Research Article

Characterization of Ground Water for Suitability as Insecticide Solvent for Insect Pest Management in Lower Sindh, Pakistan

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Abstract | Though, the performance of insecticides depends on various factors (*i.e.* pests, insecticide formulation, entry route, mode of action, dosage, calibration and application timing) but one factor that doesn't get much attention is the quality of the water used to spray the product which may reflect in the success of spray operation. To know the influence of water quality on pesticide performance, this study was proposed to evaluate the water sources used for mixing the insecticides prior to application. For this purpose, two districts of lower Sindh province i.e., Hyderabad and Tando Allahyar were selected with 20 samples from each district for assessing the carrier water quality. Samples were used for the measurement of electrical conductivity (EC), total dissolved solids (TDS), pH, cations including potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+}) and sodium (Na^+). In anions, bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), chloride (Cl^-), nitrate (NO_3^-) and sulphate (SO^{2-}) were recorded. The Durov diagram was generated which delineated that the overall water samples fell under mixed zones, therefore, the groundwater found neither anion dominant nor cation dominant, but Na-Cl type. The results further revealed that 95% of water samples (38) were alkaline in nature and unfit for dilution purposes of insecticide including Abamectin, Cyromazine, Fluvalinate, Imidacloprid, Methiocarb and Spiromesifen. Moreover, all the samples were exceeding the permissible pH level of 4.0 to 6.5 required for the mixing of commonly used insecticide such as Acephate, Azadiachtin, Buprofezin, Fenpropathrin, Fenpyroximate, Flonicamid and Pyriproxyfen. Furthermore, there were 23 samples (58%) exceeding the required level (114-342) of hardness and 39 (98%) samples were unfit in terms of TSD levels (250 ppm). The results of the study can be concluded that the water of the study area was not suitable for insecticide dilution and the regular water quality testing is mandatory. The water pH should be maintained for performance of insecticides.

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Introduction

Agriculture contributes an essential role in sustainable development and poverty alleviation particularly in low and middle-income countries (World Bank, 2008). About 2 billion people are directly or indirectly involved worldwide in agricultural related activities (Alavanja *et al*., 2009). In developing countries like Pakistan, the agricultural sector contributes (approximately 18%) significantly to the national gross domestic product (GDP) and provides an employment opportunity (approximately 64%) to the local people (GoP, 2019). The demand for food and fibre is increasing gradually with the growing population of the country but the low yield from agricultural crops remains an important challenge particularly due to pests-organisms (Donatelli *et al*., 2017). Different control measures have been applied to protect the diverse crops from pests, but pesticide application is one of the most used practices globally (Thomson and Hoffmann, 2006; Damalas, 2009; FAO, 2014; Khan *et al*., 2015; Guedes *et al*., 2016). Around 4.12 million tons of pesticides were consumed worldwide in 2018 and out of which a major percentage in Asia (53%) followed by America (30%), Europe (14%) and 3% in the rest of the world (FAO, 2019). About 400 pesticide products comprising over 200 active ingredients are registered in Pakistan (Nafees *et al*., 2008) and their usage has increased from 14,848 to 206,730 metric tons during 1987 to 2017 (Syed and Malik, 2011; GoP, 2017). The country ranked 19th in major utilizers of world pesticides (Master, 2016). Despite the large-scale application of pesticides, it still failed to provide an effective control of pests (Oerke and Dehne, 2004). The most common reason extensively studied by the researchers is the development of resistance in pests against insecticides which they evolve through their physiological and behavioral changes over a period (Guedes *et al*., 2009; Nansen and Ridsdill-Smith, 2013). In addition, substandard quality materials for pesticide preparation, mishandling, improper calibration, and selection of incorrect pesticides are also possible known reasons of pesticide ineffectiveness (Nalewaja and Matysiak, 1991; Hussain and Siddique, 2010; Arafa *et al*., 2013; Khan *et al*., 2015). However, the role of water quality in preparing pesticide (emulsifiable concentration, wettable powders and dry flowable) solution is still ignored seriously but could have an immense impact on the performance of pesticides (Wayne, 2015; Dumas, 2017). Meanwhile, it has been well emphasized that the water quality like hardness, pH, turbidity, and temperature has a great impact on the performance of commonly used pesticides (Buhler and Burnside, 1983; Sarmah and Sabadie, 2002; Ramsdale *et al*., 2003; Green and Cahill, 2003; Green and Hale, 2005; Altland, 2015; Devkota *et al*., 2016). It is now evident that the water contents such as cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Fe^{++}) and anions (SO_3^-, Cl^-, HCO_3^-, NO_3^-) can greatly influence the performance of pesticides (Douglas and Orvin, 1983; Nosratti *et al*., 2011). Similarly, the water with lower (acidic) or higher (alkaline) pH can also influence negatively on the efficacy of herbicide by disturbing the solubility and stability of the active molecules (Deer and Beard, 2001; Green and Cahill, 2003; Roskamp *et al*., 2013). Water pH is one of the reasons that can decrease the effectiveness of pesticide application (Cloyd, 2015). An improper water pH degrades the pesticides, or the chemical breakdown due to hydrolysis (Deer and Beard, 2001). Thus, most of the pesticides (insecticides, herbicides, and fungicides) are formulated at a slightly acidic pH ranging 4.0 to 6.5 and reached at or closer to neutral pH (7.0) when diluted in water for spraying and the water with pH 8.0 (alkaline) or above can cause the pesticide precipitation (Halcomb, 2012; Riden and Richards, 2013). A little increase in pH level can boost up the hydrolysis ten times (Mckie and Johnson, 2002). Although international pesticide manufacturing companies recommend pH level for most of their fungicides, insecticides and herbicides on bottle labels, no detailed information is given regarding the effect of water quality on pesticide performance. Previously, no study has been conducted in Pakistan to evaluate the suitability of water quality as solvent for pesticides dilution to control the pest associated with different crops grown in the country. Keeping in view the above facts, water samples were taken randomly from two different districts of Sindh province to analyze their quality for pesticide dilution.

