Sprayer systems) or Fischer (FAT-CH).

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CONCLUSIONS

All over the world the objectives of any spraying applied in agriculture are to balance production, effectiveness of spraying and prevention of drift generated by the application of pesticides to protect the environment. Anti-drift agents are presented in the literature as a specific class of chemical adjuvants that should not be confused with products such as surfactants, wetting agents, scattering agents or adhesives. These agents are normally long-chain polymers or gums that increase the viscosity of the spray mixture leading to more effective spraying. Various anti-drift products are known to have a wide variety of chemical formulations in their composition. Thus, it is very difficult to identify new anti-drift agents or to optimize new formulations of them. The adjuvants market is dominated worldwide by North America where modern technologies are applied to agriculture and where integrated management of harmful organisms in crops is practiced. Researchers and vegetable farmers can use this material as a resource.

REFERENCES

[1]Agricultural Adjuvants Market Report, 2020. Agricultural Adjuvants Market by Function (Activator and Utility), Application (Herbicides, Insecticides, and Fungicides), Formulation (Suspension Concentrates and Emulsifiable Concentrates), Adoption Stage, Crop Type, and Region - Global Forecast 2026, p.328.

[2]Betts, G., Gordon, B., Green, V., Burgis, M., Henderson, R., 2012, Adjuvants – Oils, surfactants and other additives for farm chemicals – revised 2012 edition, Grains Research & Development Corporation Publishing, 1-52.

[3]Bonciu, E., 2020a, Study regarding the cellular activity in garlic (A. *sativum*) bulbs affecting by *Sclerotium cepivorum*, Scientific Papers. Series A. Agronomy, Vol LXIII, No. 1: 186-191.

[4]Bonciu, E., 2020b, Aspects of the involvement of biotechnology in functional food and nutraceuticals,

Scientific Papers. Series A. Agronomy, Vol LXIII, No. 2: 261-266.

[5]Bonciu, E., Liman, R., Cigerci, I.H., 2021, Genetic bioengineering in agriculture-a model system for study of the mechanism of programmed cell death. Scientific Papers: Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(4): 65-70.

[6]Chen, Y., Hou, C., Tang, Y., Zhuang, J., Lin, J., Luo, S., 2019, An effective spray drift-reducing method for a plant-protection unmanned aerial vehicle. International Journal of Agricultural and Biological Engineering, 12(5):14-20.

[7]Cotuna, O., Paraschivu, M., Bulai, A., Toma, I., Sărăţeanu,V., Horablaga, N.M., Buzna, C., 2021. Behaviour of some oat lines to the attack of the fungus *Blumeria graminis* (D. C.) f. sp. avenae EM. Marchal. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21 (4):161-170.

[8]Cotuna, O., Paraschivu, M., Sărățeanu, V. 2022, Charcoal rot of the sunflower roots and stems (*Macrophomina phaseolina* (Tassi) Goid.) - an overview. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 22 (1):107-116.

[9]De Oliveira, R.B., Antuniassi, U.R., Mota, A.A.B., Chechetto, R.G., 2013, Potential of adjuvants to reduce drift in agricultural spraying. Eng. Agríc., Jaboticabal, 34 (5): 986-992.

[10]De Souza, C.P., Bonciu E., 2022a. Progress in genomics and biotechnology, the key to ensuring food security. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(1): 149-157.

[11]De Souza, C.P., Bonciu E., 2022b. Use of molecular markers in plant bioengineering. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(1): 159-166.

[12]European Environment Agency (EEA), 2017, Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. EEA Report 1, 424, https://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016 Accessed 15 July 2022.

[13]Fritz, B.K., Hoffmann, W.C., Bagley, W.E., 2010. Effects of Spray Mixtures on Droplet Size under Aerial Application Conditions and Implications on Drift. Applied Engineering in Agriculture 26(1):21-29.

[14]Glodeanu, M., Vasile, C., Alexandru, T., 2019, Using crop dusters for phytosanitary protection of the agricultural and forestry crops. Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series, 49(2):258-263.

