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Estimation of phytosanitary pressure and the environmental impact related to the use of pesticides

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ABSTRACT
Vegetable crops are acutely sensitive to pest attacks, disease proliferation, and weed development. To control these pests, farmers resort excessively to various chemical plant protection products. Therefore, this study aims to measure the intensity of pesticide use and estimate the phytosanitary pressure according to the phytosanitary practises of market gardeners in the region of Biskra, in the south-east of Algeria. A questionnaire survey was conducted among 96 randomly selected market gardeners in Biskra during two farming campaigns in 2016/2017 and 2017/2018. Results show that out of 70 different active substances, eighteen are mostly applied to seven inventoried vegetable species. Insecticides and fungicides are the most widespread. The average values of the calculated treatment frequency index range from 0.80 to 30.45. The phytosanitary pressure index is particularly dangerous for tomatoes, eggplants, and chilli peppers, with values ranging from 4.03 to 4.29 and 8.25, respectively. In conclusion, the surveyed areas were found to be experiencing considerable phytosanitary pressure, which would harm the environment and human health.
Keywords: Plant protection Products, Phytosanitary Pressure, Environmental Risk, Vegetable Crops.

INTRODUCTION
In Algeria, market gardening is an important and dynamic branch of agriculture. Over the past twenty years, this production increased greatly due to different factors such as the availability of large areas of potentially cultivable land, the abundance of groundwater, favorable climatic conditions and the various support programs from the state (Rekibi, 2015; Hartani *et al.,* 2015). In 2013, Algeria ranked seventeenth among vegetable producing countries in the world with 6.8 M tonnes of products (Ghelamallah, 2016). Vegetables are principally produced in Algeria's northern and coastal regions, including the desert areas, which are becoming increasingly competitive (Zenkhri, 2017). As an arid region, Biskra has a useful agricultural surface (UAS) estimated at 185,473 ha (DSA, 2019), and is classified among the pilot other desert regions in the horticultural market (Zenkhri, 2017; Boukhalfa *et al.,* 2018). This region provides 32% of the national early and extra-early productions and supplies one-third of the nation with vegetables (Bessaoud *et al.,* 2019).

In Biskra, the vegetable area is estimated to 23 488 ha in open fields and 7 238 ha in greenhouses. The latter has increased fivefold in 2019 (Soudani *et al.,* 2020b). Like any intensive farming, the market garden crops require the use of a range of plant protection products (PPPs) to control insect and mite pests, fungal diseases, and weed proliferation that affect both production and quality of product (Boukhalfa *et al.,* 2018; Son, 2018; Toumi *et al.,* 2018; El Bouzaidi *et al.,* 2020).

In 2015, approximately 11 385 L of liquids formulations and 13 257 kg of solid formulations of pesticides were used in Biskra for garden cultivation (MADR, 2016). bad phytosanitary practices (non-compliance with protective and hygienic measures recommended, no respect for prescribed dosages and mismanagement of emptied pesticides packages, etc) were reported in Algeria and particularly in Biskra (Southeast) (Ramdani *et al.,* 2009; Kheddam-Benadjal, 2012; Louchahi, 2015; Belhadi *et al.,* 2016; Soudani *et al.,* 2020a; Bettiche *et al.,* 2021). As result, these could cause human health problems (Lu and Cosca, 2011; Madani *et al.,* 2016; Nicolopoulou-Stamati *et al.,* 2016; El Marsafy *et al.,* 2018; Laohaudomchok *et al.,* 2020; Liu *et al.,* 2020; Hantchi *et al.,* 2022) and/or environmental contamination (Solomon, 2010; Gill and Garg, 2014; Papadakis *et al.,* 2015; Sharma *et al.,* 2019).

Therefore, it is important to be aware of the classical, simple, synthetic and adaptive assessment tools of plant protection practices and optimisation of the production systems (Mghirbi *et al.,* 2015; Mghirbi *et al.,* 2017). Among these tools, the Danish indicator was first developed in the 1980s in Denmark, to meet the growing use of pesticides of lower weight and which were not reported in the Danish statistics on quantities (Pingault, 2007). Later, this indicator has been used in several European countries, most notably in France, where it has been developed by MAP and INRA (Champeaux, 2006) to significantly aid in controlling and mitigating PPPs inputs in agriculture.