Materials and Methods

Site description and water sampling strategy

For this study, two districts of Sindh province *i.e.*, Hyderabad and Tando Allahyar were selected due to their rich agricultural land where varieties of crops have been cultivated. The population of district Hyderabad and Tando Allahyar is 2,199,463 and 836,887, respectively (PBS, 2017). Most of the population is living in rural areas and depending on agriculture activities. Due to cultivation of different crops throughout the year, the pesticides especially insecticides are used extensively to control different pests. The climate of the study area often remains hot during summer (average temperature ~40 °C) and cold in winter (average temperature ~27 °C). The average precipitation is around 136 mm (Pak Met, 2021). From each district, ten (10) largely populated villages were selected for water sampling during May and June months 2019 and the

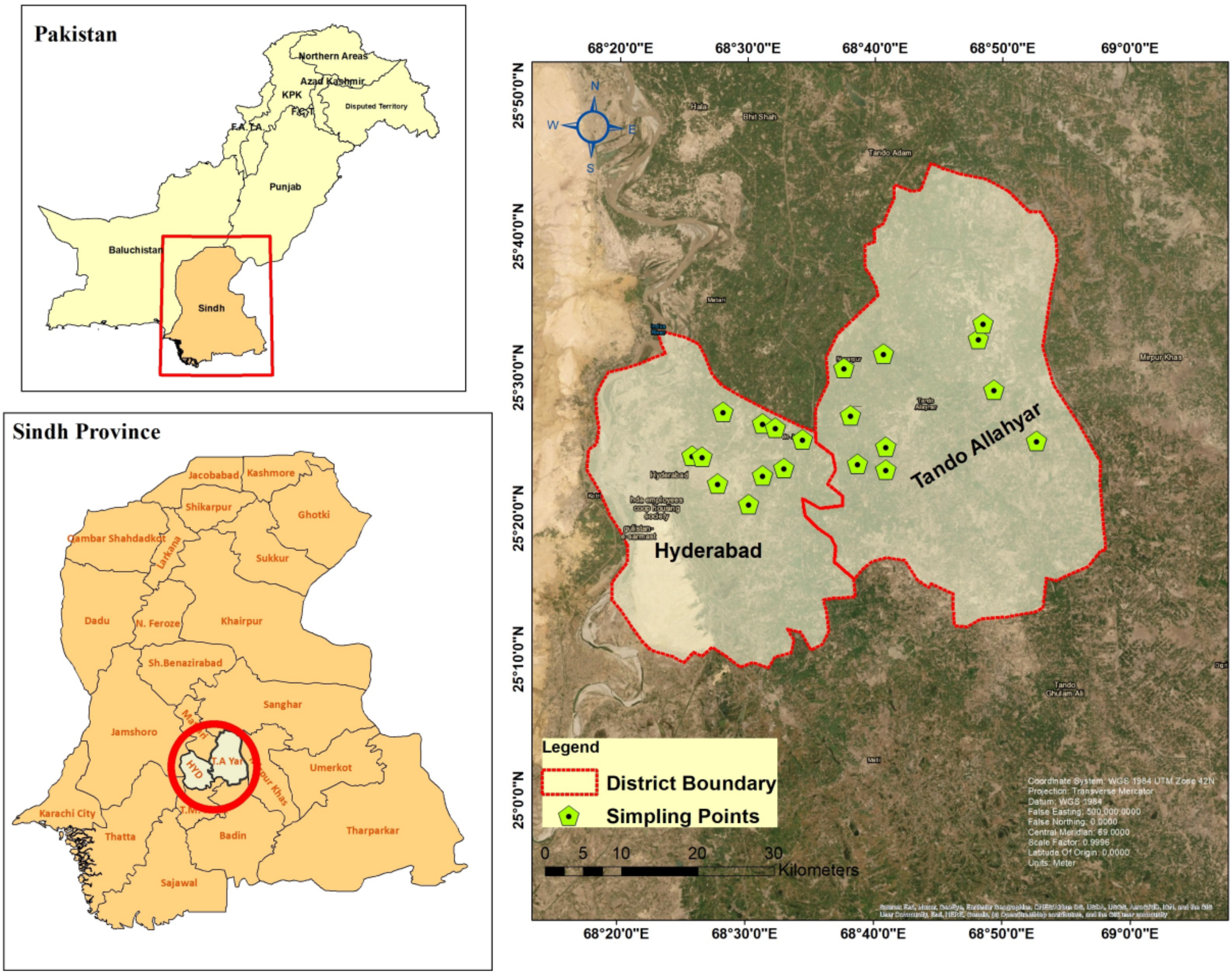

Figure 1: *The map of studied area indicating the sampling cites. Two districts of Sindh province; Hyderabad and Tando Allahyar were selected for this study*.

geological locations were recorded through coordination devices. The area map (Figure 1) was created using ArcMap (version 10.5. 1). The tube wells were operated for 5 mins before collection of samples to remove stagnant water from pipes. Two water samples from each location were collected in 500 mL clean plastic bottles. The samples were transported and brought to the Laboratory at Drainage and Reclamation Institute of Pakistan (DRIP) Tandojam for further analysis.

