Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 40
ISSUE 1
May
2010

The efficiency of different machines for controlling of western corn rootworm adults

D. Stajnko [a,*], M. Janzekovic [a], B. Mursec [a], P. Vindis [a], F. Cus [b]
[a] Faculty of Agriculture and Life Sciences, University of Maribor, Pivola 10, 2311 Hoče, Slovenia
[b] Faculty of Mechanical Engineering, University of Maribor, Smetanova 17, 2000 Maribor, Slovenia
* Corresponding author: E-mail address: denis.stajnko@uni-mb.si

Received 27.02.2010; published in revised form 01.05.2010

Manufacturing and processing

ABSTRACT

Purpose: the appearance western corn rootworm (Diabrotica virgifera virgifera LeConte) in Slovenia brings new challenges to machines used for pesticide spraying of corn. The control of western corn rootworm is difficult due to the height of the corn crop in July-August. The current paper presents the exploitation characteristics of mistblower with cannon and field sprayer with high-mounted spraying boom and vertical tube extension with distributing nozzles on pesticide distribution over the corn plant.
Design/methodology/approach: Two field experiments with different air adjustments and driving speed (mistblower with cannon) and nozzle flow and driving speed (field sprayer with high-mounted spraying boom) were research.
Findings: The ventilator of the mistblower spread the pesticide over the wider band of the field as the field sprayer, however the pesticide distribution measured as coefficient of variation did not fulfil the legislative requirements.
Research limitations/implications: The experiment results presented herein can be applied under similar equipment adjustment, working speed and growing conditions of the corn plant (78.000/ ha and the height of 2.70 m).
Practical implications: The field sprayer with high-mounted spraying boom and vertical tube extension was proved as an efficient machine for controlling of western corn rootworm adults in the developed corn growing over 2.70 m. With the presented technical procedure the damage caused by the western corn rootworm can be almost completely prevented. However due to the growing stage of the plant in the time of spreading of the adult, about 6.5 % of the plants are overridden.
Originality/value: By implementing the findings from our experiments a severe damage in corn yield caused by the western corn rootworm can be reduced significantly. On that way an effective way in production of corn can be contribute to farmers' economy.
Keywords: Technological devices and equipment; Machines; Mistblower; Sprayer

Reference to this paper should be given in the following way:
D. Stajnko, M. Janzekovic, B. Mursec, P. Vindis, F. Cus, The efficiency of different machines for controlling of western corn rootworm adults, Journal of Achievements in Materials and Manufacturing Engineering 40/1 (2010) 79-86.

1. Introduction

The western corn rootworm, Diabrotica virgifera virgifera LeConte (Fig. 1), is one of the most devastating corn rootworm species in North America. Corn rootworm larvae can destroy significant percentages of corn if left untreated. In the United States, current estimates show that 120.000 km² of corn are infested with corn rootworms and area is expected to grow over the next 20 years [1]. Since 2003 the pest has been spreading also over the Slovenian corn fields from the eastern Pannonia infestation pond [2]. Till the 2009 the western corn rootworm has infested almost all of 73,894 ha of corn fields and caused severe damage in grain as well the silage corn yield [3] . The importance of the pest is explained by the fact that in corn monoculture it may cause significant yield decrease, incomplete fructification and the accretion of the pest [4].

Fig. 1. The adult western corn rootworm, Diabrotica virgifera virgifera LeConte

The corn can be protected by indirect or direct treatment. The first one includes the choice of health environmental condition for growing the corn, appropriate field, agro-technical dimensions, crop rotation, selection of tolerance hybrid, weeds and self-seeded corn control, field tillage and the use of fertilizers. Direct methods for controlling the western corn rootworm include different methods and treatment such as biological, biotechnical and chemical [5]. Chemical treatment can be further divided into controlling the larvae, which are fed on root hairs and small roots; and adults, which prefer to feed on corn leaves and pollen sources. The larvae are treated by implementing of pesticides on seed or by using the soil granulates. However, for controlling adults different agricultural machines for distributing the pesticides (mistblowers and sprayers) all over the corn plants must be applied [6].

