

Investigation about wetting ability (surface tension) of water used for preparation of pesticide solutions

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Abstract: The investigation about surface tension of water used for preparation of pesticide solutions reveals it is quite diverse and changeable without any logical correlation towards location, time, and type of water source. Moreover, spraying with solutions with lower surface tension give bigger flow rates due to the lower resistance of fluid to the nozzles. The conducted trials show that plant surfaces with more rough texture require to be sprayed with pesticide solutions with lower surface tension. The wax content of the surfaces has no significant impact on surface tension requirement.

Key words: surface tension; pesticides; plant protection products; sprayers; wetting ability

Preučevanje omočitvene sposobnosti (površinske napetosti) vode za pripravo raztopin pesticidov

Izvleček: Raziskave glede površinske napetosti vode uporabljene za pripravo raztopin pesticidov so odkrile, da je ta zelo raznolika in, da se spreminja brez logične povezave glede na lokacijo, čas in vir vode. Škropljenje z raztopino z manjšo površinsko napetostjo daje večje pretoke zaradi manjšega upora tekočine v šobah. Izvedeni poskusi kažejo, da površine rastlin z bolj grobo teksturo zahtevajo škropljenje z raztopino pesticidov z manjšo površinsko napetostjo. Vsebnost voska na površini nima značilnega vpliva glede zahtev o površinski napetosti raztopine pesticidov.

Ključne besede: površinska napetost; pesticidi; pripravki za zaščito rastlin; razpršilci; omočitvena sposobnost

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1 INTRODUCTION

Using of pesticide solution with low surface tension (good wetting ability) is crucial for achievement of satisfactory level of pesticide effectiveness (Crease & Thacker, 1991; Ellis et al., 2001.). If the surface tension is too high (wetting ability – too low), pesticide solutions will be at the form of drops on the sprayed surfaces (they will not cover all surface and can be easily dropped down) on one hand and they will not penetrate fully in the rough surfaces from the other. (Ellis et al., 2001). In both cases, the effectiveness of pesticides can be dramatically lowered, especially when pesticide solutions are sprayed in relatively low temperatures (which increase surface tension of the water) and on plant parts with rough surface textures (which require solutions with lower surface tension for full cover in order pesticide solution fully to penetrate into of the surfaces plant tissues - cuticle). The spraying of plants with pesticide solutions over the point of run-off can cause significant risk for contamination of soil and waters (Bergström, 1990).

Traditionally it is expected that common tap water or water from rivers or lakes used for preparing of pesticide solutions have a constant surface tension only slightly depending from temperature (Gittens, 1969; Grisso et al., 1988). Different surface tension means different flow rates and respectively different sprayed dose rates (Matthews, 2008).

The main aim of present investigation was to reveal that the surface tension of the water is highly diverse and changeable and it depends on numerous factors and cannot be predicted in any way unlike common acceptance (Claussen, 1967.; Pallas & Pethica, 1983; Kalová & Mareš, 2015;). Also, the common acceptance that plant surfaces with high content of wax like cabbage leaves require to be sprayed with pesticide solution with lower surface tension (better wetting ability) also was wrong – the solutions with lower surface tension is required for surfaces with more rough textures, not with higher wax content (Bartell & Zuidema, 1936; Hess and Foy, 2000; Wagner et al., 2003). The spraying of solutions with different surface tension can significantly change the flow rates of the sprayers and must be taken into account during treatments with plant protection products (Semiao et.al., 1996; Miller and Ellis, 2000; De Schampheleire et al., 2009)

2 MATERIALS AND METHODS

Water samples from different sources in Bulgaria were taken during 2018 year. The sources were:

- tap water from different towns and villages (from different districts of given town / village);

- river and dam lake water from sources situated nearby different towns and villages in Bulgaria;

- well water which although rarely, also is used sometimes for making pesticide solutions (especially during summer drought) from sources situated in different towns and villages;

The 3 samples from one source (location) were taken four times in different time different seasons – spring (in May), winter (in February) , summer (in August) and autumn ((in October). The surface tension of water samples was established by tensiometer K6 Du Nouÿ Ring (Macy, 1935), produced by Krüss Scientific, at 24 °C checked with digital thermometer and average results was presented (used) for each taken sample.

