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PLANAR LASER FLOW VISUALIZATION OF A KNAPSACK (BACKPACK) SPRAYER

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Abstract: Within phytosanitary protection procedures, for small agricultural holdings, for gardens and parks, portable sprayers are the preferred application devices. Their large number, along with the non–uniformity of technical or operational parameters, justifies a thorough investigation of them. The present work represents a first step in investigating the quality of the jet produced by a portable sprayer by a simple method, that of visualizing the jet produced by the sprayer nozzle with the help of a laser plane. For this purpose, an investigation method is proposed with components highly available and low costs, respectively, a digital camera and a laser level capable of projecting a laser plane.
Keywords: agricultural nozzle, knapsack sprayer, flow visualization, planar laser

1. INTRODUCTION

In order to ensure sufficient and quality agricultural production it is necessary to use pesticides to protect against diseases and pests (*Godfrey, L.D.*, 2014), but the side effects of pesticides on the environment and human health must also be considered (*Gil,Y.; Sinfort, C.*, 2005; *Franzen, M.*, 2007).

The Knapsack sprayer is the equipment most often used for the application of phytosanitary treatments on small farms or in developing countries as well as for applying treatments within gardens and parks. Apart from the advantages they offer, these sprayers pose several problems in terms of precise and consistent application of pesticides (due to challenges in ensuring constant pressure and flow) leading to negative effects such as: reduced treatment efficiency, operator exposure to chemicals, environmental pollution, etc.

The proper functioning of a knapsack sprayer depends primarily on the technical condition of the equipment (wear of some components, operating mode, etc.), as malfunctions occurring lead to contamination of the environment and the operator, waste of pesticides and therefore increased costs for plant protection treatments.

The field of knapsack sprayers is covered by ISO 19932–2013 standards (part 1 and 2). These standards are currently being revised and updated. According to this standard the knapsack sprayer is a self–contained sprayer that is carried on the operator's back or shoulder by means of straps or a belt.

Following the revision of ISO 19932 standards will be replaced by:

– ISO / DIS 19932–1 Equipment for crop protection — Knapsack sprayers — Part 1: Safety and environmental requirements, which specifies the safety and environmental requirements and their means of verification for the design and construction of knapsack sprayers for use with plant protection products. In addition, it specifies the type of information on safe working practices (including residual risks) to be provided by the manufacturer.

≡ ISO/DIS 19932–2 Equipment for crop protection — Knapsack sprayers — Part 2: Test methods, which specifies test methods for the verification of requirements of ISO 19932–1:2013 for knapsack sprayers for use with plant protection products.

≡ ISO/DIS 19932–3 Equipment for crop protection — Knapsack sprayers — Part 3: Inspection of knapsack sprayers in use, which specifies the requirements and test methods for inspection of the use of knapsack sprayers for use with plant protection products (PPPs). The requirements relate mainly to the condition of the sprayer with respect to its potential risk to the operator and the environment and its performance to achieve good application.

Until now, different studies have been conducted on knapsack sprayer performance (*Alheidary, M., 2017; Gatot P. and Anang R, 2018; Ferreira M.C. and Cardozo R.P., 2014*), on operator contamination when using different pesticide application techniques (*Godyń, A. et all*, 2012; *Bjugstad N. and Hermansen P*, 2009) and some operator–related studies (*Lambrecht E. et all*, 2019).

This paper presents a preliminary investigation in monitoring and verification of backpack sprayers as a first step to determine some quality parameters, using a cheap, fast, and available source for a planer laser flow visualization.

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2. MATERIALS AND METHODS

To investigate the nozzle flow pattern, we used an optical method of flow visualization based on planar laser. For that, according to the presented principle in Figure 1, the jet spray from the nozzle is sectioned by a planar sheet of light. Based on setup arrangements the section can be made along either axis to study the spray pattern in the associated plan.