2. Description of the approach, work methodology, materials for research, assumptions, experiments etc.

The spray distribution and coverage measurements presented in the article are the outcome of experiments carried out in the research field of Mostje (46°27'26"N 15°57'19"E) owned by the Agricultural Institute of Slovenia. The experiment was performed in the corn (Zea mays L.),which was sown with a four-row Monosem NX pneumatic planter for direct and conventional seeding with precise seed and fertilizer metering units [7]. The corn hybrid used was a Pioneer PR37M34 for silage and the seeding rate was 80.000 seeds ha^{-1} with 70 cm row width and 6 cm planting depth.

In the field experiment the efficiency of two different types of machines for distribution of pesticides were researched. The first one represents a commercial misblower Unigreen AP1000 (Fig. 2); the second one was a prototype sprayer developed by modification of a trailed air-assisted sprayer AGS 1000 EN (Agromehanika, Kranj), equipped with a piston pump and a 1000 l tank sprayer (Fig. 3).

Fig. 2. A mistblower Unigreen AP1000

Fig. 3. A field sprayer AGS 1000 EN with mounted high boom

During the tests the following mean values for the meteorological conditions were recorded: temperature 19.9-24.2°C, relative humidity 60.8-75.8%, wind speed 1.1-1.7 ms^{-1} and wind direction 16-41 deg deviation from perpendicular direction of the sprayer track.

The spraying was performed on both fields at forward speed of 1.39 ms^{-1} (5.00 kmh^{-1}) for both spraying modes. In the case of mistblower a characterization of the air stream was obtained with a 3D ultrasonic anemometer (Young 81000, R.M. Young Co., USA). To ensure proper sampling, air velocities were measured in an axial horizontal direction, 500 mm apart from the spouts of the mistblower. During all tests, the PTO rotational speed was 540 min ^{1}, which gave in mistblower a mean air volumetric flow rate of 4.13 $m^3 s^{-1}$ and a mean air velocity of 15.8 ms^{-1}.

As presented in Table 1 the mistblower sprayer was equipped with six hollow cone nozzles TeeJet TXA8001VK and four hollow cone nozzles TeeJet TXA8002VK (2.8 l min^{-1}) operating with a pressure drop of 10.0 bars, to give total spray flow rates of 19.36 l min^{-1}. Thus, the maximum range of values for the applied spray volume per unit of ground area was 500 l ha^{-1}, when all the nozzles were opened.

Table 1.
Nozzles parameters of the mistblower [11]

Nozzle type	TeeJet TXA 8001	TeeJet TXA 8002
Colour	Orange	Red
No. of nozzles	6	4
Pressure	10 bar	10 bar
Spray flow rate per nozzle	1.36 l min^{1}	2.80 l min^{1}
Spray flow rate all nozzles	8.16 l min^{-1}	11.20 l min^{-1}
Forward speed	5.0 km h^{-1}	5.0 km h^{-1}
Working width	7.75 m	7.75 m
PTO speed	540 min^{-1}	540 min^{-1}
Volumetric air flow rate	4.13 ($m^3 s^{-1}$)	4.13 ($m^3 s^{-1}$)

From Table 2 we can see that the sprayer was equipped with six hollow cone nozzles Albuz TVI 80015 operating with a pressure drop of 5.0 bar, to give total spray flow rates of 4.62 l min^{1}. Thus, the maximum range of values for the applied spray volume per unit of ground area was 272 l ha^{-1}, when all the nozzles were opened.

Table 2.
Nozzles parameters of the sprayer [12]

Nozzle type	Albuz TVI 80015
Colour	Orange
No. of nozzles	6
Pressure	5 bar
Spray flow rate per nozzle	0.77 l min^{-1}
Spray flow rate all nozzles	4.62 l min^{-1}
Forward speed	5.0 km h^{-1}
Working width	9.0 m
PTO speed	540 min^{-1}

Percentage insecticide efficacy on total as well as on individual western corn populations was determined using the Henderson-Tilton formula [9] based on no-uniform beetle infestation in the plots before application:

$$\text{Corrected } \% = \left(1 - \frac{\text{n in Co before treatment} * \text{n in T after treatment}}{\text{n in Co after treatment} * \text{n in T before treatment}}\right) * 100$$

n = Insect population, T = treated, Co = control

This formula was used because the coincidental fluctuations of the beetle counts in the plots before insecticide application could increase the deviation of the efficacy values and render the interpretation of the results more difficult. Henderson-Tilton's formula corrects arithmetically the various initial beetle infestation numbers without separating sampling errors from the actual differences in infestation [9].

