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Effect of pH and Temperature On "Organosilicon Spreaders" Used as Agricultural Spray Adjuvant

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***Abstract*: Various products are being used for enhancing crop quality and quantity in modern agriculture throughout the world. Most of these products are administered to the plant by foliar spraying. Pesticides like insecticides, miticides, bactericides and fungicides are aimed to plant protection. Foliar fertilizers like NPK, secondary and micronutrients, plant growth regulators and promoters and used for plant nutrition and growth. Lack of or limited spreading capacity, penetration and wetting properties of these products limit their efficacy in field. Sometimes spraying at high temperature and inappropriate pH of spray solution also cause loss of active ingredient/s. Hence studies of these products under various temperature conditions and pH range are conducted.**

***Keywords*: Organosilicon spreaders, surfactants, agricultural spray adjuvant, pesticides, spreading, spreaders, effect of pH, effect of temperature.**

1. Introduction

Various products are being used for enhancing crop quality and quantity in modern agriculture throughout the world. Most of these products are administered to the plant by foliar spraying. Pesticides like insecticides, miticides, bactericides and fungicides are aimed to plant protection. Foliar fertilizers like NPK, secondary and micronutrients, plant growth regulators and promoters and used for plant nutrition and growth. Lack of or limited spreading capacity, penetration and wetting properties of these products limit their efficacy in field. Sometimes spraying at high temperature and inappropriate pH of spray solution also cause loss of active ingredient/s. Many spray adjuvants are used to overcome these limitations. Adjuvant includes spreaders, stickers, defoamers etc. One of the major types of adjuvant used is spreaders in general and surfactants in particular. In surfactants, organosilicon surfactants are widely used. In this paper we will discuss two such organosilicon surfactants. In the field where these products are used, temperature variation is very high. Also these products are used as admixture with pesticide formulations wherein there can be different pH. For applications these admixtures are diluted with water available in the field which again can have different pH. Thus, spray conditions like temperature and pH can vary in different fields so we have studied adjuvant under various temperature conditions and various pH conditions. From these studies we can conclude that these adjuvants are stable excluding few extreme conditions.

There are two categories of adjuvant available in the market based on product composition;

1. In one category adjuvant are already formulated as integral part of the pesticide ready to use formulation and can be used as is and
2. While in another category only spray adjuvant which are to be mixed prior to application with the pesticide spray solution by the applicator are available.

In this publication we will be focusing on the second category; adjuvant as separate entity [1].

A. Glossary

1. NanoWet-Pro®: Organosilicon surfactant adjuvant used as spreader manufactured by Green Vision Life Sciences Pvt. Ltd.
2. NanoWet-Eco®: Organosilicon surfactant adjuvant used as spreader manufactured by Green Vision Life Sciences Pvt. Ltd.
3. Spreading: Extent of spreading measured in cm.
4. DM water: Demineralised water.

B. Working of agricultural spray adjuvant (silicone surfactant used as super spreader, wetter and penetrant)

Surfactants are the subject of following discussions. Surfactants are "surface acting agents" as suggested by name. Out of many surfactants, our discussions will be pertaining to specific class of surfactants; viz. organosilicone surfactant NanoWet-Pro® and NanoWet-Eco®. These surfactants modify physical properties of spray solutions especially that of droplets. Following figure (Figure 1) and discussions by Winand K. Hock [1] will clarify this point.

The basic principle of working of adjuvant is reduction of surface tension of the aqueous solution thereby improving its ability to spread (Figure 1) on the surface on which it is applied.

Reduction of surface tension increases droplet's ability to spread on larger area and to remain in contact with the surface longer time. This phenomenon results in spreading of droplet to larger area enabling the formulation in which it is used to spread

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on more area resulting in requirement of lesser quantity of formulation. This fact serves two purposes; one less negative impact on environment and second better economy.

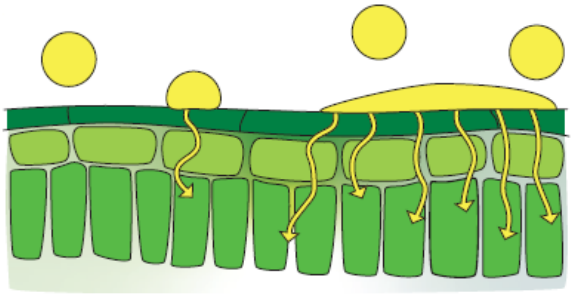

Fig. 1. Flattened droplet spreads on surface due to surfactant increasing both surface area and absorption

Temperature in the field where these products are used falls in very wide range. Wikipedia [2] compiles maximum temperature of some of the countries as give below (Table 1).