Considering that farmers' are heavily dependent on PPPs, the use of the Danish indicator TFI can be useful in reasoning pesticide application, guiding farmers, and facilitating the decision-making process to reduce their use (Brunet *et al.,* 2008). This indicator is exclusively useful in developing countries in general and specifically in Mediterranean countries. This is mainly due to the lack of economically and agro-efficient alternatives. Noteworthy, there are insufficient previous studies supporting the application of this approach, not even on a small scale (Le Grusse, 2009; Aydi Hadji, 2013; El Azzouzi *et al.,* 2014).

As for Algeria, the lack of studies undertaken for the calculation of the Treatment Frequency Index (TFI) or the Phytosanitary Pressure Index (PPI), confirms the nonexistence of reference values in terms of local (regional) or national standards. In this regard, the present paper aims to measure the pesticide use intensity and to estimate the phytosanitary pressure based on the market gardeners‘ practices in Biskra South-East of Algeria.

MATERIAL AND METHODS
Data collection:
A survey was carried out in two different locations: namely, Ain Naga (Eastern Ziban) and Doucen (Western Ziban) (**Fig.1**). The selection criteria of those areas focused on the importance of market garden production. Thus, these two communes rank among the major pole producing and supplying fresh vegetables for a large number of markets in the Algerian territory(DSA, 2018 ; Soudani *et al.,* 2020a, 2020b). A total of 96 market gardeners were chosen randomly in 18 different localities for each

commune, during two agricultural seasons (15 months). Interviews with producers focused on their crop cultivation, their phytosanitary practices, and the applied dose of PPP (**Table 1)**.

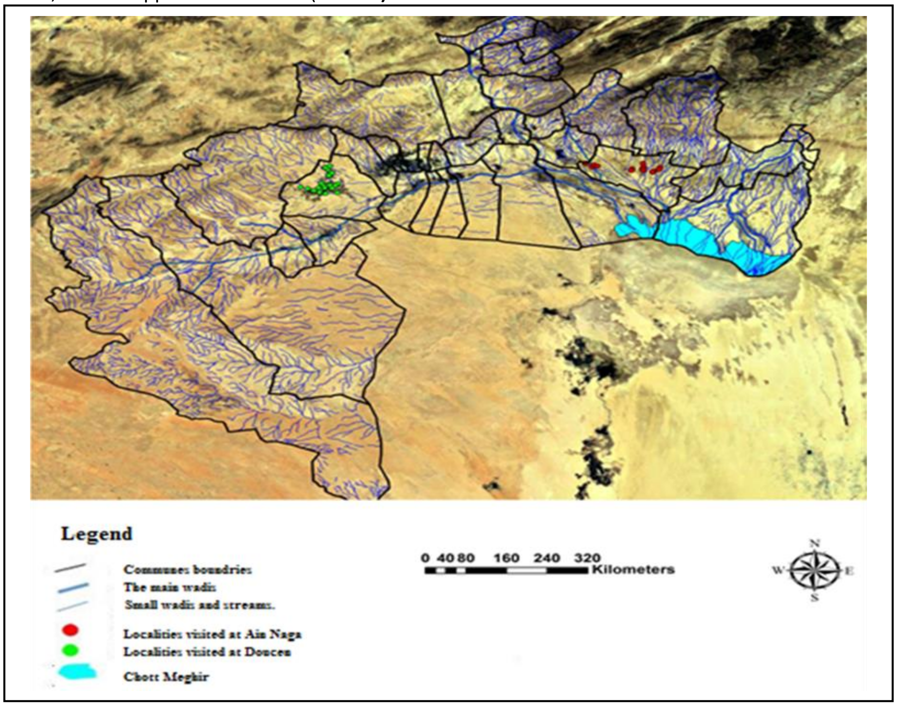

Fig.1. Map of the study area indicating the sites visited in each commune of Biskra (South-East of Algeria) (Source Google Earth, 2020).

