

The analysis of technical suitability of the equipment for application of plant protection products in Southeastern Slovenia

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Received January 23, 2017; accepted July 26, 2017.

Delo je prispelo 23. januarja 2017, sprejeto 26. julija 2017.

ABSTRACT

Technical testing of the equipment for the application of plant protection products (PPP) was performed in Southeastern Slovenia in the period from 2004 to 2013. The technical conditions of boom or orchard sprayers was examined in details and the following parts were checked: drive, anti-drip valves, nozzles, filters, pipes and tubes, manometers, all valves, pressure regulators, agitator, pump, liquid discharge, spray solution reservoir and spray boom or fan system. The analysis revealed a poor condition of most devices in the initial years. However, technical suitability improved drastically until 2013. Technical condition was not directly related to the region of inspection although the lowest number of defective sprayers was recorded in the Posavje region. This can be linked to higher frequency of use and maintenance of the sprayers in this region as it stands out as the area with larger farms. Occasional technical disorders of the equipment can be recorded each year. It is therefore essential to continue with regular technical inspection to ensure optimal and accurate functioning of the sprayers.

Key words: boom sprayers; orchard sprayers; technical conditions; cross application

IZVLEČEK

ANALIZA TEHNIČNE USTREZNOSTI OPREME ZA UPORABO SREDSTEV ZA ZAŠČITO RASTLIN V JOGOVZHODNI SLOVENIJI

V letih od 2004 do 2013 smo opravljali tehnične preglede za nanos FFS na območju jugovzhodne Slovenije. Pregledovali smo dve vrsti naprav in sicer škropilnice in pršilnike. Ugotavljali smo njihovo tehnično brezhibnost. Na vsaki napravi so bili pregledani sklopi kot so pogon, protikapni ventili, šobe, filtri, cevi, manometri, pipe in zasuni, regulatorji tlaka, mešalo, črpalka, praznjenje, rezervoar ter škropilne letve oziroma puhala pri pršilnikih. Analizirali smo podatke o napakah in ugotovili, da je bilo tehnično stanje naprav v začetnem obdobju, zelo slabo. Tehnično stanje naprav se je do leta 2013 zelo izboljšalo. Ugotovili smo tudi, da tehnično stanje naprav ni odvisno od območja njenega nahajanja. Je pa območje Posavja izstopalo po najmanjšem deležu okvarjenih naprav. Razlog za to vidimo predvsem v tem, da se naprave nahajajo na velikih kmetijah, kjer jih redno uporabljajo in vzdržujejo. Ker pa se okvare in napake, sicer v manjši meri, pojavljajo vsakoletno sklepamo, da je s pregledi potrebno nadaljevati, če hočemo obdržati doseženo stanje tehnične brezhibnosti, kajti naprave se ob uporabi prej ali slej obrabijo.

Ključne besede: škropilnice; pršilniki; fitofarmacevtska sredstva; tehnično stanje; prečni nanos

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1 INTRODUCTION

Devices used for the application of plant protection products (PPP) are machines, which enable uniform application of PPP to the plant surface. Devices usually utilize water to dissolve and apply PPP and can be categorized as sprayers and air assisted sprayers (Mrhar, 1997). Phytopharmaceutical products, which are applied via sprayers, destroy, suppress, control or deter harmful organisms and prevent their negative effect on plant growth and development or storage of plant products (Blažič, 2009).

Technical flawlessness of the spraying equipment is crucial for optimal distribution of PPP. The quality of the sprayer is important but it does not guarantee good results if the device is not properly managed and maintained. Up-to-date development of spraying equipment and its technical assistance and inspection are generally focused to ensure accurate PPP application (exact dosage, uniform distribution) and ameliorate other factors (such as working speed) (Roettele et al., 2011). Sprayers must provide exact application and uniform dosage of PPP during the entire lifespan of the device. To ensure their proper functioning, sprayers must be regularly tested and potential technical faults eliminated (Ganzelmeier, 2004a).