[15]Glodeanu, M., Vasile, C., Saracin, I., Glodeanu, A., 2021, Study of process of electronic flow regulation for sprinkling machines. In Engineering for Rural Development. Proceedings of the International Scientific Conference (Latvia). Latvia University of Life Sciences and Technologies, 699-705.

[16]Harrison, G.M., Mun, R., Cooper, G., Boger, D.V., 1999, A note on the effect of polymer rigidity and concentration on spray atomisation. J Nonnewton Fluid Mech 85: 93–104.

[17]Heidary, Al., M., Douzals, J.P., Sinfort, C.,Vallet, A., 2014, Influence of spray characteristics on potential spray drift of fi eld crop sprayers: a literature review. Crop Prot., 63:120-130.

[18]Hilz, E., Vermeer, A.W.P.P., 2013, Spray drift review: the extent to which a formulation can contribute to spray drift reduction. Crop Prot 44: 75–83.

[19]Kilian, B., Dempewolf, H., Guarino, L., Werner, P., Coyne, C., Warburton, M.L., 2021. Crop Science special issue: Adapting agriculture to climate change: A walk on the wild side. Crop Science, Vol:61:32–36.

[20]Lewis, R.W., Evans, R.A., Malic, N., Saito, K., Cameron, N.R., 2016, Polymeric drift control adjuvants for agricultural spraying. Macromol. Chem. Phys., 217: 2223-2242.

[21]Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., 2015, Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic Reviews, Vol. 4(1):1-9.

[22]Paraschivu, M., Cotuna, O., Matei, Gh., Sărățeanu, V., 2022, Are food waste and food loss a real threat for food security? Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22 (1):479-484.

[23]Păunescu, G., Paraschivu, M., Păunescu, R.A., Roșculete, C.A., 2022, The relationship between yield and pathogens attack on the advanced breeding winter wheat lines assessed for adult plant resistance. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22 (1): 493-501.

[24]Prioteasa, A.M., Olaru, A.L., Vasilescu, C.O., 2018, Research regarding the influence of the levelling of sands from the left part of the Jiu River upon the energy balance in the case of growing black-eyed peas. Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series, Vol.48(1):286-289.

[25]Prioteasa, A.M., Olaru, L.A., Grecu, F., Vasilescu, C.O., 2019, The influence of the levelling of sands from the left part of the river Jiu up on the energy balance in the case of growing barley in the fall. Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series , Vol.49(1):116-118.

[26]Snyder, H., 2019, Literature review as a research methodology: An overview and guidelines. Journal of Business Research, Vol.104:333-339.

[27]Song, Y., Zhu, F., Cao, C., Cao, L., Li, F., Zhao, P., Huang, Q., 2021, Reducing pesticide spraying drift by folate/Zn2+ supramolecular hydrogels. Pest Manangement Sci. 77 (11): 5278-5285.

[28]Spanoghe, P., De Schampheleire, M., Van der Meeren, P., Steurbaut, W., 2007, Influence of agricultural adjuvants on droplet spectra. Pest Manag. Sci. 63: 4–16.

[29]Tranfield, D., Denyer, D., Smart, P., 2003, Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, Vol.14:207-222.

[30]Velea, L., Bojariu, R., Burada, C., Udristioiu, M.T., Paraschivu, M., Burce, R.D., 2021, Characteristics of extreme temperatures relevant for agriculture in the near future (2021-2040) in Romania. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. X:70-75.

[31]Wang, X., He, X., Song, J., Wang, Z., Wang, C., Wang, S., Meng, Y., 2018, Drift potential of UAV with adjuvants in aerial applications. International Journal of Agricultural and Biological Engineering, 11(5):54-58.

[32]Yi, R., Yan, J., Shi, D., Tian, Y., Chen, F., Wang, Z., Duan, S., 2021, Improving the performance of drifted/shifted electronic nose systems by cross-domain transfer using common transfer samples. Sensors and Actuators B: Chemical, 329:129162.