The investigation setup was made using several commercially available components:

- the knapsack (backpack) sprayer (Figure 2 a): model Evotools 677760 electric / hand operated; 16 l capacity; 12 V, 8Ah lead–acid battery; 0,52–0,95 m extendable lance; 4 nozzles; 0,4 MPa max. pressure;
- laser level: ±3 mm at 10 m precision; 532 nm (green) class 2 laser; ≤ 3° self levelling; up to 3 perpendicular planes (3 x 360°); 0,59 – 1,52 m tripod adjustable height (Figure 2 b);
- nozzle assortments: SA–7 hydraulic nozzle (with sprayer provided), 5 hydraulic and 5 air–injector nozzles (www.lechler.com);
- photo camera (Figure 2 c): 16 Mp, 1/3.1'' sensor (1.0 μm pixel), f–1/6 lens, 30 mm – equivalent focal length, built–in LG G7 Thin–Q.

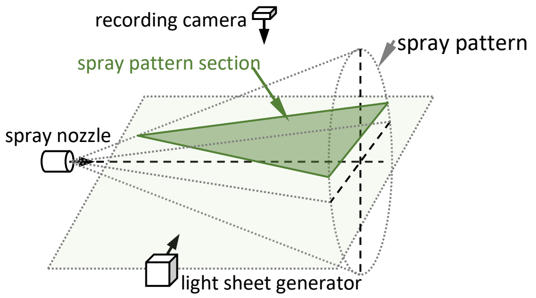


Figure 1 – Flow pattern visualization basic principle.

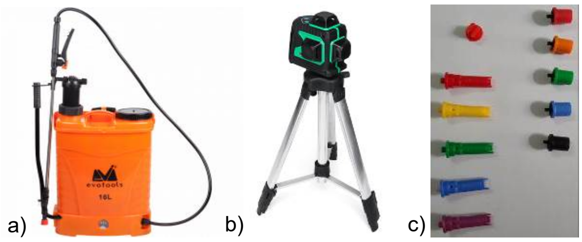
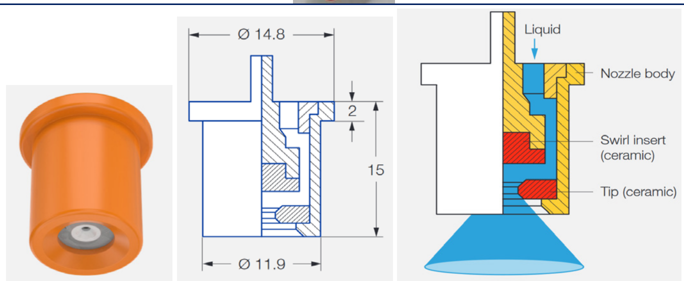
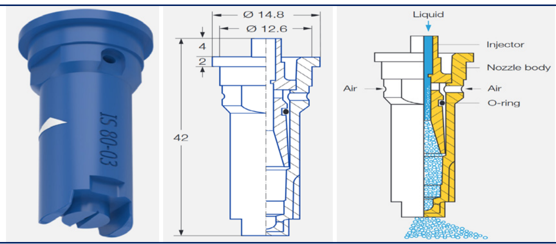
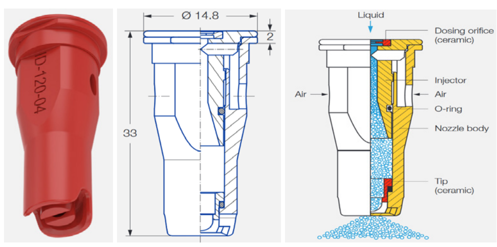


Figure 2 – Components used for setup visualization: a) knapsack sprayer; b) self–levelling three–line green laser with tripod; c) agriculture nozzle assortments.

In order to enhance the visual quality of spray pattern section in the recorded photos, within the water from the sprayer reservoir 1% TiO_2 was added for its high light reflectivity, low light absorption and small particle size needed to seed droplets. The parameters of the nozzles used can be seen in Table 1 below.