SIST EN 13790-1 (2004) and SIST EN 13790-2 (2004) standards were implemented in EU member states in order to unify the technical demands for testing of the devices for PPP application. The purpose of the standards is to ensure comparable testing conditions throughout the EU. Their contents can be summarized into the following significant points (Ganzelmeier, 2004b):

- (1) unification of different procedures, findings and technical demands, previously implemented in specific EU member states;
- (2) methodology and technical requirements are based on successful practices, previously implemented in specific EU member states;
- (3) high technical level is ensured with minimum time and funding;
- (4) EU member states are obliged to accept and implement new standards and withdraw old standards;
- (5) standards represent the basis for the unification of technical testing in the EU and serve as potential interactive tool in the future;
- (6) standards set technical requirements but do not regulate the decisions of specific EU member states.

In case of Poland, technical testing of the devices for the application of PPP started in 1995 and became

mandatory in 1999. Holownicki et al. (2004) reported similar national standards to that of SIST EN 13790-1 (2004) and SIST EN 13790-2 (2004) prior to their implementation. However, several parts of the spraying equipment were tested according to a less strict methodology, which frequently only included visual assessment.

Norway began technical testing of spraying equipment in 1990 (boom sprayers) and in 1995 (air assisted sprayers) on a voluntary level. The testing became mandatory for all devices in 2000. Although national technical tests were very sophisticated, slight changes were made after the implementation of SIST EN 13790-1 (2004) and SIST EN 13790-2 (2004) (Bjugstad et al., 2004) standards.

Italy started voluntary testing of air assisted sprayers in the Bolzano region as far back as in 1980. Oddly, technical testing of spraying devices has not been performed in several other regions to this day. In 2004, only 9 of 20 Italian regions had developed a system for technical testing. Some technical testing stations were established in 1996 – 1999 but most were founded in 2002 – 2004 (Balsari et al., 2004). Up to now, 120 testing stations are active in Italy but the testing is only mandatory in Tuscany region. Most technical tests are performed by private institutions. Public testing stations are mostly focused on voluntary testing and experimental testing of the spraying equipment (Balsari et al., 2004).

Germany implemented technical testing practices of spraying devices in late 1960 (boom sprayers) and in the middle of 1980 (air assisted sprayers) on a voluntary level. About 1000 testing stations are located in Germany today, which cover 2000 different locations. Testing became mandatory in 1993 and until then approximately 30.000 devices were tested each year. Today, as many as 63.000 sprayers are tested yearly (Osteroth, 2004).

In Slovenia, technical testing of spraying equipment was already defined in 1994 Plant Health Act (Zakon o zdravstvenem ..., 1994). Tests have been performed for the last two decades and the aim of the present paper is to present the testing results to a broader scientific community. The effects and results of the testing are discussed and strategies for their improvement suggested.

2 MATERIALS AND METHODS

Experimental data include the records of technical testing from 2004 until 2013. Inspections were performed at 86 different locations in Southeastern Slovenia, encompassing Agricultural advisory services Trebnje, Novo Mesto, Metlika, Črnomelj, Krško, Sevnica and Brežice. The research covers the area from Trebnje, Bela krajina, Novo Mesto, Škocjan, Šentjernej, Kostanjevica na Krki, Krško, Brežice to Bizeljsko. Micro locations (testing stations) varied each year (according to the suggestions of local communities) but this did not affect the groups of spraying devices subjected to inspection.

Technical testing was performed according to Rules on terms and procedures, which must be met by all authorized supervisory companies for regular inspection of PPP application devices (Pravilnik o pogojih ..., 2000, Pravilnik o spremembi pravilnika ..., 2002, Pravilnik o spremembah in dopolnitvi ..., 2005). The details on technical inspection are specified in aforementioned Rules on terms and procedures.

2.1 Measuring devices and other equipment

- Measuring set Herbst ROT-650/60/40/10
- Measuring of pump flow
- Measuring of the working pressure and the pressure gauge
- Measuring burettes Herbst ED 16 ECO
- Mobile Electronic Sprayer Test Equipment SprayerTest 1000

- Wireless rectifier Linksys
- Computer IBM Lenovo R60
- Drip tray
- Aluminum tracks for the trolley
- Inspection protocol (printed)

Boom sprayers and air assisted sprayers were inspected separately.

The following sections of the boom sprayer were inspected: spray solution reservoir, liquid discharge, agitator, pressure gauge, gate valves and other valves, manometer, pipes and tubes, filters, nozzles, spray boom, anti-drip valves and drive.

Several parts of the air assisted sprayer are identical to the parts of a boom sprayer but some segments are different. The following segments of air assisted sprayers were inspected: spray solution reservoir, liquid discharge, agitator, pressure gauge, gate valves and other valves, manometer, pipes and tubes, filters, nozzles, anti-drip valves, drive and blower.