Characterization of water

The water samples were sent to the laboratory, DRIP Tandojam. Different water quality parameters including electrical conductivity (mS cm-1), pH, cations (mg L^{-1}) potassium (K^{+}), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}) and anions (mg L^{-1}) bicarbonate (HCO_3^{-}), carbonate (CO_3^{-2}), chloride (Cl^{-}), nitrate (NO_3^{-}) and sulfate (SO_4^{-2}) were determined. The standard methods for cations and anions analysis were followed (APHA, 1995). The Durov diagram (Durov, 1948) was constructed by using GrapherTM (Golden Software, LLC) to describe the hydrogeochemical characters of the study area. The classification of groundwater based on measured cations, anions concentration involving Food and Agriculture Organization (FAO, 1985 and 1989). The permissible standards (Table 1) were taken from already published literature (USDA, 2013; Cloyd, 2015).

Effect of pH on efficacy of Insecticides against Bemisia tabaci Genn

Rearing of *B. tabaci*: The collection of *B. tabaci* was done from the cotton fields at Latif farm, Sindh Agriculture University Tandojam with the help of aspirator and further reared on fresh cotton leaves as described by Kumar and Poehling (2006) in the Laboratory of Molecular Entomology, Department of Entomology, Sindh Agriculture University, Tandojam under controlled environment at 27 ± 1°C, photoperiod 14L: 10D and relative humidity 60 ± 5%.

Links Researchers

Table 1: *List of insecticides with their groups, route of entry, mode of action, targeted pests, permissible range of Ph, Bicarbonates, hardness and TDS.*