Samples (leaves, barks, fruits) from different plants (mainly agricultural, but also decorative and forest plants) in different BBCH growth stages were taken and were sprayed with solutions made from distilled water and organosilicone surfactant Silwet L 77, produced by Momentive Performance Materials with different surface tension at 24 °C (Stevens et al., 1988). The ability of solutions to form even film, to spread easily and uniformly over the treated surfaces (wetting ability) was examined. A liquid with high wetting ability forms a thin, continuous film when it spreads over the surface which allow compete cover of the treated surface with pesticide solutions for maximal effectiveness (maximum cover, exposure and retention) from one side and minimal pollution of the environment (minimal amounts of pesticides fall on soils and waters from treated plants) – from the other (Prado et al., 2016; Zhu et al., 2019). Lower surface tension means better wetting ability (Bonn et al., 2009). Effective wetting ability requires the surface tension of the adhesive (γ_{adhesive}) to

$$\gamma_{LV} \cos \theta = \gamma_{SV} - \gamma_{SL}$$

Complete wetting when $\theta = 0$, or when $\cos \theta = 1$

Thus $\gamma_{LV} = \gamma_{SV} - \gamma_{SL}$

Or $\gamma_{LV} \leq \gamma_{SV}$

Or $\gamma_{\text{ADHESIVE}} \leq \gamma_{\text{SUBSTRATE}}$

Figure 1: Wetting surface requirement

be less than or equal to that of the substrate ($Y_{\text{substrate}}$) (Yuan & Lee, 2013) (Figure. 1)

The flow rate with solution with different surface tension was examined by hand compression Knapsack Sprayer Matabi super green 12, produced by Goizper. The size of droplets was visually determined by water sensitive papers, produced by Syngenta by method described by Turner and Huntington (1970); Salyani and Fox (1999) and Cerruto et al.(2016) and by digital micrometer (KINEX ABSOLUTE ZERO, 0-25 MM, 0,001MM, DIN 863, IP 65) produced by KINEX Measuring. Nozzles were set to produce spray plum consisting of relatively uniform droplets with diameter of 25 μm or 300 μm .

3 RESULTS AND DISCUSSION

The results from conducted trials with measurements of the surface tension from different water sources

are presented below as tables indicated location of the taken water samples, geographical coordinates, height above the sea level (m), date of taking samples and the average value surface tension of each sample.

3.1 RESULTS OF TAP WATER ANALYSIS

The presented Table 1 shows that surface tension of water is absolutely changeable and of unpredictable value and can vary in remote places or on a very short distance. For example – town of Plovdiv, Bulgaria, has approximately 102 square kilometers area. The tap water from different residential districts has different surface tension. The same situation is in the towns of Karlovo and Sopot in Central Bulgaria, where the distance between towns is only 4 km or town of Stamboliiski and village of Joakim Gruevo, where the distance between them is 2 km. The surface tension value of tested tap water was completely different and unpredictable.

Table 1: Surface tension of tap water samples taken in Bulgaria during 2018 in different seasons (winter, spring, summer and autumn)

Location	Coordinates	Height above the sea level (m)	Date of taking sample	Measured surface tension (mN m^{-1})
Town of Karlovo	42°63'66"N 24°79'98"E	452	10.02.2018	64
Town of Karlovo	42°63'66"N 24°79'98"E	452	10.05.2018	58
Town of Karlovo	42°63'66"N 24°79'98"E	452	10.08.2018	71
Town of Karlovo	42°63'66"N 24°79'98"E	452	10.10.2018	57
Village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'95"E	444	10.02.2018	78
Village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'95"E	444	10.05.2018	55
Village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'95"E	444	10.08.2018	58
Village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'95"E	444	10.10.2018	64
Town of Stamboliiski	42°13'25"N 24°52'20"E	200	03.02.2018	63
Town of Stamboliiski	42°13'25"N 24°52'20"E	200	03.05.2018	72
Town of Stamboliiski	42°13'25"N 24°52'20"E	200	03.08.2018	71
Town of Stamboliiski	42°13'25"N 24°52'20"E	200	03.10.2018	65