2.2 Data analysis

Data were statistically analyzed in program R, version 3.0.2. Regression models- linear mixed models were used to interpret the correlation between the year and rate of faults. The level of risk was 5 %.

3 RESULTS AND DISCUSSION

3.1 Technical condition of all spraying devices

Technical condition of spraying devices varied according to the year of inspection. Data is presented in Table 1.

Table 1: Data on inspected devices (data on boom sprayers and air assisted sprayers merged) in a particular year

Preglednica 1: Podatki o pregledanih napravah (škropilnice in pršilniki skupaj) v posameznem letu

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Inspected devices	1440	2037	799	1419	1012	2006	1013	1939	1056	1823
Defected devices	708	851	374	517	188	150	56	63	39	29
Share of defected devices	49.2%	41.8%	46.8%	36.4%	18.6%	7.5%	5.5%	3.2%	3.7%	1.6%

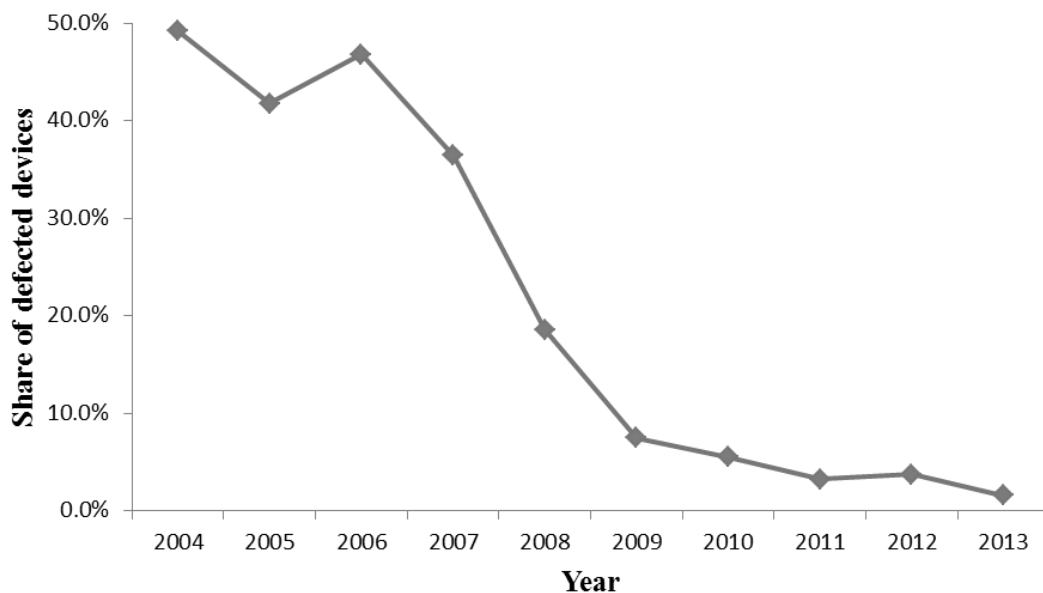


Figure 1: Share of defected devices in a particular year (data on boom sprayers and air assisted sprayers merged)

Slika 1: Delež okvarjenih naprav za obe vrsti naprav v posameznem letu

The share of defected spraying devices declined consistently from 2004 until 2013, with a slight increase detected in 2006. The greatest decline in the share of defected sprayers was observed between the years 2004 and 2009, when the share dropped to less than 10 %. The share of defected devices gradually declined until

2013 but in a smaller proportion compared to the initial experimental period.

3.2 Technical condition of boom sprayers

Data on boom sprayer technical testing is presented in Table 2.