S. No	Insecticide	Group	Route of Entry	Action Mode	Target pests	Ph Range	Bicar-bonates (PPM)	Hardness (PPM)	TDS
1	Abamectin	Avermectins	Systematic	Neurotoxin	Sucking	6.0-7.0	500	114-342	250
2	Acephate	Organophosphates	Systematic	Neurotoxin	Sucking	5.5-6.5	500	114-342	250
3	Acequinocyl	Acequinocyl	Contact	Antifeedant	Mites	6.5-7.0	500	114-342	250
4	Acetamiprid	Neonicotinoids	Systematic	Neurotoxin	Sucking	5.0-9.0	500	114-342	250
5	Azadirachtin	Azadirachtin	contact or Stomach	Growth regulator	Sucking/ Chewing	5.5-6.5	500	114-342	250
6	Bacillus thur-ingiensis	*Bacillus thuringiensis*	Stomach	Antifeedant	Chewing	5.0-8.0	500	114-342	250
7	Bifenazate	Bifenazate	Contact	Antifeedant	Mites	6.5-9.0	500	114-342	250
8	Bifenthrin	Pyrethroids/ Pyrethrins	Contact/ Stomach	Neurotoxin	Sucking	5.0-9.0	500	114-342	250
9	Buprofezin	Buprofezin	Systematic	Growth regulator	Sucking	5.5-6.5	500	114-342	250
10	Chlorfenapyr	Chlorfenapyr	Stomach	Antifeedant	Mite	5.0-7.0	500	114-342	250
11	Chlorpyrifos	Organophosphates	Systematic	Neurotoxin	Sucking	5.0-9.0	500	114-342	250
12	Clofentezine	Clofentezine	Contact	Growth regulator	Mites	5.0-8.0	500	114-342	250
13	Cyfluthrin	Pyrethroids/ Pyrethrins	Contact/ Stomach	Neurotoxin	Sucking	5.0-9.0	500	114-342	250
14	Cyromazine	Cyromazine	Stomach	Growth regulator	Dipterans	6.5-7.0	500	114-342	250
15	Diflubenzuron	Benzoylureas	Stomach	Growth regulator	Mites/ Sucking	5.0-9.0	500	114-342	250
16	Dinotefuran	Neonicotinoids	Systematic	Neurotoxin	Sucking	5.0-8.0	500	114-342	250
17	Etoxazole	Etoxazole	Contact	Growth regulator	Mites	6.0-8.0	500	114-342	250
18	Fenpropathrin	Pyrethroids/ Pyrethrins	Contact/ Stomach	Neurotoxin	Sucking	5.5-6.5	500	114-342	250
19	Fenpyroximate	METI acaricides and insecticides	Contact	Antifeedant	Sucking/ Mites	5.5-6.5	500	114-342	250
20	Flonicamid	Flonicamid	Systematic	Neurotoxin	Sucking	4.0-6.0	500	114-342	250
21	Fluvalinate	Pyrethroids/ Pyrethrins	Contact	Neurotoxin	Sucking	5.0-7.0	500	114-342	250
22	Imidacloprid	Neonicotinoids	Systematic	Neurotoxin	Sucking	5.0-7.0	500	114-342	250
23	Methiocarb	Carbamates	Systematic	Neurotoxin	Sucking	6.5-7.0	500	114-342	250
24	Novaluron	Benzoylureas	Stomach	Growth regulator	Mites/ Sucking	6.5-9.0	500	114-342	250
25	Pyriproxyfen	Pyriproxyfen	Contact	Growth regulator	Sucking	5.5-6.5	500	114-342	250
26	Pymetrozine	Pyridine azomethines	Systematic	Neurotoxin	Sucking	7.0-9.0	500	114-342	250
27	Pyridaben	METI acaricides and insecticides	Contact	Antifeedant	Sucking/ Mites	5.0-8.0	500	114-342	250
28	Sulfoxaflor	Sulfilimine	Stomach/ Systematic	Neurotoxin	Sucking/ Chewing	5.0-9.0	500	114-342	250
29	Spinosad	Spinosyns	Contact/ Stomach	Neurotoxin	Sucking/ Chewing	6.5-7.5	500	114-342	250
30	Spiromesifen	Tetronic and Tetramic acid derivatives	Systematic	Neurotoxin	Mites/ Sucking	5.0-7.0	500	114-342	250
31	Thiamethoxam	Neonicotinoids	Systematic	Neurotoxin	Sucking/ Chewing	6.5-9.0	500	114-342	250

Noted: The table is prepared from the previously published literature (USDA, 2013; Cloyd, 2015).