Table 1
Temperature data of some countries

Sr. No.	Country	Maximum temperature ^{0}C
01	India [3]	51.0 °C
02	Bangladesh [4]	45.1 °C
03	Bhutan [5]	40.0 °C
04	Cambodia [6]	42.6 °C
05	Indonesia [7]	40.6 °C
06	Iran [8], [9], [10]	54.0 °C
07	Iraq	53.9 °C
08	Malaysia	40.1 °C
09	Philippines	42.2 °C
10	Saudi Arabia	52.0 °C
11	South Korea	41.0 °C
12	Thailand	44.6 °C
13	Egypt	51.0 °C
14	South Africa	50.0 °C
15	Sudan	49.7 °C
16	Morocco	51.7 °C
17	Botswana	44.0 °C
18	Eswatini	47.7 °C
19	Tunisia	55.0 °C
20	Afghanistan	49.9 °C

Highest and average high temperatures recorded in some of the states of India [11] are tabulated in Table 2.

Table 2
Temperature data of some of the states of India

Sr. No.	Indian state	Temperature ^{0}C	
		Highest	Average
01	Rajasthan	50	41
02	Uttar Pradesh	48	46
03	Maharashtra	48	40
04	Jharkhand	48	40
05	Chhatisgarh	49	45
06	Andhra Pradesh	49	45
07	Odisha	48	40
08	Telangana	47	32

It is clear from the above tables (Table 2 & 1) that temperature range is very wide in different parts India and also of the globe.

End user uses different pesticide formulations having various pH with adjuvants and also dilution is made with available water which can have varied pH. Rain water pH is normally in acidic range viz. 5 to 6 while river water pH range is 6.5 to 8.5 and according to Faruk Bin Poyen et. al [12], underground water like well water & bore-well water pH is in the range of 7.0 to 8.5. Underground water pH varies before and after monsoon as reported by M. Sridharan and D. Senthil Nathan [13]; pre-monsoon range is 5.99 to 8.56 and after monsoon it is 6.09 to 7.45. In his thesis entitled Assessing local water quality in Saudi Arabia and its impact on food safety Dhafer Alsalah [14] reported range for irrigation water of 6.0 to 8.4.

Since these two factors; one based on natural temperature conditions prevalent on the actual field and second based on default pH of pesticide product used and also on pH of the water used for dilutions are default factors, we have decided to study performance of two adjuvant viz. NanoWet-Pro® & NanoWet-Eco® under these conditions. Because temperature variations are major than pH variations experienced during application of these products we will discuss first effect of temperature and then effect of pH on performance of these adjuvant. For this study we have simulated these conditions in the laboratory. Measurement of spreading is used to evaluate performance of these adjuvant.

2. Materials and Methods

NanoWet-Pro® & NanoWet-Eco® are used to study effect of pH and effect of temperature on spreading. For all these studies 0.1% aqueous solution of NanoWet-Pro® & NanoWet-Eco® is prepared in DM water and 200µl is used for determining spreading.

Method used for checking spreading (analogy [15]) is: 0.1% solutions of the sample of NanoWet-Pro® and NanoWet-Eco® in DM water are prepared. 200µL of this solution is dropped on plain surface and allowed to spread. After spreading stops circumference of the spread is measured in cm. This procedure is repeated two more times and average of three readings is recorded.

3. Results and Discussions

A. Effect of temperature on spreading

In this section we will study effect on temperature on spreading.

1) NanoWet-Pro@

Table 3
Spreading of NanoWet-Pro@ at various temperatures

Sr. No.	Temperature	Spreading (cm.)
1	RT (36˚C)	44.1
2	5.6˚C	40.4
3	10˚C	42.3
4	20˚C	43.9
5	30˚C	43.9
6	40˚C	43.8
7	50˚C	43.9
8	60˚C	43.9
9	70˚C	43.7
10	80˚C	43.7
11	90˚C	43.6

0.1% solutions NanoWet-Pro® at temperature room temperature (RT 36^{0}C), 5.6^{0}C, 10^{0}C, 20^{0}C, 30^{0}C, 40^{0}C, 50^{0}C, 60^{0}C, 70^{0}C, 80^{0}C and 90^{0}C are prepared using DM water. Spreading of all the sample is checked by the above mentioned method and results are tabulated (Table 3).

Observations from Table 3 are;

- Spreading is less only at extreme low temperature of 5.6 ^{0}C.
- Spreading is almost stable throughout remaining range.
- Deviation of highest temperature from mean value is 0.96%.
- Deviation of lowest temperature from mean value is 3.16%.