Table 1. Technical specifications of tested nozzles

Nozzle type/ spray pattern		Nozzle colour	Flow [l/min]			
			0.2 MPa	0.3 MPa	0.4 MPa	
SA–7		red	NA	NA	NA	
TR 80–005	Hollow cone 80°	black	0.16	0.20	0.23	
TR 80–0067		green	0.22	0.27	0.31	
TR 80–01		orange	0.32	0.39	0.45	
TR 80–03		blue	0.97	1.19	1.37	
TR 80–04		red	1.29	1.58	1.82	
IS 80–02	Flat air–aspirating off center nozzle	yellow	0.49	0.60	0.69	
IS 80–025		purple	0.70	0.86	0.90	
ID 120–03	Air–aspirating flat spray nozzle	green	0.59	0.68	0.76	
ID 120–04		blue	0.97	1.19	1.37	
ID 90–03		red	1.29	1.58	1.82	

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According to the principle presented in Figure 1, the method used for observing the spray pattern consist in visualizing and recording of several images, evenly spaced along the longitudinal axis of the nozzle. Then within an image processing application, the images are enhanced and geometrical corrected to obtain the real shape and dimensions of the spray section pattern. With the adjusted spray sections pattern with a CAD application the 3D model is constructed by aligning the section across an axis at the same distances as the recorded images, having the starting point the equivalent nozzle tip point on the mentioned axis. From the starting point a surface or a volume can be generated, as desired, with cross section perpendicular to the equivalent longitudinal nozzle axis which will represent the investigated 3D modeled spray pattern.

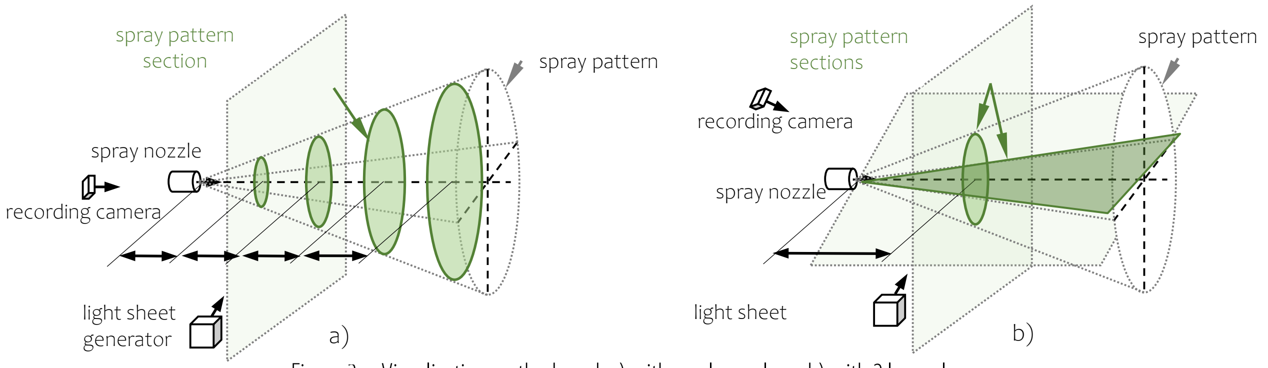

Figure 3 – Visualization method used: a) with one laser plane; b) with 2 laser planes

Taking into consideration the above stated, to generate the desired spray pattern sections, a setup was used according to Figure 3. Thus, in fig 3, a) cross sections perpendicular to nozzle longitudinal axis were obtained by translating laser sheet generator (laser level) parallel to specified axis with the same distance, respectively, in Figure 3 b) overlapping a cross section previously generated with another one, perpendicular, generated by the second laser sheet to obtain in a single image two sections perpendicular on each other.

The physical layout of the components used during measurement setup is presented in Figure 4.