Table 2: *Descriptive statistics of measured parameters of collected samples during the study.*

Parameter	Unit	Min	Max	Mean	Std Dev	Median	Mode
Ph		6.90	8.50	7.38	0.28	7.30	7.30
Alkalinity	(m.mol/1)	3.80	10.00	7.00	1.60	7.00	7.00
Turbidity	(NTU)	0.00	93.00	3.88	15.34	0.00	0.00
Conductivity	(micro-S/cm)	500.00	5240.00	1755.70	1009.34	1474.00	1086.00
Hardness	(PPM)	60.00	1350.00	399.93	251.37	350.00	350.00
TDS	(PPM)	4.90	3353.00	1113.12	660.40	943.00	695.00
Bicarbonate	(PPM)	190.0	500.00	347.75	83.16	350.00	350.0
Carbonate	(PPM)	0.00	30.00	0.75	4.74	30.00	-
Chloride	(PPM)	18.0	900.00	176.93	186.45	109.50	60.0
Nitrate	(PPM)	0.00	2.30	0.80	0.56	0.80	0.50
Sulfate	(PPM)	8.0	970.00	279.53	226.75	205.00	305.0
Calcium	(PPM)	4.00	220.00	70.70	49.58	60.00	80.0
Iron	(PPM)	0.01	10.10	0.45	1.60	0.13	0.03
Magnesium	(PPM)	7.75	218.70	60.48	37.56	51.03	55.89
Potassium	(PPM)	1.30	14.10	6.21	2.74	5.750	5.50
Sodium	(PPM)	0.30	620.0	208.18	161.85	139.00	70.0

Experimental procedure: The synthetic pesticides Bifenthrin (Talstar, FMC) was on its recommended dose (200 ml/acre) was used and mixed with water samples against *B. tabaci*. The doses for laboratory experiments were calculated according to the standard formula such as Required dose= recommended dose per acre/ recommended water per acre. Considering the pH as a main factor during the evaluation of collected water samples from the field, three water pH levels based on the water quality analysis *i.e.*, 7 (standard), 9 (basic) and 5 (acidic) were used. The water pH was adjusted with the addition of either hydrochloric acid (HCL) or Sodium hydroxide (NaOH). The pH meter (Model: HI 8424, HANNA) was used to confirm the desired pH. For bioassay, leaf dipping method as previously described by Bacci *et al*. (2007) was used. Fresh cotton leaves (90 mm in diameter) were immersed in different treatments for 5 sec and dried for 2 hrs at room temperature. Later, the treated leaves were placed on the bottom of clean petri dishes (9.0 cm2). In each petri dish, 10 *B. tabaci* adults were released with the help of aspirators. All the experiments were Randomized Complete Design (RCD) with three treatments and each treatment was replicated five times. The mortality data of *B. tabaci* were recorded after 24, 48, 72, 96 hrs and one week. Abbott's formula was used to calculate the mortality percentage of *B. tabaci* for the individual treatments, whereas Analysis of variance (ANOVA) and Least Significant Difference (LSD) at p value 0.5 were used for the analyzing through STATIX 8.1 software.

Results and Discussion

Groundwater Hydrogeochemical Characterization

The descriptive analysis of anions and cations is presented in Table 2 showing an average value with maximum and minimum range for all essential parameters of groundwater. The mean value for HCO3- concentration was 347.75 ppm (190-500 ppm), anions including Cl- 176.93 ppm (18-900 ppm), NO3- 0.80 ppm (0.00-2.30 ppm) and SO4-2 279.53 (8.0-970 ppm). In all collected samples, only one sample contained CO3 -2 at the rate of 30 ppm. Further, the mean value for others were Ca 70.70 ppm (4 to 220ppm), Fe 0.4498 ppm (0.01- 10.1 ppm), Mg 131.58 ppm (7.75 - 315 ppm), K (1.30 -14.1 ppm) and Na (0.30 - 620.0 ppm). The pH of overall water samples was 7.38 (6.9 to 8.5) that clearly displayed an alkaline nature of water. In other chemical characteristics of water, the mean value for TDS was 1113 ppm (3353- 4.9 ppm), alkalinity 7.00 m.mol-L (3.80- 10.00 mmol-L), turbidity 7.00 NTU (0.00 -93.00 NTU) and conductivity 1755.70 micro-S/cm (500.00- 5240.00 micro-S/cm) were recorded, respectively. A Durov diagram was generated to explain the groundwater hydrochemical characteristics. The Figure 2 revealed that the dominant cations were Na+ and K+ in comparison to others. The second most area where the samples are falling was a non-dominant region. Further, anion triangle indicated that most of the samples were mixed type. The results revealed that one sample was in Ca+Mg+Cl+SO_4^+ type, 14 samples in Na+K+Cl+SO_4^+, one sample in Na+K+HCO_3 and nine samples in Ca+Mg+HCO_3. Ten samples were recorded in the category of mixed Ca-Mg-Cl and four samples in mixed Ca-Na-HCO_3 category. The mixed zones showed that the groundwater was neither anion dominant nor cation dominant, in fact it was a mixed zone having Na-Cl type. Only one sample had TDS below 250 ppm, while four samples were between 250-500 ppm. Moreover, 17 samples had TDS ranging 500-1000 ppm and 14 samples were found to be brackish water with ranges of higher than 1000 ppm and less than 2000 ppm. The four samples were fall > 2000 ppm with higher concentration of SO_4 and Na+K. As per the constructed diagram, there were 1, 8, 9 and 29 water samples having pH range <7.0, >8.0, 7.5-8.0 and 7.0-7.5, respectively.