Table 1. Number of surveyed market gardeners in the studies areas

Location (Number of respondents)	
Ain Naga (n=47)	**Doucen (n=49)**
AlbGhenim (03)	Berouth (04)
Choucha (01)	Chouiter (01)
Dhibia (01)	Draa Belamri (01)
Djalaya (02)	Draa R'mal (03)
Elhamra (01)	Elamri (06)
Feidh Sala (01)	Elmaleh (01)
Ghemoug (01)	Elmerhoum (05)
Horraya (07)	Hai Elgame (01)
Lamnisaf (05)	Khafoura (02)
Mabdouaa (03)	Louzen (01)
Mansoria (07)	MatbakhKdar (03)
Methnane (03)	MegaderSoltane (01)
Nebka (03)	Mhissar (01)
SaflTadjdid (01)	Noumer (04)
Bel M'rimet (01)	Tamda (09)
Sidi Salah (04)	Elguataa (02)
TabetChanouf (05)	MaatherKhaira (03)
Zemoura (01)	Douisse (02)

Survey data processing:
All relevant data collected from the survey were entered, coded, and analyzed using both IBM SPSS Statistics (Version 24) predictive analytics software and Microsoft Excel 2013. The identified pesticides were checked on the national index of agricultural pesticides (2015 edition).

Estimation of phytosanitary pressure:
Calculation of the Frequency Treatment Index (TFI):
The Treatment Frequency Index (TFI) has been calculated based on the recommended doses of PPPs "Minimum Dose" by-product and the real doses applied per hectare and per crop, following the Eq.1 (Pingault, 2007).

$$TFI\ treatment = ((Applied\ dose)\ /\ (Registered\ dose)) \times ((Treated\ area)\ /\ (Total\ plot\ area)) \qquad (1)$$

If several plant protection products are applied to a single plot, then the sum of the treatments' TFI is computed. In addition, the TFI can also be calculated per crop, per plot (Eq.2), or per farm (Eq.3). Regardless of the aggregation levels, the average TFI per crop can be calculated for a group of plots or for an entire farm by dividing the TFI of each plot by the total surface of these plots (Pingault, 2007).

$$TFI\ Plot = \sum(TFI \times Plot\ area)\ /\ PST) \qquad (2)$$

Where: PST is the proportion of the treated area.

$$TFI\ Farm = (\sum(TFI\ plot \times Plot\ area))\ /\ ((\sum Plot\ area)) \qquad (3)$$

Calculation of the phytosanitary pressure index (PPI):

Phytosanitary pressure Index (PPI) is calculated using the Eq.4 (DRAAF, 2014; MAAF, 2015):

$$PPI = TFI(crop\ 1) \times area(crop\ 1) + TFI(crop\ 2) \times area(crop\ 2) + \cdots + TFI(crop\ n) \times area(crop\ n)\ /\ Global\ area \qquad (4)$$

The classes characterizing the phytosanitary pressure are given in **table 2** (DRAAF, 2014; MAAF, 2015; Boussier, 2015).

Table 2. Phytosanitary pressure scale (PPI)

Pressure level	PPI
Low	< 0.7
Moderate	[0.7 ; 1.4 [
High	[1.4 ; 2.1 [
Very High	> 2.1

The data needed to calculate the TFI and PPI of the locality were extracted from the survey. For the calculation of plant protection pressure at the overall scale, the total area of vegetable crops used in Ain Naga is 2500 ha and in Doucen is 1220 ha. For the purpose of the study, these values based on the 2018 agricultural statistics of Biskra are adopted. The data needed to calculate the TFI and PPI of the locality were extracted from the survey. For the calculation of plant protection pressure at the overall scale, the total area of vegetable crops used in Ain Naga is 2500 ha and in Doucen is 1220 ha. For the study, these values have been adopted based on the 2018 agricultural statistics of Biskra.