2.1. Experiment with mistblower

In the field close to the town Mostje, the treatment was performed in the time of maximum corn flowering on August 14th 2007. The average height of the plant was 2.70 m.

The experimental field was a 50 m long and 22.4 m wide (32 rows) parcel. As shown on Fig. 4. eleven rows were included in the trial beginning from the second one on the east (right) and followed by every third one. Each row represents one block in which 12 corn plants were randomly selected for measuring the pesticide distribution on the WSP papers.

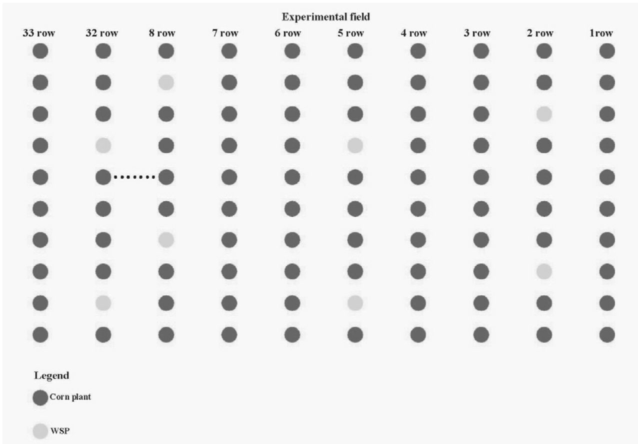

Fig. 4. A plan of experiment with mistblower

2.2. Experiment with sprayer

The experiment with a sprayer was performed one the same day on the same field as the one with the mistblower.

However, due to the sprayer design from a 50 m long and 9.5 m wide (14 rows) parcel only 5 rows from the middle to the left and 5 rows from the middle to the right were selected for the experiment (Fig. 5). Each row represents again one block. In one block 12 corn plants were randomly selected for measuring the pesticide distribution on the WSP papers as described previously.

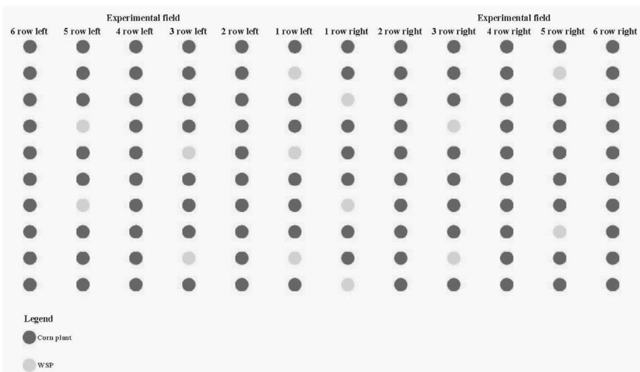

Fig. 5. A plan of experiment with sprayer

2.3. Analysis of spray coverage

In order to quantify the produced spray coverage and to study the penetration efficiency of the drops by different spray modes, Water Sensitive Papers (75x 26 mm, WSP, Novartis) were placed every time immediately before each spraying as proposed by [10]. The WSP were collected approximately 10 minutes after they had completely dried.

Each selected plant was divided into 2 zones as shown in Fig. 6. (AC) represents the position on the first leaf above the corn cob and the (BC) represents the position of the first leaf beyond the corn cob.

Fig. 6. The position of the WSP papers (yellow circles) on the corn plant

From each WSP three randomly selected samples were captured and digitized by using the Optomax Image Analysis system (Hollis, New Hampshire), consisting of a CCD camera with a zoom lens, a monitor to control the picture being analyzed [13], and a PC with a Frame Grabber card (Fig. 7).

Fig. 7. Equipmernt for masuring the pesticide coverage on WSP with Optomax Image Analysis system

The area resolution of the system was 1/417600 per field of view (720×580 pixels), so the smallest spot size detected by 1 pixel was 8 μm and image depth was 256 grey levels as described by [14]. By using this system, coverage (with stains covered area - % coverage) the number of impacts and the number of impacts per area were all analyzed. All data were transferred from Optomax to formatted computer spread-sheets (Microsoft Excel) before statistical analysis of variance using the SPSS 16.0 Package Program [15].