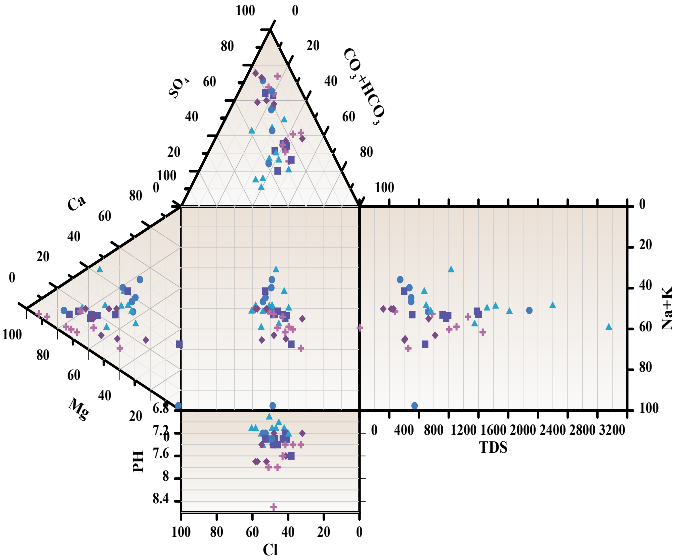

Figure 2: *Durov diagram representing groundwater parameters of the study area.*

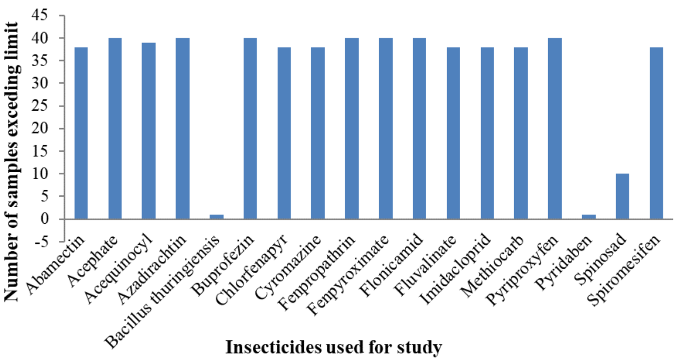

Figure 3: *Number of samples exceeding pH permissible limit for diluting each insecticide.*

Suitability of water for insecticide dilution

The data in Figure 3 shows the number of samples exceeding the recommended pH level of water for insecticide dilution. The results indicates that 38 water samples were not suitable to use as a solvent to dilute seven insecticides/miticides *i.e.*, Abamectin, Chlorfenapyr, Cyromazine, Fluvalinate, Imidacloprid, Methiocarb and Spiromesifen. The permissible range of the carrier water for these pesticides were 6.0-7.0, 5.0-7.0, 6.5-7.0, 5.0-7.0, 5.0-7.0, 6.5-7.0 and 5.0-7.0, respectively (Table 1). Furthermore, all the tested samples (40) were unfit for dilution of eight insecticides/miticides including pH range for Acephate (5.5-6.5), Azadiachtin (5.5-6.5), Buprofezin (5.5-6.5), Fenpropathrin (5.5-6.5), Fenpyroximate (5.5-6.5), Flonicamid (4.0-.6.0) and Pyriproxyfen (5.5-6.5). There 10 water samples were not suitable for Spinosad (6.5-7.5), one sample was not fit for Bacillus thuringiensis and Pyridaben as both have a permissible pH range of 5.0-8.0. Furthermore, the hardness and TDS level of all the samples were determined to evaluate their fitness for dilution of commonly used insecticides. The Figure 4 demonstrates that 23 samples were found exceeding with the recommended level of hardness. Similarly, the TSD level of 39 samples was higher than the permissible limit of water which can be used as a solvent to prepare in the sprayer tank for management of insect pests.