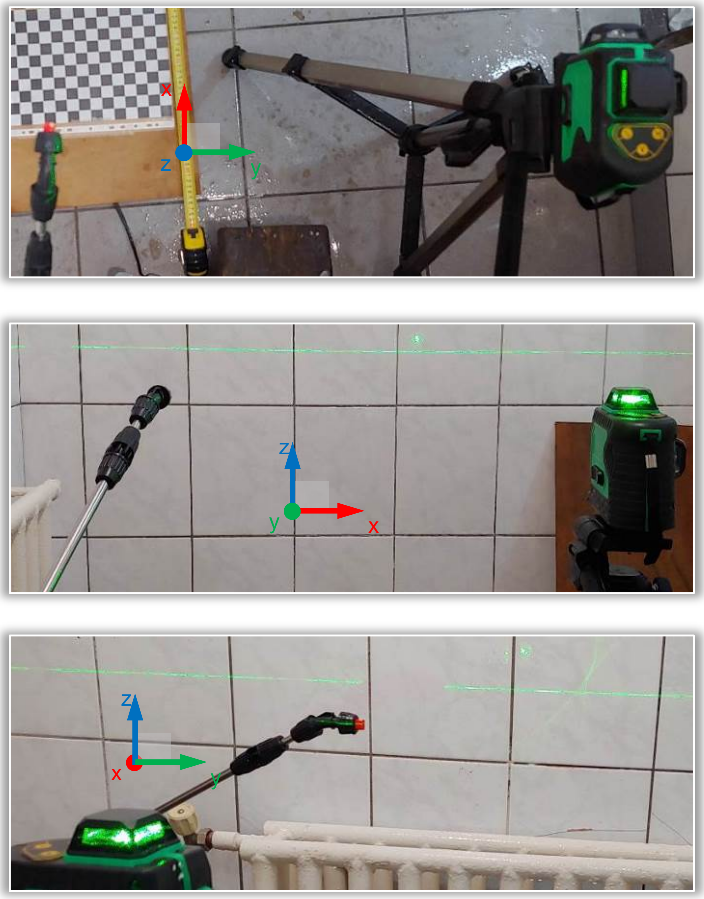

Figure 4 – Setup visualization, top, back, and lateral views

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3. RESULTS

According to the method presented above, for SA–7 nozzle provided by the knapsack sprayer manufacturer the planar laser sections made normal to the nozzle orifice are at 0.05 m from the nozzle respectively at 0.15, 0.25, 0.35 and 0.45 m (Figure 5). The images were processed with specific image processor (Figure 6) and then in a generic CAD application the 3D pattern was generated (Figure 7).

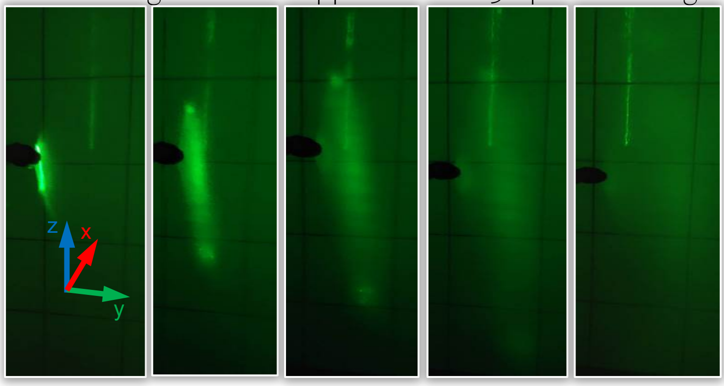

Figure 5 – Spray pattern section visualization – raw images

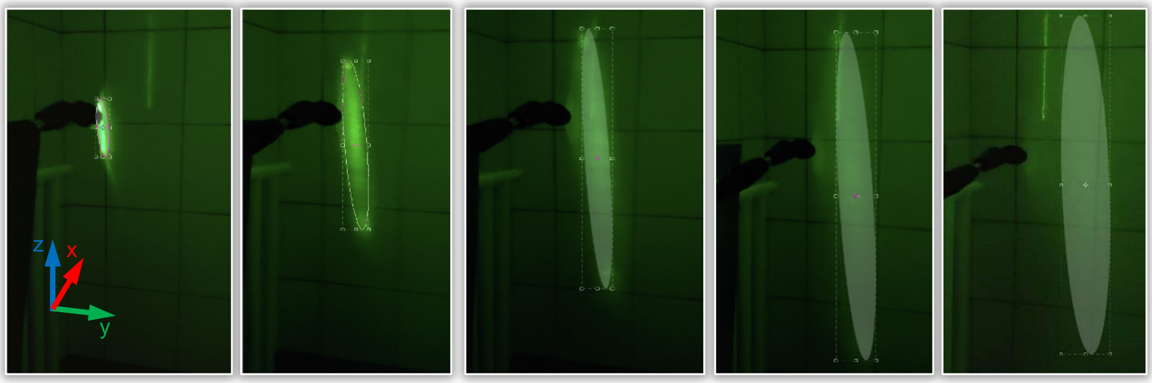

Figure 6 – Spray pattern section visualization – processed images

Based on spray pattern section raw images (Figure 5) after enhancing the images and making geometrical correctios, process images were available through which the real projection of each section was drawn. Image enhancing was necessary due to inappropriate environmental setup – walls covered in white, reflective tiles, presence of other reflective surfaces, lack of directional laser guide. Image geometrical corrections were necessary due to geometric deviations of the setup (axis misalignment) and geometrical aberrations from the optical lens.