3. Description of achieved results of own researches

3.1. Total spray distribution and coverage

The quality of spray distribution determined by analysis of WSP was expressed as the percentage of coverage, the impact area (mm^2) and the number of impacts per cm^{-2}. Whenever comparing Fig. 8 and Fig. 9 we can obviously see that both machines effect the distribution of droplets across the field differently. In the case of mistblower (Fig. 8) the average coverage was falling rapidly from the second row (53 %) to 11th row (7.5 %), while in case of sprayer (Fig. 9) the average coverage varied only from 19-25 %. Knowing that according 15 – 25 % coverage is necessary for biological effectiveness [14] all the deposits from the 11th to 32nd row was lower and can be assumed as losses – drift. The main reason for such distribution lies in the way of transporting the droplets, which in the case of mistblower are directly driven by the air stream produced by a radial fan. Thus, after the 8th row the air stream lost the initial speed and power to such extend that it could not penetrate the corn crop efficiently anymore.

This is contrary to the sprayer, which produces and transfers the droplets to the leaves only by a pressure produced by a piston pump without additional wind support.

The impact area measured in mm^2 as the total deposits on the WSP is represented in Fig. 10 and Fig. 11. Once again it can be seen that each machine produce different distribution of the impacts. The mistblower (Fig 10) produced the highest area in the second row (over 900 mm^2 per WSP), but then this number was reduced to 700 mm^2 (in the fifth) and only 110 mm^2 in the 11th row.

Contrary, in the experiment with sprayer (Fig. 11) the impact area varied significantly smaller i.e. from 160 to 220 mm^2 per WSP than in mistblower, which means that all the parts of corn plants were also sprayed more evenly.

The most important parameter of pesticide distribution is without any doubt the number of impact per cm^2 of WSP, which is presented in Fig. 12 and Fig. 13 respectively. Contrary to the coverage and the total impact area this feature expresses the real number of impacts detected on particular image (sample) captured by the Optomax Image Analysis system.

As seen from Fig. 12 the droplets were detected all over the experimental field whenever produced by a mistblower, although it was not assumed from the % of coverage, because it was too low. However, the number of droplets varied significantly across the field from the highest (900) in the 11th row to the lowest (25) in the 32nd row. It is very interesting that contrary to the coverage the number is falling from the second to eighth row and then suddenly risen up. The main reason for such sample lies in the double air sprout of the mistblower, which obviously interference over this particular part of the field. But, because of the very high mixture of the air, the particles were very small. Therefore, in case of eleventh row despite the huge number the droplets (900) coverage remained very small (7.5 %). However, those small particles can be driven away from the field or even evaporate very easily, thus the practical effect remained almost unimportant.

When we now look on the Fig. 13 representing experiment with the sprayer, the situation is quite different. All the values are distributed very even lying in the narrow band from 325 to 470 impacts per cm^2 of WSP than in the case of mistblower, which also means that those particles had very even diameter (mass). On that way the drift (loss caused by the air movement) is much smaller or even omitted.