Village of Joakim Gruevo, town of Stambiliiski district	42°11'93"N 24°55'83"E	289	03.02.2018	69
Village of Joakim Gruevo, town of Stambiliiski district	42°11'93"N 24°55'83"E	289	03.05.2018	72
Village of Joakim Gruevo, town of Stambiliiski district	42°11'93"N 24°55'83"E	289	03.08.2018	68
Village of Joakim Gruevo, town of Stambiliiski district	42°11'93"N 24°55'83"E	289	03.10.2018	64
Town of Jambol	42°47'78"N 26°49'22"E	114	20.02.2018	70
Town of Jambol	42°47'78"N 26°49'22"E	114	20.05.2018	70
Town of Jambol	42°47'78"N 26°49'22"E	114	20.08.2018	74
Town of Jambol	42°47'78"N 26°49'22"E	114	20.10.2018	68
Town of Varna	43°22'20"N 27°88'18"E	80	25.02.2018	72
Town of Varna	43°22'20"N 27°88'18"E	80	25.05.2018	58
Town of Varna	43°22'20"N 27°88'18"E	80	25.08.2018	71
Town of Varna	43°22'20"N 27°88'18"E	80	25.10.2018	70
Agricultural University, town of Plovdiv	42°13'35"N 24°76'68"E	164	01.02.2018	71
Agricultural University, town of Plovdiv	42°13'35"N 24°76'68"E	164	01.05.2018	70
Agricultural University, town of Plovdiv	42°13'35"N 24°76'68"E	164	01.08.2018	72
Agricultural University, town of Plovdiv	42°13'35"N 24°76'68"E	164	01.10.2018	65
town of Plovdiv, residential district Trakia	42°13'68"N 24°79'46"E	164	01.02.2018	63
town of Plovdiv, residential district Trakia	42°13'68"N 24°79'46"E	164	01.05.2018	70
town of Plovdiv, residential district Trakia	42°13'68"N 24°79'46"E	164	01.08.2018	63
town of Plovdiv, residential district Trakia	42°13'68"N 24°79'46"E	164	01.10.2018	70
town of Plovdiv, residential district Komatevo	42°10'38"N 24°70'54"E	164	05.02.2018	72
town of Plovdiv, residential district Komatevo	42°10'38"N 24°70'54"E	164	05.05.2018	63
town of Plovdiv, residential district Komatevo	42°10'38"N 24°70'54"E	164	05.08.2018	68
town of Plovdiv, residential district Komatevo	42°10'38"N 24°70'54"E	164	05.10.2018	71
town of Plovdiv, residential district Karshiaka	42°16'16"N 24°74'23"E	164	01.02.2018	65

town of Plovdiv, residential district Karshiaka	42°16'16"N 24°74'23"E	164	01.05.2018	72
town of Plovdiv, residential district Karshiaka	42°16'16"N 24°74'23"E	164	01.08.2018	70
town of Plovdiv, residential district Karshiaka	42°16'16"N 24°74'23"E	164	01.10.2018	65
Town of Sopot	42°65'04"N 24°76'51"E	417	10.02.2018	58
Town of Sopot	42°65'04"N 24°76'51"E	417	10.05.2018	70
Town of Sopot	42°65'04"N 24°76'51"E	417	10.08.2018	67
Town of Sopot	42°65'04"N 24°76'51"E	417	10.10.2018	70
Town of Kalofer	42°61'11"N 24°97'78"E	666	10.02.2018	67
Town of Kalofer	42°61'11"N 24°97'78"E	666	10.05.2018	66
Town of Kalofer	42°61'11"N 24°97'78"E	666	10.08.2018	69
Town of Kalofer	42°61'11"N 24°97'78"E	666	10.10.2018	70

3.2 RESULTS OF RIVER WATER ANALYSIS

From Table 2 we can see that just like in the case of tap water, the samples from river water also have different surface tension in different seasons. The water from river Nevolia in the village of Vasil Levski, in February had surface tension of 71 mN m^{-1} , the sample taken from same river, at the same time in the town of Bania, which is situated lie about 7 km south, had surface tension of 59 mN m^{-1} . The tap water however taken from house 5 m away from the river Nevolia during February has 78 mN m^{-1} surface tension. The results confirm the unpredictable nature of the surface tension value towards river waters just like tap waters. Some early investigations reveal direct connection between natural waters contaminations and changes in the surface tension (Pockels, 1893). Certain contaminants can alter water surface tension significantly. The value of surface tension is almost independent of pH of the water (Sridhar & Reddy, 1984; Beattie et al., 2014).