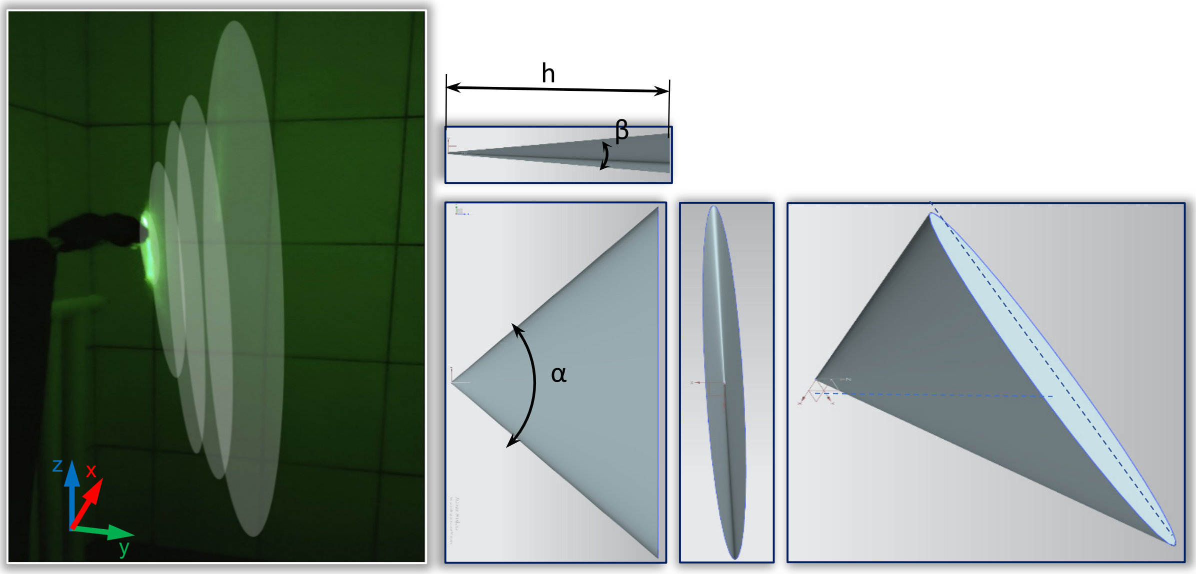

Figure 7 – Spray pattern section visualization – overlaid processed images and approximate 3D spray pattern with investigated parameters.

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As can be seen from on image in figure 7, several parameters of the jet spray can be determined using specific tools available in CAD software application.

Besides generating 3D spray pattern for a nozzle, another objective was to make preliminary investigations regarding flow visualizations for different nominal flow with similar geometry nozzles. As can be seen in the following visualizations (Figure 8), using the same pressure, at the same distance from nozzle tip, for different nozzles according to values from above table, there are noticeable differences corresponding to the prescribed flow values for each nozzle. This way a spatial distribution flow can be observed and is potentially quantifiable.