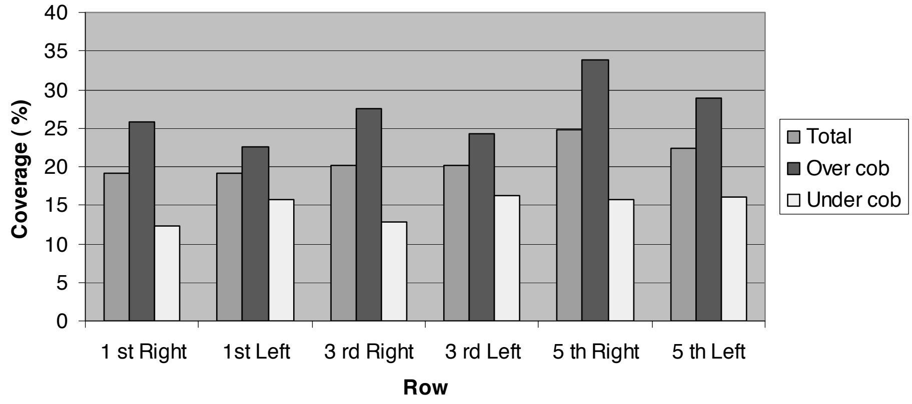

Fig. 8. The total coverage on WSP in experiment with sprayer

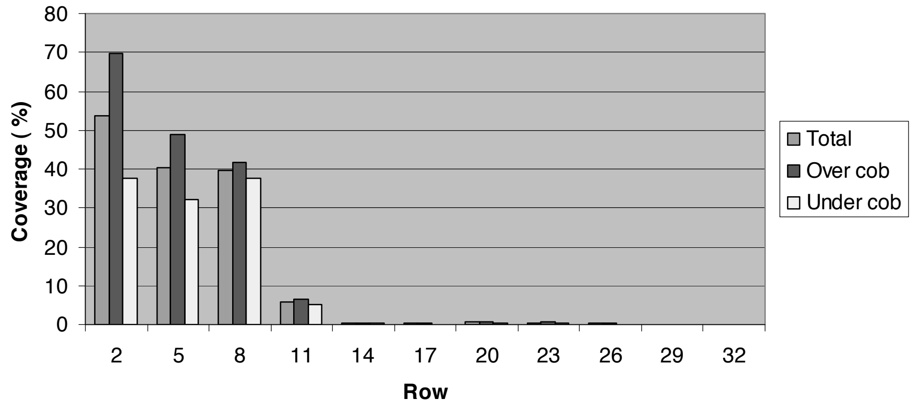

Fig. 9. The total coverage on WSP in experiment with mistblower

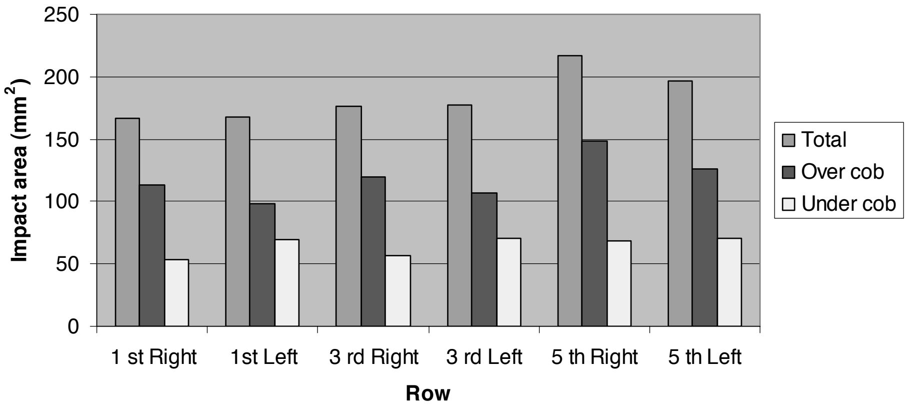

Fig. 10. The impact area on WSP in experiment with sprayer

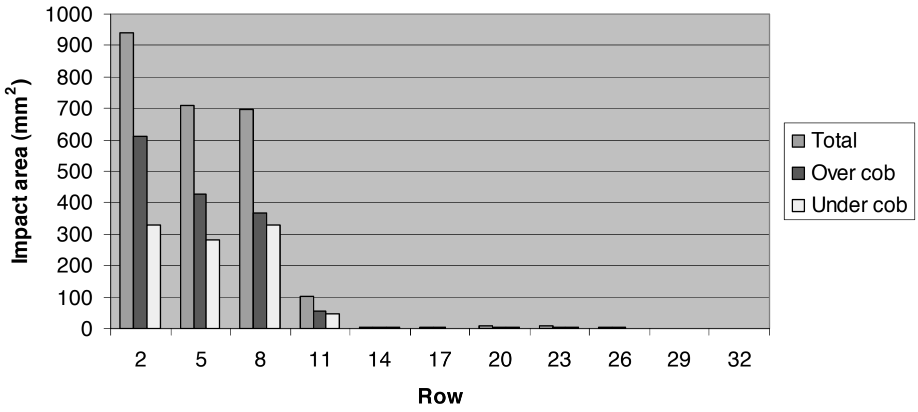

Fig. 11. The impact area on WSP in experiment with mistblower

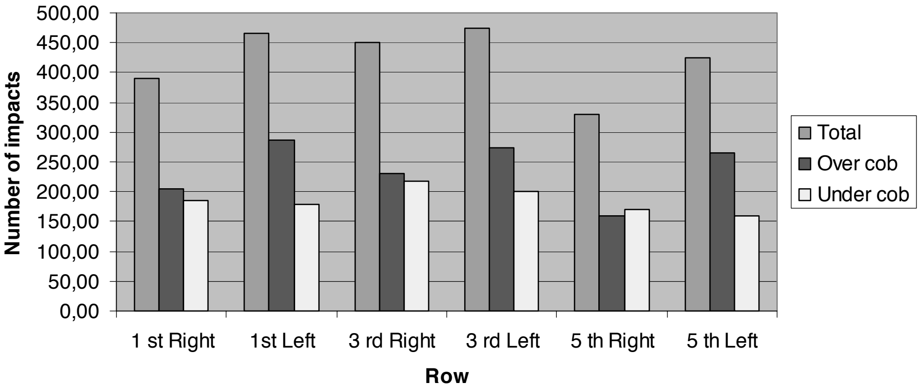

Fig. 12. The number of impacts on WSP in experiment with sprayer

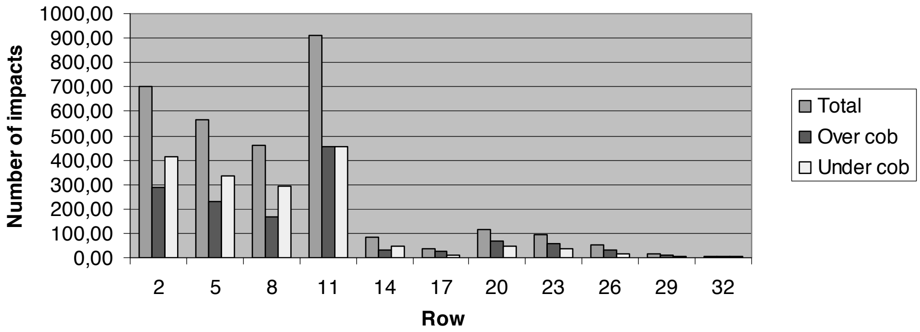

Fig. 13. The number of impacts on WSP in experiment with mistblower

3.2. Crop looses during spraying

Although the distribution of the pesticide over the field was much even and precise in the experiment with the sprayer as was the case with the mistblower, a certain percentage of crops are destroyed during spaying because of direct driving on the field. As seen from Table 3 the percentage of looses depends on the distance between the rows and the wide of the spraying boom. Since the distance between the sowing elements on the planter is usually set on 70 cm, it is difficult and unpractical to adjust it on a single field. From this reason the only alternative for reducing looses remains the use of sprayer with wider spraying boom.

Table 3.
Looses of the corn crop during spraying

Distance between rows (cm)	Losses of plants (%)				
	Spraying boom (m)				