3.3 RESULTS OF LAKE WATER ANALYSIS

Just like river and tap water samples, the results show absolutely changeable and unpredictable surface tension values for lake. For example, the tap water of the village of Vasil Levski in February had 78 mN m^{-1} surface tension, the value of this index of river water

sample taken from river 5 meters away was 71 mN m^{-1} , the surface tension of dam lake water taken from dam lake Vasil Levski situated approximately 1,8 km away from the river was 65 mN m^{-1} .

3.4 RESULTS OF WELL WATER ANALYSIS

The tap water of the village of Vasil Levski in February had 78 mN m^{-1} surface tension, the value of this index of river water sample taken from river 5 meters away was 71 mN m^{-1} , the surface tension of dam lake water taken from dam lake Vasil Levski situated approximately 5 km away from the river was 65 mN m^{-1} , however the water sample taken from well situated 20 m away from place where river sample and tap water sample were taken, had 57 mN m^{-1} surface tension. The previously conducted research also confirmed that surface tension of water of soils (underground water) is less than that of pure water (Tschapek et al., 1978). From the results for well waters in present study, is obvious that this value sometimes is less, sometimes is bigger. For sure is completely unpredictable and changeable. However, in present study only freshwater sources were examined. Other study shows that according to the seawater sample analysis there is similar uncertainty in prediction on surface tension as sweet water (Nayar et al., 2014).

Table 2: Surface tension of river water samples taken in Bulgaria during 2018 in different seasons (winter, spring, summer and autumn)

Location	Coordinates	Height above the sea level (m)	Date of taking sample	Measured surface tension (mN m ⁻¹)
River Nevolia, village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'99"E	444	10.02.2018	71
River Nevolia, village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'99"E	444	10.05.2018	56
River Nevolia, village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'99"E	444	10.08.2018	74
River Nevolia, village of Vasil Levski, town of Karlovo district	42°60'80"N 24°88'99"E	444	10.10.2018	62
River Nevolia, town of Banija	42°56'33"N 24°83'02"E	295	10.02.2018	59
River Nevolia, town of Banija	42°56'33"N 24°83'02"E	295	10.05.2018	63
River Nevolia, town of Banija	42°56'33"N 24°83'02"E	295	10.08.2018	68
River Nevolia, town of Banija	42°56'33"N 24°83'02"E	295	10.10.2018	72
River Strjama, town of Banija	42°54'20"N 24°82'08"E	295	10.02.2018	60
River Nevolia, town of Banija	42°56'33"N 24°83'02"E	295	10.05.2018	74
River Nevolia, town of Banija	42°56'33"N 24°83'02"E	295	10.08.2018	75
River Nevolia, town of Banija	42°56'33"N 24°83'02"E	295	10.10.2018	57
River Jantra, town of Gabrovo	42°89'09"N 25°32'42"E	392	27.02.2018	71
River Jantra, town of Gabrovo	42°89'09"N 25°32'42"E	392	27.05.2018	68
River Jantra, town of Gabrovo	42°89'09"N 25°32'42"E	392	27.08.2018	65
River Jantra, town of Gabrovo	42°89'09"N 25°32'42"E	392	27.10.2018	65
River Osam, town of Trojan	42°91'52"N 24°71'01"E	380	27.02.2018	64
River Osam, town of Trojan	42°91'52"N 24°71'01"E	380	27.05.2018	65
River Osam, town of Trojan	42°91'52"N 24°71'01"E	380	27.08.2018	55
River Osam, town of Trojan	42°91'52"N 24°71'01"E	380	27.10.2018	65

Table 3: Surface tension of dam lake water samples taken in Bulgaria during 2018 in different seasons (winter, spring, summer and autumn)