Table 2: Data on inspected boom sprayers in a particular year

Preglednica 2: Podatki o pregledanih škropilnicah v posameznem letu

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Inspected devices	1080	1504	594	1085	713	1461	719	1381	722	1287
Defected devices	594	731	316	472	170	132	48	56	28	23
Share of defected devices	55.0%	48.6%	53.2%	43.5%	23.8%	9.0%	6.7%	4.1%	3.9%	1.8%

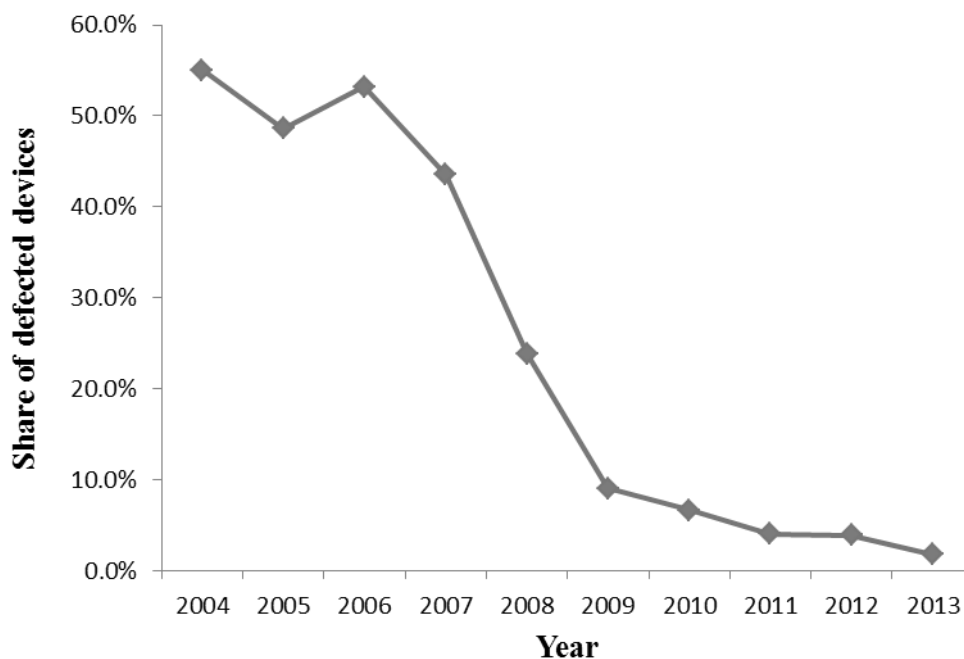


Figure 2: Share of defected boom sprayers in a particular year

Slika 2: Delež okvarjenih škropilnic v posameznem letu

We assumed that the share of defected boom sprayers decreased during the 10-year period. Data analysis was performed on several segments of the boom sprayer.

Table 3: Results of data analysis using the linear mixed model for several boom sprayer segments

Preglednica 3: Rezultati linearnega mešanega modela na podatkih za posamezne sklope - škropilnice

	Coefficient	Standard error	df	t	p-value
Intersect	0.079	0.016	116	4.863	0.0000
Year	-0.010	0.002	116	-4.895	0.0000

The negative value of the coefficient suggests that the defects on boom sprayers decreased in the examined period.