	10 m	12 m	18 m	24 m	36 m
62.5	12.5	10.4	6.9	5.2	3.5
66.0	13.2	11.0	7.3	5.5	3.7
70.0	14.0	11.7	7.8	5.8	3.9
75.0	15.0	12.5	8.3	6.3	4.2

3.3. Biotical efficiency

The pesticide distribution is just the first step towards biotical efficiency of the pesticide, therefore additional Henderson – Tilton test was proceed during our experiment.

Table 4.
The biotical efficiency of the pesticide

The biotical efficiency according to Henderson – Tilton (%)		
Time after treatment (h)	Mistblower	Sprayer
24	75	79
96	48	62
144	35	46
192	22	21

It is clearly seen from Table 4, that the way of distribution did not significantly effects the biotical efficiency after 24 and 192 hours after treatment, however after the 96 and 144 hours after the treatment the efficiency was slightly higher in sprayer than in mistblower. Knowing that the first 24 hours is the most important time from practical point of view, we may conclude, that both machines provide efficient biotical efficiency against western corn rootworm adults.

4. Conclusions

Since 2003 the appearance of western corn rootworm (Diabrotica virgifera virgifera LeConte) in Slovenia caused a significant decrease in produce of grain and silage corns, which demand a big challenge to machines for spraying of corn. In the time of beetle fly (July-August) the height of the corn crop a mistblower with cannon and field sprayer with high-mounted spraying boom was tested under the field condition.