Location	Coordinates	Height above the sea level (m)	Date of taking samples	Measured surface tension (mN m ⁻¹)
Dam lake Vasil Levski, village of Vasil Levski, Karlovo district	42°61'48"N 24°91'16"E	444	10.02.2018	65
Dam lake Vasil Levski, village of Vasil Levski, Karlovo district	42°61'48"N 24°91'16"E	444	10.05.2018	60
Dam lake Vasil Levski, village of Vasil Levski, Karlovo district	42°61'48"N 24°91'16"E	444	10.08.2018	67
Dam lake Vasil Levski, village of Vasil Levski, Karlovo district	42°61'48"N 24°91'16"E	444	10.10.2018	70
Dam lake Murla, town of Sopot	42°64'74"N 24°77'21"E	417	10.02.2018	55
Dam lake Murla, town of Sopot	42°64'74"N 24°77'21"E	417	10.05.2018	55
Dam lake Murla, town of Sopot	42°64'74"N 24°77'21"E	417	10.08.2018	65
Dam lake Murla, town of Sopot	42°64'74"N 24°77'21"E	417	10.10.2018	68
Dam lake Kovatchevo, village of Kovatchevo, town of Stara Zagora district	42°21'83"N 24°20'90"E	133	20.02.2018	59
Dam lake Kovatchevo, village of Kovatchevo, town of Stara Zagora district	42°21'83"N 24°20'90"E	133	20.05.2018	70
Dam lake Kovatchevo, village of Kovatchevo, town of Stara Zagora district	42°21'83"N 24°20'90"E	133	20.08.2018	67
Dam lake Kovatchevo, village of Kovatchevo, town of Stara Zagora district	42°21'83"N 24°20'90"E	133	20.10.2018	65
Dam lake Zrebchevo, town of Nikolaevo	42°63'19"N 25°84'95"E	274	20.02.2018	58
Dam lake Zrebchevo, town of Nikolaevo	42°63'19"N 25°84'95"E	274	20.05.2018	68
Dam lake Zrebchevo, town of Nikolaevo	42°63'19"N 25°84'95"E	274	20.08.2018	57
Dam lake Zrebchevo, town of Nikolaevo	42°63'19"N 25°84'95"E	274	20.10.2018	73
Dam Lake Radetski, village of Radetski, town of Nova Zagora District	42°28'51"N 26°09'65"E	156	20.02.2018	66
Dam Lake Radetski, village of Radetski, town of Nova Zagora District	42°28'51"N 26°09'65"E	156	20.05.2018	70
Dam Lake Radetski, village of Radetski, town of Nova Zagora District	42°28'51"N 26°09'65"E	156	20.08.2018	70
Dam Lake Radetski, village of Radetski, town of Nova Zagora District	42°28'51"N 26°09'65"E	156	20.10.2018	65
Dam Lake Matza, village Matza, town of Polski Gradetz district	42°22'14"N 26°15'20"E	190	20.02.2018	71
Dam Lake Matza, village Matza, town of Polski Gradetz district	42°22'14"N 26°15'20"E	190	20.05.2018	74
Dam Lake Matza, village Matza, town of Polski Gradetz district	42°22'14"N 26°15'20"E	190	20.08.2018	71
Dam Lake Matza, village Matza, town of Polski Gradetz district	42°22'14"N 26°15'20"E	190	20.10.2018	70

Table 4: Surface tension of well water samples taken in Bulgaria during 2018 in different seasons (winter, spring, summer and autumn)

Location	Coordinates	Height above the sea level (m)	Date of taking sampels	Measured surface tension (mN m ⁻¹)
Village of Radetski, town of Nova Zagora district	42°28'39"N 26°11'45"E	156	20.02.2018	71
Village of Radetski, town of Nova Zagora district	42°28'39"N 26°11'45"E	156	20.05.2018	58
Village of Radetski, town of Nova Zagora district	42°28'39"N 26°11'45"E	156	20.08.2018	72
Village of Radetski, town of Nova Zagora district	42°28'39"N 26°11'45"E	156	20.10.2018	70
Village of Vasil Levski, town of Karlovo district	42°60'84"N 24°88'83"E	444	10.02.2018	57
Village of Vasil Levski, town of Karlovo district	42°60'84"N 24°88'83"E	444	10.05.2018	68
Village of Vasil Levski, town of Karlovo district	42°60'84"N 24°88'83"E	444	10.08.2018	55
Village of Vasil Levski, town of Karlovo district	42°60'84"N 24°88'83"E	444	10.10.2018	71

3.5 RESULTS ON ANALYS OF REQUIREMENTS FOR DIFFERENT PLANTS ABOUT WETTING ABILITY OF SPRAYS IN PESTICIDES APPLICATION

Figures 2, 3 and 4 shows the wetting requirements of the leaves of different cultures in four different growing stages.