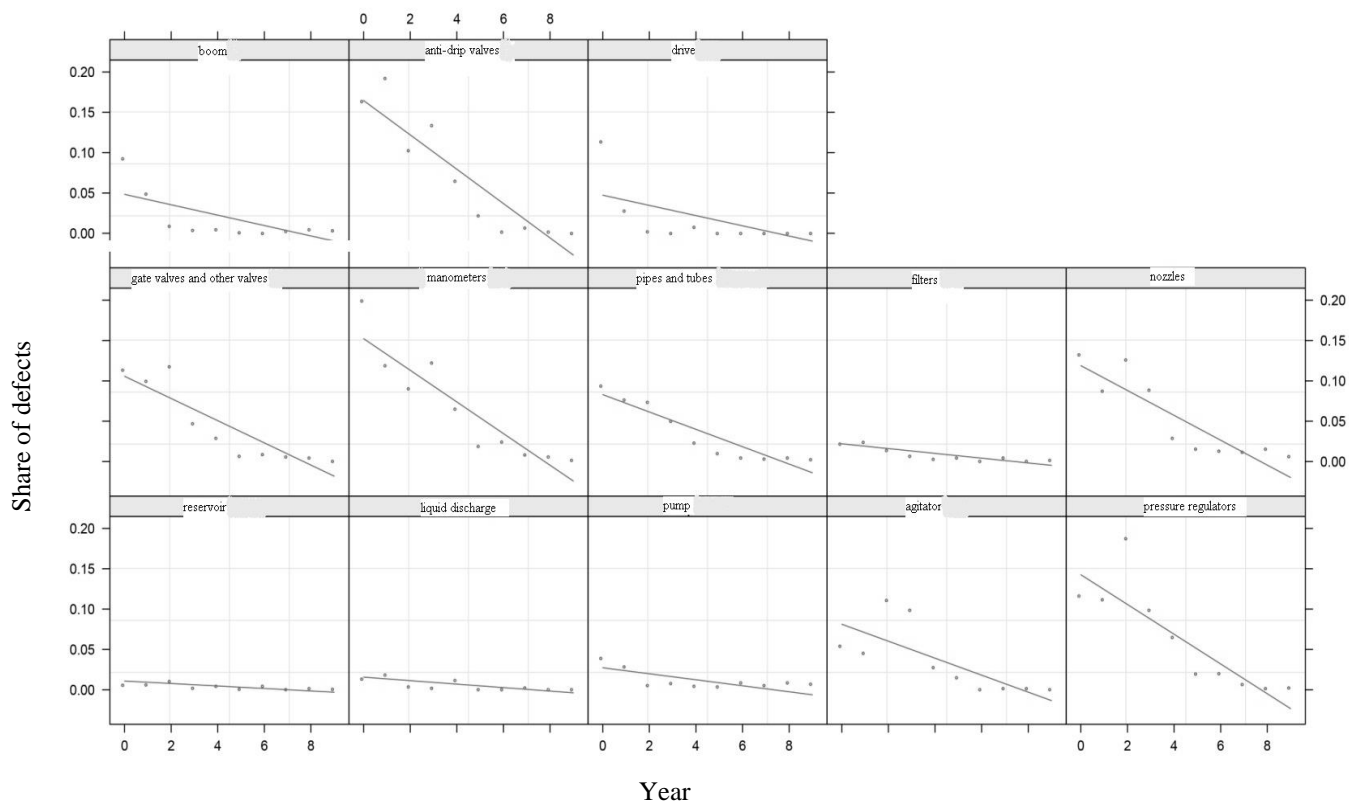


Figure 3: Share of defects on individual segments of a boom sprayer depending on the year – 0 marks year 2004

Slika 3: Delež napak za posamezen sklop v odvisnosti od leta - število 0 na abscisni osi ponazarja začetno leto 2004

Figure 3 depicts the decrease of share of devices with defects in all segments of boom sprayers in the period from 2004 to 2013. Some differences were minor but the condition of several segments was significantly improved.

3.3 Technical condition of air assisted sprayers

Differences in technical conditions of air assisted sprayers are reported in Table 4.

Table 4: Data on inspected air assisted sprayers in a particular year

Preglednica 4: Podatki o pregledanih napravah (pršilniki) v posameznem letu

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Inspected devices	356	531	204	332	299	541	294	555	334	534
Defected devices	114	119	58	45	18	18	8	7	11	6
Share of defected devices	32.0%	22.4%	28.4%	13.6%	6.0%	3.3%	2.7%	1.3%	3.3%	1.1%