Although the ventilator of the mistblower spread the pesticide over the wider band of the field than the field sprayer, the pesticide distribution measured on the WSP was not favourable. Due to the number of impacts and coverage on the WSP, which was much better in case of field sprayer, the spaying with high mounted boom is suggested in the very next future. However, in this particular way of pesticide distribution 4.2 to 15.0 % of corn plants are additionally lost because of travelling directly on the field.

From this reason it is suggested to use a high track tractor (straddle tractor) with mounted sprayer, which does not destroy corn plants and would represent the most effective way in protection of corn and can contribute to farmers' economy significantly.

Acknowledgements

This research was funded by The Ministry of Agriculture, Forestry and Food of the Republic of Slovenia, project number V4-0336. The funding is gratefully acknowledged. The authors also acknowledge the vital contributions made by the following colleagues: Peter Berk and Gregor Leskošek, who was responsible for the manual measurements, and to Professor Mrs. Michelle Gadpaille, for his lectureship of the manuscript.

References

[1] S.P. Strnad, P.E. Dunn, Host search behaviour of neonate western corn rootworm (Diabrotica virgifera virgifera), Journal of Insect Physiology 36/3 (1990) 201-205.

[2] Statistical Yearbook, Statistical Office of the Republic of Slovenia, Ljubljana, 2009.

[3] P. Vindiš, B. Muršec, M. Janžekovič, F. Čuš, The Impact of mesophilic and thermophilic anaerobic digestion on biogas production, Journal of Achievements in Materials and Manufacturing Engineering 36/2 (2009) 192-198.

[4] M. Janžekovič, B. Muršec, P. Vindiš, F. Čuš, Energy saving in milk processing, Journal of Achievements in Materials and Manufacturing Engineering 33/2 (2009) 197-203.

[5] T. Poje, T. Godeša, D. Stajnko, V. Jejčič, G. Urek, Š. Modic, Špela, G. Leskošek, M. Rak-Cizej, M. Sagadin, M. Lakota, Miran, Technical aspects of machines chosen for the control of adult Western Corn Rootworm, Proceedings of Symposium "Novi Izzivi v Poljedelstvu", Slovenia, 2008, 303-308.

[6] D. Stajnko, M. Janžekovič, M. Brus, F. Čuš, The Effect of direct seeding on soil resistance and the silage corn yield, Journal of Achievements in Materials and Manufacturing Engineering 35/2 (2009) 184-190.

[7] D. Stajnko, M. Janžekovič, M. Brus, F. Čuš, The Effect of direct seeding on the soil characteristics and the silage corn yield, Proceedings of the Worldwide Congress "Materials and Manufacturing Engineering and Technology" COMMENT'2009, Gliwice-Gdańsk, 2009, 107.

[8] D. Kavas, Machines for secondary soil cultivation-comparison of rollers, Graduate work, University of Maribor, Maribor, 2002.

[9] W. Puntener, Manual for Field Trials in Plant Protection, Ciba-Geigy Limited, Basle, Switzerland, 1981.

[10] J.V. Cross, P.J. Walklate, R.A. Murray, G.M. Richardson, Spray deposits and losses in different sized apple trees from an axial fan orchard sprayer: 1. Effects of spray liquid flow rate, Crop Protection 20 (2001) 13-30.

[11] TeeJet TXA 8001 nozzles, http://www.agrifarm-maschinen.com/Catalog49_Metric_p009-026.pdf.

[12] Agricultural machines functional and safety testing service, European Network for Testing of Agricultural Machines, 2003.
[13] R. Hołownicki, G. Doruchowski, A. Godyn, W. Swiechowski, Variation of Spray Deposit and Loss with Air-jet Directions applied in Orchards, Journal of Agricultural Engineering Research 77 (2002) 129-136.
[14] R. Holownicki, G. Doruchowski, W. Swiechowski, Uniformity of spray deposit within apple tree canopy as detected by direction of the air-jet in tunnel sprayers, Journal of Fruit and Ornamental Plant Research 3-4 (1997) 129-136.
[15] M. J. Norusis, SPSS 16.0 Guide to Data Analysis, Prentice Hall, 2008.