From presented results above can be clearly seen that wetting ability of the sprayed liquid does not depend on plant surface structures wax content, but on the roughness of plant surface texture. The cabbage leaves although have a high wax content but are relative smooth (Lee et al., 1988), require to be sprayed with solutions with surface tension 25 mN m⁻¹ for full wetting (Figure 4). However, the bean leaves with less wax content but more rough textures for full wetting require solutions with surface tension 21 mN m⁻¹ (Figure 4). The tomato leaves in earlier growing stages when are more rough require solutions with 22 mN m⁻¹ surface tension, while in late growing stages when they develop more smooth texture need to be sprayed with solutions with 30 mN m⁻¹ surface tension. The leaves of apples (*Malus domestica* Borkh.), potato (*Solanum tuberosum* L.), maize (*Zea mays* L.) and cauliflower (*Brassica oleracea* L. ssp. *oleracea* convar. *Botrytis* (L.) Alef) which are relatively smooth in all phenophases require to be sprayed with solutions with surface tension close to 22 mN m⁻¹ (Figure 3).

There is obvious difference between leaves of cabbage and cauliflower, leaves of the second have more rough texture and for full wetting required solutions with lower surface tension. The test with bark also reveals that for good wetting of more rough textured plant surfaces – liquids with lower surface tension is required.

3.6 RESULTS OF ANALYSIS OF IMPACT OF WATER SURFACE TENSION ON NOZZLE FLOW RATE

Figure 5 shows flow rates obtained with Matabi sprayer with solutions with different surface tensions.

The nozzle of the sprayer was adjusted to spray with droplets with the size of 25 and 300 microns (diameter). The size of the droplets was visually determined by water sensitive papers and digital micrometer. The difference is obvious - the same sprayer with the same nozzle adjusted to a constant position and sprayed droplets with the same size but with solutions with different surface tension (wetting ability) achieved different flow rates. When sprayer works with distilled water (66 mN m⁻¹ surface tension) 500 ml m⁻¹ flow rate was achieved. The same sprayer, with the same nozzle adjustment working with the same water but with addition of organosilicone surfactant Silwet L 77 at 0.01 % concentration (22 mN m⁻¹ surface tension), achieved

900 ml m⁻¹ flow rate – 80 % more solution pass through nozzle. With increase of the droplet size from 25 to 300 microns, and addition of organosilicone surfactant Silwet L 77 to the distilled water again at 0.01 % (22 mN m⁻¹ surface tension), only 37 % more solution pass from the nozzle.

In both cases (25 and 300 microns size of droplets) the addition of the same amount of organosilicone surfactant (0.01 % concentration) to the distilled water decreased the surface tension to the same level (22 mN m⁻¹) and dramatically increased the flow rate of the sprayer nozzle.