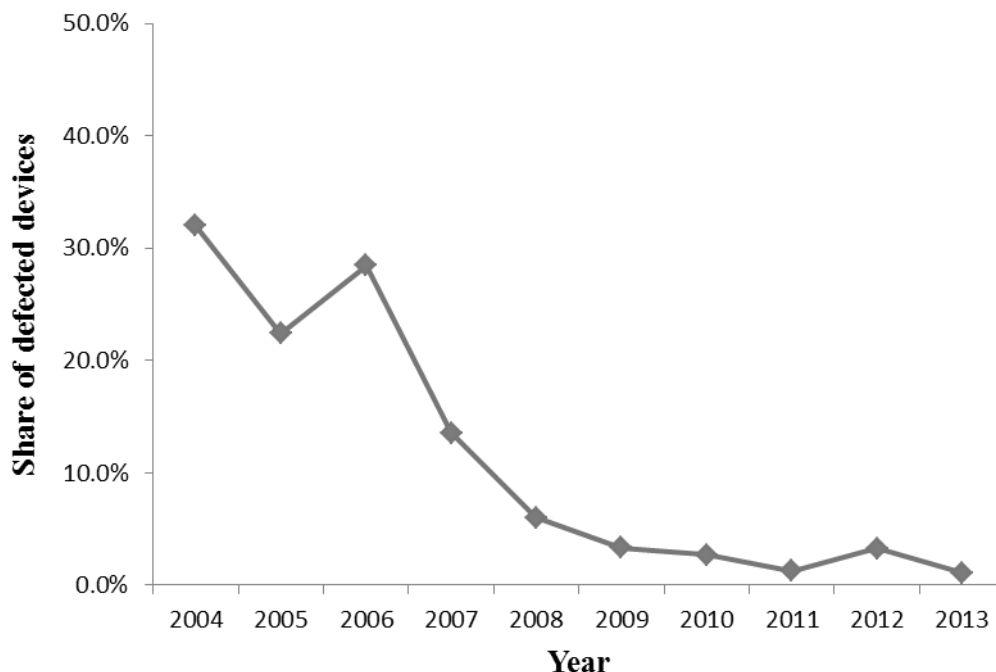


Figure 4: Share of defected air assisted sprayers in a particular year

Slika 4: Delež okvarjenih pršilnikov v posameznem letu

The share of defected air assisted sprayers ranged between 20 and 30 % in the period of 2004- 2006 and dropped to 13.6 % in 2007. The share was less than 10 % after 2008.

Data were statistically analyzed and a decrease of defected air assisted sprayers was expected in the 10-year period.

Analysis was performed on several segments of air assisted sprayers.

Table 5: Results of the linear mixed model analysing data of several air assisted sprayer segments

Preglednica 5: Rezultati linearnega mešanega modela na podatkih za posamezne sklope - pršilniki

	Coefficient	Standard error	df	t	p-value
Intersect	0.023	0.008	116	3.313	0.0012
Year	-0.004	0.001	116	-3.239	0.0016

The negative value of the coefficient denotes a decrease of defects in air assisted sprayers during the examined period.

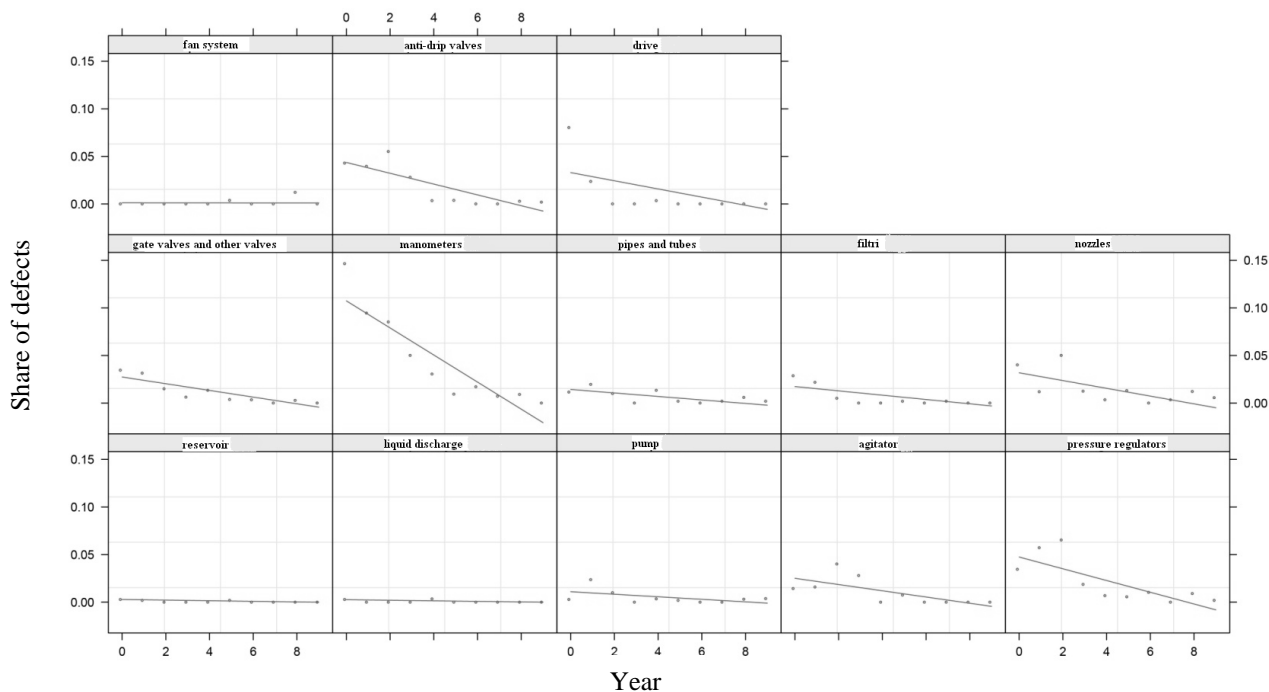


Figure 5: Share of defects on individual segments of an air assisted sprayer depending on the year – 0 marks year 2004

Slika 5: Delež napak za posamezen sklop v odvisnosti od leta - številka 0 na abscisni osi ponazarja začetno leto 2004

The share of defects on all segments of air assisted sprayers decreased in the period from 2004 to 2013. The only exceptions were defects on the air blower, which increased slightly from 2009 to 2012.