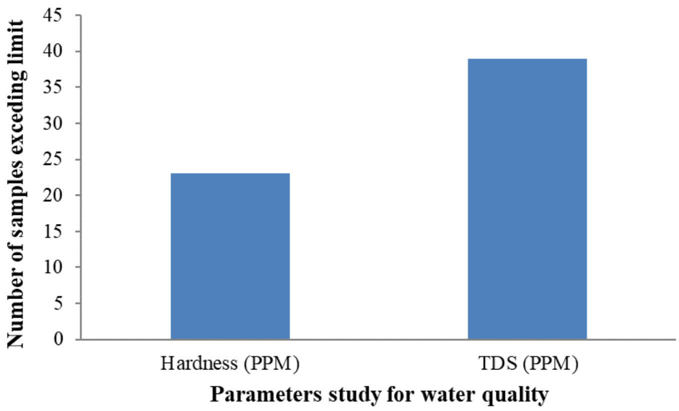

Figure 4: *Total number of water samples exceeding hardness and TDS permissible limit for dilution of insecticides.*

Effect of insecticide against Bemisia tabaci under laboratory conditions

The results shown in Figure 5 revealed the percentage mortality of *B. tabaci* due to the application of bifenthrin mixed with various water samples. A significant impact of water quality samples was observed on the performance of bifenthrin to cause mortality of *B. tabaci*. Among the treatments, pH 7 diluted Bifenthrin treatment was found most effective to cause maximum mortality of *B. tabaci* (92.50%) after one week of application followed by pH 5 (52.50%) and pH 9 (37.50%). A gradual rise was also recorded in the mortality of *B. tabaci* in all treatments from 24 hrs till one week of various treatments.

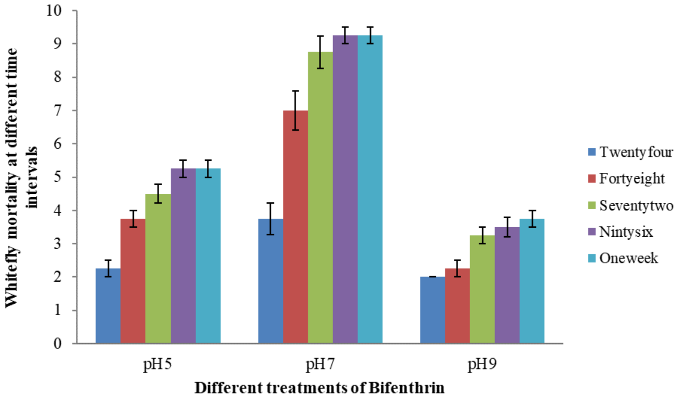

Figure 5: *Bioassay of whitefly against Bifenthrin at different pH level.*

The demand for water for agriculture is increasing day by day due to growing global population and climate changes (Edmunds, 2003; Qureshi, 2020). Correspondingly, it is one of the key components for controlling the pests associated with the crop cultivated all over the world as a universal solvent. For evaluating quality of water as a carrier for spray mix, there are some parameters widely used such as EC, pH, TDS, hardness, cations and anions (Ayers and Westcot, 1985; Qureshi and Barrett-Lennard, 1998). Halcomb (2012), Cloyd (2015) and Wayne (2015) suggested that the characteristics of water used in a spray mix could impact on the efficiency of many pesticides. The results of the current study showed that groundwater of the selected area might be influenced by fresh recent recharge of groundwater with dominant dissolution process or water mixing with no dominant ion either cation or anion and flow of irrigation return (Ravikumar *et al*., 2015; Vasilache *et al*., 2020). Generally, the Durov diagram (Durov, 1948) is believed as a suitable strategy to classify the groundwater based on the ionic composition (Baba *et al*., 2008; Al-Omran *et al*., 2012). The mixed zones showed that the groundwater found neither anion dominant nor cation dominant, but it was noticed as a mixed zone having Na-Cl type (Todd and Mays, 2005). Brackish water is usually found where groundwater receives recharge from boundary inflow with high salinity (Li *et al*., 2016).