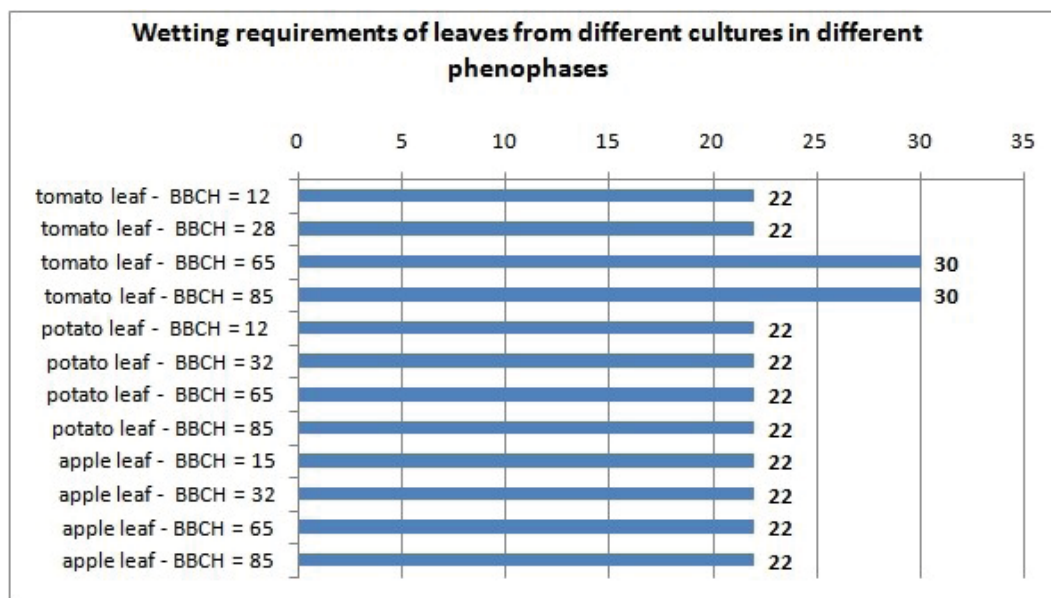


Figure 2: Wetting ability requirements of the crop leaves – on y axis are presented different plant leaves taken in different growth stages (BBCH stages); on x axis is measured surface tension (mN m⁻¹) of pesticides spray needed for full coverage and penetration in the texture of the leaves.

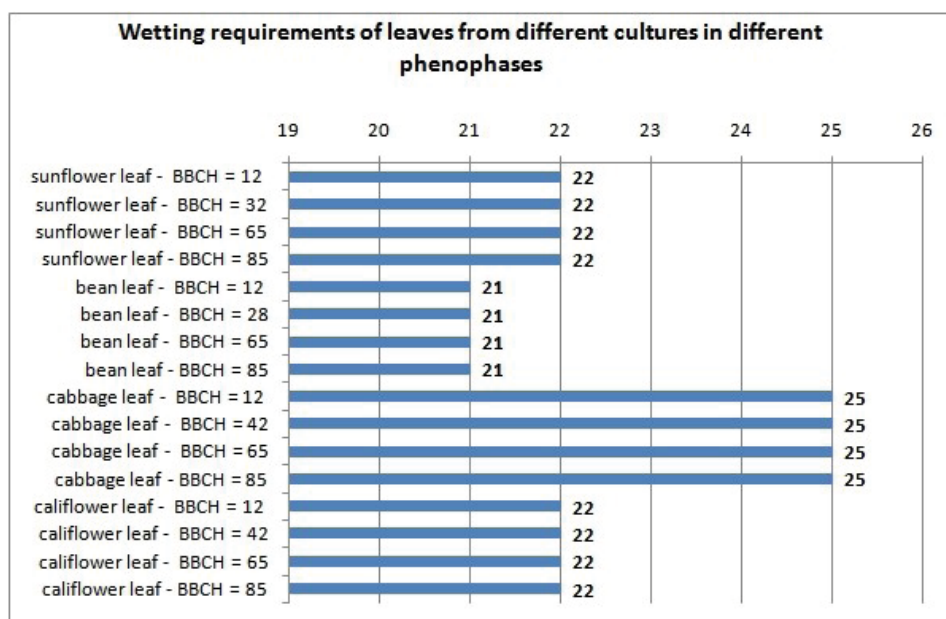


Figure 3: Wetting ability requirements of the crop leaves – on y axis are presented different plant leaves taken in different growth stages (BBCH stages); on x axis is measured surface tension (mN m⁻¹) of pesticides spray needed for full coverage and penetration in the texture of the leaves