3.4 Technical condition linked to the region of the technical testing

The locations for technical testing were not the same each year and therefore, the area was divided into seven units, each corresponding to the jurisdiction of a single

Agricultural advisory service (Trebnje, Novo Mesto, Metlika, Črnomelj, Krško, Sevnica and Brežice). Three main regions were formed based on geographical similarities for easier data analysis: (1) Osrednja Dolenjska (combining KSS Novo Mesto and Trebnje; NMTr), (2) Bela Krajina (combining KSS Črnomelj and Metlika; ČrMe) and (3) Posavje (combining KSS Brežice, Krško and Sevnica; BKKSe). Results report combined data on defects of both types of sprayers for each region.

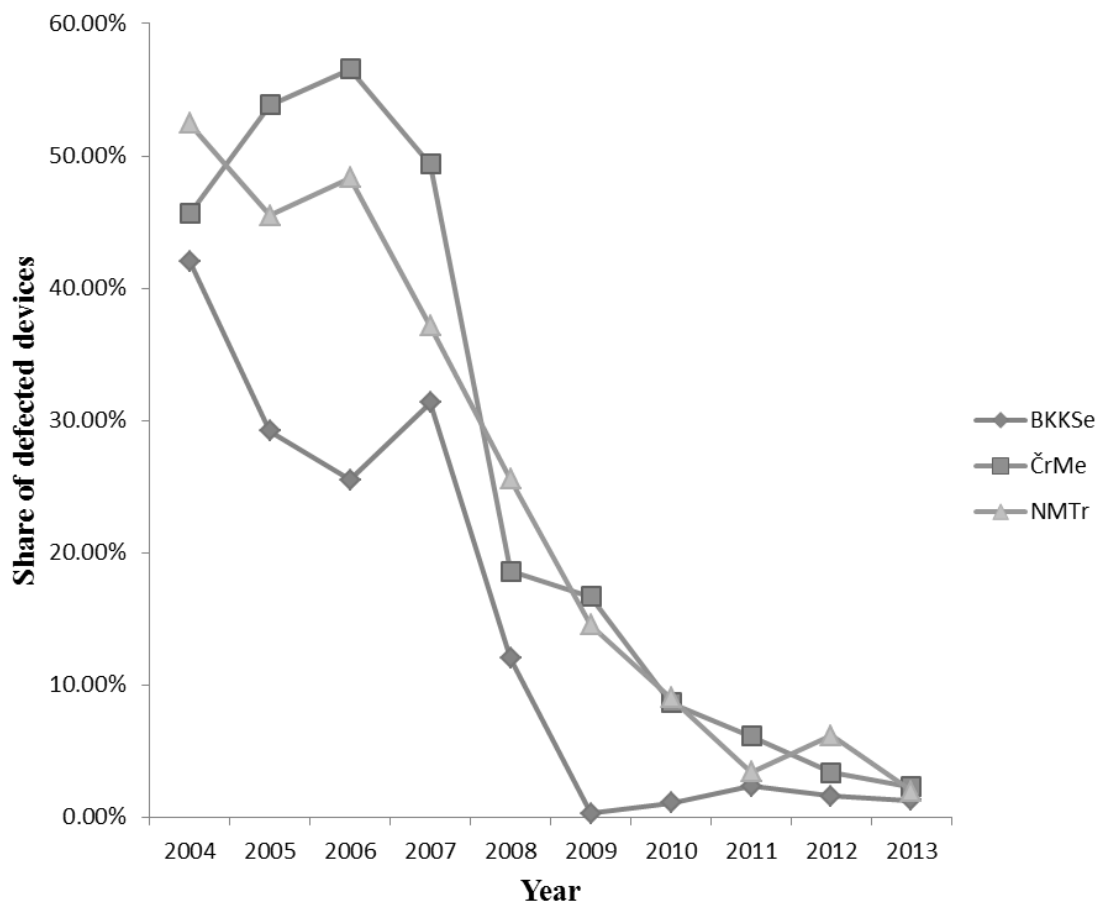


Figure 6: Share of defected sprayers in a specific region during the period of 2004-2013