RESULTS

Data on market gardening:

Market gardening is practiced in small to medium-sized greenhouses (0.12 to 02 ha) or in open fields (0.50 to 12 ha). The farmers interviewed produce vegetables of three groups: Solanaceae (tomatoes, chilies, and peppers), Cucurbitaceae (cucumbers and melons), and Fabaceae (Faba beans) (**Table.3**). The most cultivated products were tomatoes and chilies.

Table 3: Main crops grown in the study communes

	Percentage of responding Farmers producing main vegetable crops						
Study communes	Chili	Cucumber	Eggplant	Faba Beans	Melon	Pepper	Tomato
Ain Naga	68	2	13	13	9	26	72
Doucen	59	4	31	24	4	10	65

Assessment of phytosanitary pressure:

A total of 143 commercial formulations and 70 active substances were identified and inventoried by the Algerian Agricultural Plant Protection Products Index of 2015 (Soudani *et al.,* 2020a). The TFI index was calculated for the eighteen most widely applied active ingredients in the studied areas (**Table 4**).

Table 4. The different active substances selected for the calculation of the TFI and PPI indices

Category	Commercial formulations	Active substances	Registered dose	Applied dose	
				Ain Naga	**Doucen**
Insecticides (including acaricides)	Metry	Abamectin	75 cc/hl	0.50 L/ha	0.50 L/ha
	Bactimec		25-35 ml/hl		
	Aceplan 20 Sp	Acetamiprid	100-125g/ha	600 g/ha	500 g/ha
	Mopistop				
	Morspilan 20 Sp				
	Rustilan				
	Coragen 20	Chlorantraniliprole	150 ml/ha	100 ml/ha	200 ml/ha
	Arrivo 25% Ec	Cypermethrin	12-20 ml/hl	1 L/ha	1.50 L/ha
	Cypermethrine 25Ec				
	Cypra-Plus				
	Sherpa 2gc				
	Diazinon	Diazinon	75-125 ml/ha	3000 ml/ha	1000 ml/ha
	Mitrus Dumper	Fenbutatin Oxide	0.90 L/hl	1 L/ha	1 L/ha
	Acarol 10 Wp	Hexythiazox	40-50 g/hl	500 g/hl	400 g/hl
	Confidor Supra	Imidacloprid	150 g/ha	600 g/ha	500 g/ha
	Fidor Super 70				
	Zinad 15	Indoxacarb	25 ml/hl	250 ml/hl	500 ml/hl
	Calypso	Thiacloprid	0.20-0.30 L/ha	0.50 L/ha	0.50 L/ha
Fungicides	Agrivil	Hexaconazole	10-20 ml/hl	1000ml/ha	75 ml/hl
	Tachigazole,	Hymexazole	1 L/ha	3000 ml/ha	1 L/ha
	Tachigaren 30 Sl				
	Dithane M 45	Mancozeb	2 kg/ha	2.50 kg/ha	2.50 kg/ha
	Manco 80 Riva				
	Mancophyt				
	Trifidan 25	Triadimenol	37-100 ml/ha	500 ml/ha	1000 ml/ha
	Flint 50 Xg	Trifloxystrobin	20-25 g/hl	250 g /hl	1000 g/hl

Table 4 Contionued					
Herbicides	Fusitop, Fluazifop	Fluazifop-P-Butyl	1-2 L/ha	1 L/ha	2 L/ha
	Etalon	Linuron	2.50-3 kg/ha	500 g/ha	1 kg/ha
	Turbo Ribuzine	Metribuzin	500-700 g/ha	600 g/ha	1000 g/ha

Frequency of phytosanitary treatments per season:

Pesticide use is considered essential to manage pest aggression on vegetable crops. However, this survey showed that the frequency of application depends also on environmental conditions. The average application frequency was about 3± 1.11 times per fortnight in the rainy season (Min. 2 times and Max. 6) compared to 7± 2.51 times in the dry season (Min. 1 time and Max. 12) in Ain Naga.

While in Doucen, an average of about 4± 1.56 applications per fortnight were applied in the rainy season (Min. 3 and Max. 8) against 9± 2.38 applications in the dry season (Min. 5 and Max. 15) (**Table 5**). On the other hand, the application of two different products in a single treatment is possible and has been reported in both surveyed communes.