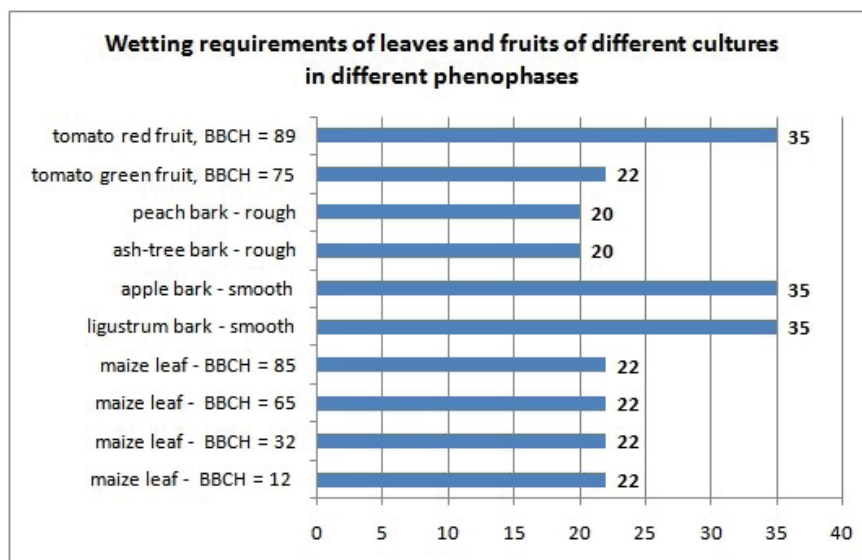


Figure 4: Wetting ability requirements of the crop leaves – on y axis are presented different plant leaves taken in different growth stages (BBCH stages); on x axis is measured surface tension (mN m⁻¹) of pesticides spray needed for full coverage and penetration in the texture of the leaves

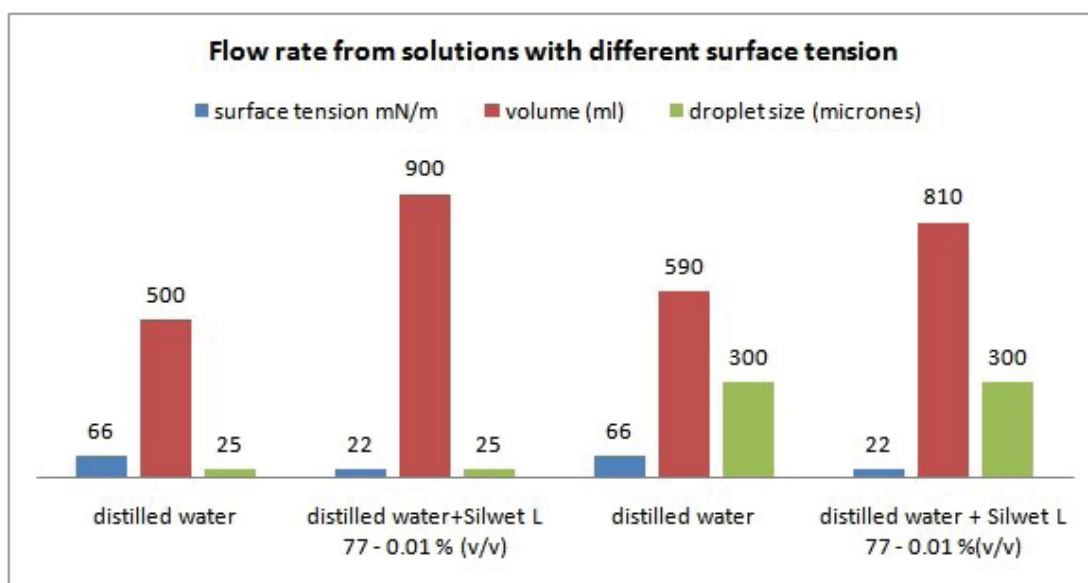


Figure 5: Flow rates (ml min⁻¹) of solutions with different surface tensions - left two columns small droplets (25 μ m) and right two big droplets (300 μ m)

4 CONCLUSION

The conducted tests proved that surface tension of the water used for preparation of the pesticide spray was not of constant value and depended not only from temperature, but also on many other factors and could be completely different from different sources and time periods (season, weather) without any logical correlation with location, time and type of water source.

Sprayed surfaces with more rough texture require to be treated with pesticide solutions with lower surface tension. The solutions with lower surface tension give a bigger nozzle flow rates than solutions with higher surface tension, especially when spray consists of smaller size droplets. The addition of wetting agent to the pesticide solutions can dramatically increase the flow rate from the sprayer.

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