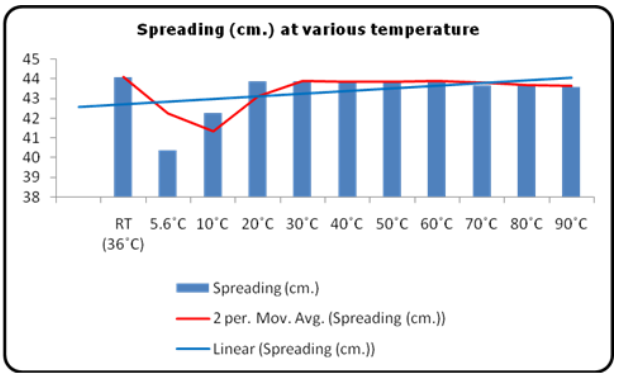

Fig. 2. Spreading of NanoWet-Pro® at various temperatures

Figure 2 is graphical presentation of these observations. The stability of NanoWet-Pro@ at complete temperature range excluding extreme low temperature of 5.6 ^{0}C is apparent from almost straight trend line parallel to X-axis. If we look at finer details we can see that average spreading increases as temperature increases, though changes are minor; total variation being 1.8cm.

2) NanoWet-Eco@

0.1% solutions NanoWet-Pro® at temperature room temperature (RT 34 ^{0}C), 5.5^{0}C, 10^{0}C, 20^{0}C, 30^{0}C, 40^{0}C, 50^{0}C, 60^{0}C, 70^{0}C, 80^{0}C and 90^{0}C are prepared using DM water. Spreading of all the sample is checked by the above mentioned method and results are tabulated (Table 4).

Table 4
Spreading of NanoWet-Eco@ at various temperatures

Sr. No.	Temperature	Spreading (cm.)
1	RT (34˚C)	40.0
2	5.5˚C	39.5
3	10˚C	39.7
4	20˚C	39.8
5	30˚C	39.9
6	40˚C	40.0
7	50˚C	39.9
8	60˚C	39.8
9	70˚C	39.6
10	80˚C	39.6
11	90˚C	39.5

Observations from Table 4 are;

- Spreading is almost stable throughout the range from coldest 5.5^{0}C to hottest 90.0^{0}C.
- Deviation of highest temperature from mean value is 0.62%.
- Deviation of lowest temperature from mean value is 0.64%.

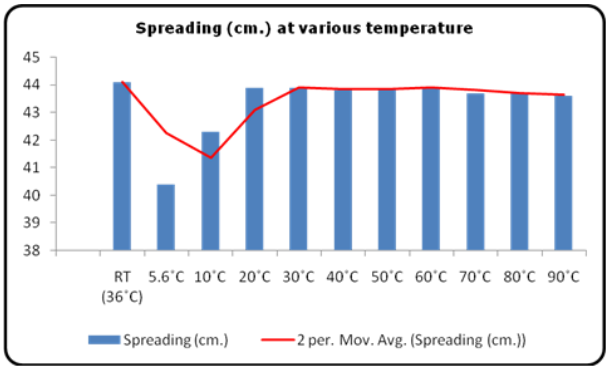

Fig. 3. Spreading of NanoWet-Eco® at various temperatures

Figure 3 is graphical presentation of these observations. The stability of NanoWet-Eco@ at complete temperature range is apparent from almost straight trend line parallel to X-axis. If we look at finer details we can see that spreading increases as temperature increases, reaches a peak and then decreases though changes are minor; total variation being 0.5cm.

B. Effect of pH on spreading

In this section we will study effect on pH on spreading.

1) NanoWet-Pro@

0.1% solutions of NanoWet-Pro® at pH 1.23, 2.09, 3.12, 4.08, 5.10, 6.12, 7.10, 8.06, 9.08, 10.12, 11.10 and 12.15 are prepared using sulfuric acid and sodium hydroxide solution. Spreading of all the sample is checked by the above mentioned method and results are tabulated (Table 5).

Table 5
Spreading of NanoWet-Pro@ at various pH

Sr. No.	Sample pH	Spreading (cm.)		
		Initial	After 0.5hrs	After 1.0hr.
1	1.23	0	0	0
2	2.09	35.2	0	0
3	3.12	43.3	43.4	43.2
4	4.08	43.5	43.3	43.3
5	5.10	43.6	43.6	43.4
6	6.12	43.5	43.7	43.8
7	7.10	43.8	43.8	43.8
8	8.06	43.6	43.6	43.7
9	9.08	43.6	43.8	43.7
10	10.12	43.7	43.8	43.7
11	11.10	43.9	43.9	43.8
12	12.15	44	43.9	43.9

Various observations from Table 5 are;

- At 1.23 pH there is no spreading.
- At 2.09 pH there is spreading only immediately after pH is adjusted; that too low as compared to spreading at further pH values but there is no spreading after keeping for 0.5hrs & also 1.0h at this pH.
- Spreading is stable from pH 3.12 till pH 12.15.