Some of the samples showed high turbidity levels that can impair pesticide performance and these findings are in accordance with McDougall (2012) who found similar results in his study. It occurred due to high levels of turbidity because the negatively charged molecules of the pesticide could not be absorbed by the plants and delivery of pesticide can be affected through clogging screens and nozzles (Wayne, 2015). Similarly, the high iron content in the water can oxidize and form the rust particles that can settle down in the bottom of the spray tank. These particles further can clog the nozzles and screens and can reduce the pesticide activities especially found in the case of glyphosate (A and L Canada, 2018). It is also reported that the presence of iron in the solvent (water) accelerates decomposition of Dimethoate insecticide belonging to the organophosphate group (Burfitt *et al*., 2006). The role of water hardness is one of the most important factors that should be considered for mixing pesticides. The harness in water is usually determined by the presence and amount of certain minerals such as calcium, magnesium, iron, sodium and considered as moderately hard, hard or extremely hard when value more than 115 ppm (Whitford *et al*., 1986). The positively charged mineral contents of hard water can bind up negatively charged pesticide molecules which results in precipitation of active ingredients out of solution and reduce the effectiveness.

The most vital factor that plays a significant role in the performance of insecticides is pH. The pesticide is rendered and hydrolyzed and becomes ineffective when it is mixed with water pH greater than 7. Water pH of 4 to 7 is recommended for mixing with most pesticides (Fishel and Ferrell, 2010; Cloyd, 2015; Wayne, 2018). Water pH higher than 7 is alkaline and many pesticides commonly used like carbamate and organophosphate insecticides undergo a chemical reaction in the existence of alkaline water that decreases their efficiency (Halcomb, 2012). However, organochlorine and pyrethroids are less exposed to hydrolysis as compared to organophosphates and carbamate (Deer and Beard, 2001). Apart from this, the pH can affect the half-life of many insecticides. For example, acephate has a half-life of 40 and 46 days at the pH of 5 and 7 respectively but at pH 7 the half observed was only 16 days. Similarly, dimethoate, malathion and Carbaryl showed half-life of 12 hours, 8 days, and 125 days, respectively. At pH 9 dimethoate has a half-life of only 48 min, whereas Carbaryl has only one day half-life (Deer and Beard, 2001; Mckie and Johnson, 2002). The results obtained from laboratory experiments revealed that bifenthrin used against whitefly performed less when mixed with water having pH greater than 7. Previously it was also recommended water with pH 4 to 7 for mixing most pesticides (Fishel and Ferrell, 2010; Cloyd, 2015; Wayne, 2018). Correspondingly, in this research the treatment of pH 9 was found less effective than pH 7 and pH 5. Water pH higher than 7 is alkaline and many pesticides commonly used like carbamate and organophosphate insecticides undergo a chemical reaction in the existence of alkaline water that decreases their efficiency (Halcomb, 2012). However, organochlorine and pyrethroids are less exposed to hydrolysis as compared to organophosphates and carbamate (Deer and Beard, 2001). Treatment of pH 7 was found more effective than pH 5 and pH 9 treatments. Therefore, it is suggested to correct the pH of solvent water according to the manufacturer instruction given on the label before mixing fungicides and insecticides such as propineb, mancozeb, pirimiphos-methyl and imidacloprid (Ferrel and Aagard, 2003; Perovic, 2006) so that better management of target pesticides can be obtained for longer periods

Conclusions and Recommendations

The hydro chemical analysis of water samples collected from different villages of two districts; Hyderabad and Tando Allahyar revealed that there was diversity in the contents available in the ground water. Moreover, the study proved that the water quality parameters especially pH, hardness and TDS were above the permissible level. Most of the samples had pH above neutral level and alkali in nature which is not suitable for all types of insecticides available in the market. Therefore, it is recommended that the farmers should test the water quality before the application of pesticides and should use the water as per recommendations of the manufacturers. Lastly, the government extension department should give awareness to the farmers regarding the impact of water quality on pesticide performance. The pesticide manufacturing companies, especially, local companies must be bound to give the standards of water on the labels for their products.

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Novelty Statement

This research work highlighted one of the key insecticide failure causes in the study area and first ever study conducted in Pakistan focusing on importance of groundwater in insecticide performance.

Author's Contribution

Kirshan Chand: Conducted the research work.
Fahad Nazir Khoso: Designed and supervised the entire work.
Arfan Ahmed Gilal and Abdul Mubeen Lodhi: Provided the technical assistance.
Agha Mushtaque Ahmed: Helped in manuscript writing.
Ghulam Murtaza Jamro: Helped in data analysis.
Sohail Ahmed Otho and Jamal U Din Hajano: Assisted in survey and proof reading.

Conflict of interest
Authors have declared no conflict of interests.

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