Slika 6: Delež okvarjenih naprav v posameznem območju v letih 2004-2013

The share of defect sprayers was somewhat higher in Bela Krajina region in 2006 compared to 2004 and decreased significantly after 2006. A similar pattern was detected in Osrednja Dolenjska region, where the share of defected sprayers increased slightly in 2006 and

decreased dramatically after that period. In Posavje region the pattern shows a significant decrease of defected sprayers from 2004 until 2007. In that year the share increased prior to a significant decrease of defected sprayers after 2008.

4 CONCLUSIONS

4.1 Technical condition of all spraying devices

As anticipated, technical condition of all spraying devices (boom sprayers and air assisted sprayers) increased during the examined time period.

Although technical inspection of PPP spraying devices in Slovenia began two decades ago, it only became mandatory in 2002. The initial technical condition of spraying devices was therefore poor, which can be ascribed to the general non-attendance at testing prior to 2002. Only environmentally conscious individuals and larger farmers tested their sprayers on a regular basis as

they were aware of the importance of proper functioning of the devices. The latter are only effective in distribution of PPP if their technical condition is optimal. Frequently, leakage, poor distribution of the liquid solution and inadequate dosing (output) were recorded at testing, which resulted in reduced quality of application and economic loss. Every deviation from standard functioning of the sprayer inevitably leads to inefficient use of PPP.

Sadly, it seems that many farmers were not concerned with inferior performance of their sprayers as they only

cultivate small areas of land and are thus satisfied with reduced performance - functioning of the devices. Small-scale farmers only require minor quantities of PPP and do not regard plant protection as a major economic cost of farming. This can be linked to a great number of defects on sprayers in the initial years of technical testing, i.e. in 2004 and 2005. Later, farmers were obliged to test their spraying equipment by law and a qualified mechanic serviced their devices on site. Many minor defects were corrected and users were simultaneously educated on a proper use and maintenance of the spraying equipment.

The results of this practice came to sight in the following years as the number of defects on sprayers greatly reduced. This proves the importance of regular technical testing for improved condition of spraying equipment in Slovenia.

However, defects can be recorded each year and it is therefore essential to proceed with technical testing of PPP sprayers in the future. Spraying devices have a limited lifespan and technical performance of every sprayer is reduced in time. For example, defected sprayers from the period of 2004-2008 were once in immaculate condition but because of their use and/or poor maintenance flaws occurred. That is why sprayers must be tested on a yearly basis to limit the use of faulty equipment on Slovenian farms and uncover hidden defects on the equipment such as inferior transversal distribution of spraying solution.

Technical condition of boom sprayers

As expected, technical condition of boom sprayers greatly improved in the experimental period. Many defects were recorded on different segments of boom

sprayers in 2004 and 2005 and their number was reduced in later years.

Technical condition of air assisted sprayers

As in boom sprayers, technical condition of air assisted sprayers improved dramatically from 2004 to 2013. Most defects were similarly recorded in 2004 and 2005 and a superior condition of these devices was recorded in later years.

4.2 Technical condition linked to the region of the technical testing

Locations were grouped according to the jurisdiction of Agricultural advisory services and three main regions were formed based on geographical similarities of the area. We assumed that the technical condition of spraying devices is not defined by region and the hypothesis was confirmed. No significant differences were detected among the three regions. Nevertheless, smaller share of defected sprayers was recorded in the Posavje region which can be ascribed to several factors. Many large farms are active in this region and consequently, the farmers possess newer and better equipment for PPP application. The spraying devices are less prone to develop any defects and are also regularly serviced. Experiences show, that small-scale farmers frequently use defected sprayers on their land. The devices are old and poorly maintained but the farmers cannot afford new mechanization due to non-favorable economic calculation based on limited land use. The other reason for superior results of the Posavje region may be linked to better technical support of Agricultural advisory services and education on the importance of proper PPP use in this area. These practices should be inspected in detail and implemented in other areas.

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