- Deviation of highest spreading immediately after adjusting pH is 0.80% while that of lowest spreading is 0.80%.
- Deviation of highest spreading after 0.5hrs post pH adjustment is 0.50% while that of lowest spreading is 0.87%.
- Deviation of highest spreading after 1.0h post pH adjustment is 0.62% while that of lowest spreading is 0.99%.

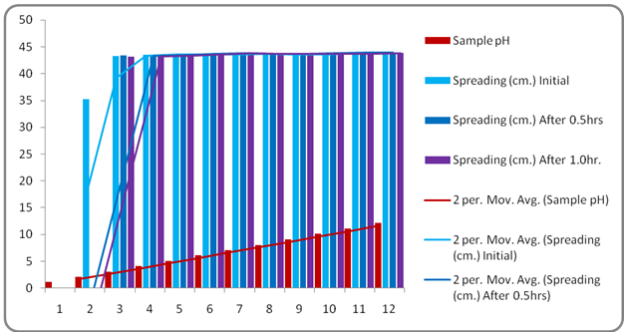

Fig. 4. Spreading of NanoWet-Pro® at various pH

It is apparent from the graph (Figure 4) that spreading is almost stable in the total pH range from 3.12 to 12.15. Trend lines parallel to X-axis clearly indicate this observation.

2) NanoWet-Eco@

0.1% solutions of NanoWet-Pro® at pH 1.12, 2.05, 3.04, 4.12, 5.10, 6.05, 7.11, 8.09, 9.15, 10.10, 11.10 and 12.09 are prepared using sulfuric acid and sodium hydroxide solution. Spreading of all the sample is checked by the above mentioned method and results are tabulated (Table 6).

Table 6
Spreading of NanoWet-Eco@ at various pH

Sr. No.	Sample pH	Spreading (cm.)		
		Initial	After 0.5hrs	After 1.0hr.
1	1.12	0	0	0
2	2.05	34.8	0	0
3	3.04	39.6	39.6	39.5
4	4.12	39.8	39.6	39.5
5	5.10	39.9	39.5	39.5
6	6.05	39.6	39.7	39.6
7	7.11	40.1	40	40
8	8.09	39.9	39.8	39.9
9	9.15	39.9	39.9	39.9
10	10.10	40	40	39.9
11	11.10	40.1	40.1	40
12	12.09	39.9	39.9	39.8

Various observations from Table 06 are;

- At 1.12 pH there is no spreading.
- At 2.05 pH there is spreading only immediately after pH is adjusted; that too low as compared to spreading at further pH values but there is no spreading after keeping for 0.5hrs & also 1.0h at this pH.
- Spreading is stable from pH 3.04 till pH 12.09.
- Deviation of highest spreading immediately after adjusting pH is 0.55% while that of lowest spreading is 0.70%.
- Deviation of highest spreading after 0.5hrs post pH adjustment is 0.73% while that of lowest spreading is 0.78%.
- Deviation of highest spreading after 1.0h post pH adjustment is 0.60% while that of lowest spreading is 0.65%.

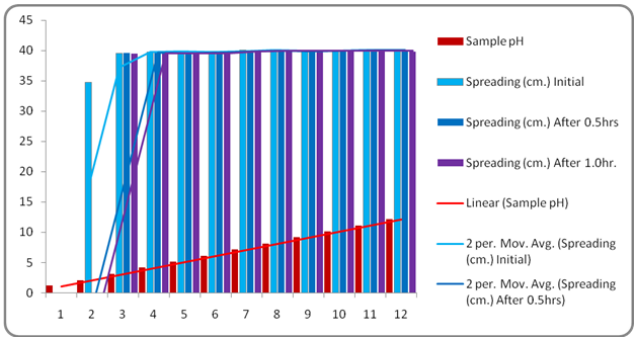

Fig. 5. Spreading of NanoWet-Pro® at various pH

It is apparent from the graph (Figure 5) that spreading is almost stable in the total pH range from 3.04 to 12.09. Trend lines parallel to X-axis clearly indicate this observation.

4. Conclusion

From the interpretation of the results obtained in study of NanoWet-Pro® and NanoWet-Eco® it can be safely concluded that these two products are highly stable under most of the temperature conditions and similarly under various pH conditions. Spreading immediately after pH adjustment, 0.5hrs post pH adjustment and 1.0hr post pH adjustment is also same excluding very low <2 pH. Thus these two products can be used in fields at various temperature ranges as well as at almost all pH conditions.

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