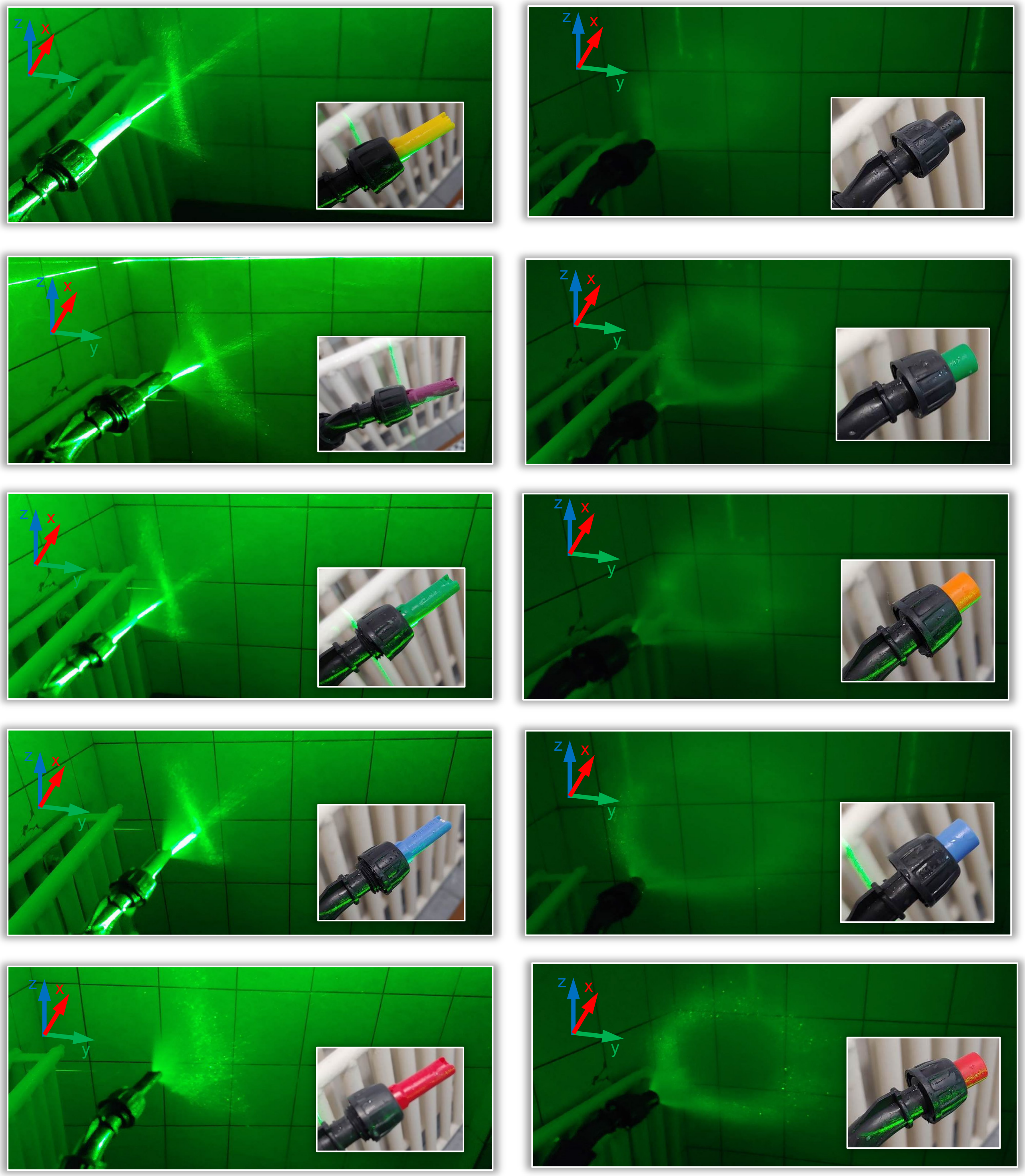

Figure 6 – Spray pattern sections visualization: a) with two laser planes for flat spray nozzles; b) with one laser plane for hollow cone spray nozzles

To obtain flow visualization, the method used, appear as a valid approach to investigate spray nozzle in a qualitative, fast, and economic way. Further refinements are necessary to maximize the quality of obtained visualizations. The easiest steps to do that are in correlations with minimising reflections within the used

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setup – black, light absorbent walls, use of lateral panels as a laser guide etc. Beside this using a finer TiO_2 powder, from micro to nano scale, further investigation should be made.

4. CONCLUSIONS

Within the paper a preliminary investigation of the planar laser flow visualization is made. The proposed method is using cheap, easily available instrumentation as digital camera, laser level, tripod for the hardware part. Regarding the software, generic applications can be used to enhance the quality of the pictures taken and to generate a 3D model as desired.

The results obtained confirm the approach used to preliminary investigate the quality of the nozzles flow. The laser level can be used to obtain jet sections in either plan. More than that, most of the laser level offer a second (and even a third) laser plan which can be used to easily obtain perpendicular section planes of the jet.

Using this technique several parameters of the spray jet can be determined. With an appropriate optical setup, a further and more detailed investigation can be made, respectively an analysis of size, number, and distribution of droplets.

According to the findings, a refinement of the proposed method is needed to increase the quality of flow visualizations which is going to be further investigated.

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