Table 5. Number of phytosanitary treatments applied per season (wet and dry season) in the investigated study communes

	Ain Naga		**Doucen**	
	Wet season	Dry season	Wet season	Dry season
Average	3.36	7.00	4.49	8.80
SEM	0.16	0.37	0.22	0.34
SD	1.11	2.51	1.56	2.38
Range	4.00	11.00	5.00	10.00
Minimum	2.00	1.00	3.00	5.00
Maximum	6.00	12.00	8.00	15.00

The treatment frequency index (TFI) and the phytosanitary pressure index (PPI):

Table (6) summarizes the TFI and PPI indicators computed and reported per species for both communes. The total treatment frequency and phytosanitary pressure index values obtained for the seven species were generally related to insecticides and fungicides. For TFI and PPI on herbicides, values were generally low (almost zero), due to their limited use in the vegetable cropping system. In Doucen, total TFI and PPI values were the highest compared to those in Ain Naga.

The tomato had the greatest cropping area and the highest total TFI and PPI values in both study communes, followed by the chili pepper crop in Ain Naga and the eggplant variety in Doucen (**Table 6**). In addition, these three crops showed very high phytosanitary pressure values.

Table 6. TFI and PPI indices by crop and per study communes

Commune	**Indicators**	**Eggplant**	**Cucumber**	**Faba Beans**	**Melon**	**Chili pepper**	**Pepper**	**Tomato**
Ain Naga	TFI Insecticides	1.54	1.08	6.96	4.16	100.6	17.15	110.03
	TFI Fungicides	0.38	0.00	2.17	0.73	48.44	2.15	28.93
	TFI Herbicides	0.01	0.00	0.01	0	0.03	0.01	0.06
	TFI Total	1.92	1.08	9.14	4.89	149.07	19.31	139.01
	TFI Average	0.80	1.08	3.10	1.38	5.86	2.26	7.72
	PPI Culture	0.03	0.01	0.06	0.02	2.05	0.08	4.03
Doucen	TFI Insecticides	110.09	8.48	19.74	25.77	81.17	14.35	88.27
	TFI Fungicides	35.00	3.13	2.64	2.5	32.51	5.22	65.34
	TFI Herbicides	0.10	0.13	0.01	0.06	0.12	0.00	1.31
	TFI Total	145.18	11.74	22.39	28.32	113.8	19.57	154.92
	TFI Average	14.08	6.22	3.65	13.45	30.45	4.46	8.66
	PPI Culture	4.29	0.15	0.19	0.27	8.25	0.20	2.52

Regarding the average TFI values on farms, six localities of Ain Naga (Mansoria (42.06), Nebka (39.00), Feidh Sala (25.47), Ghemoug (14.43), Djalaya (10.32) and Safl Tadjdid (10.25)) and four localities of Doucen (Berouth (21.47), Noumer (19.13), Tamda (16.13) and Elmarhoum (11.39)) were recorded a significant consumption of plant protection products and presented the highest values (>10)(**Table (7)**. Furthermore, calculating the index of phytosanitary pressure on the environment (PPI) using the TFI total average and the ratio between the treated surface and the total surface devoted to all crops allowed to define two levels: on a locality level (PPI Locality) and on a global level (PPI Locality/Commune). The obtained results indicated that more than 75% of localities (14 in Ain Naga and 15 in Doucen) showed a low degree of phytosanitary pressure. A moderate degree of pressure was found in two localities in Ain Naga (Feidh Sala and Safl Tadjdid) and in a locality of Doucen (Noumer). However, a very highly phytosanitary pressure degree was measured at two localities in Ain Naga (Mansoria (15.04) and Nebka (5.30) and two others in Doucen (Berouth (7.15) and (Tamda (3.02)) (**Table (7)**. At the global scale (PPI Locality/Commune), the extent of phytosanitary pressure was considered as low in most localities of both communes, whereas, the pressure degree was moderate in Mansoria locality of Ain Naga.

Table 7. TFI and PPI indices by study communes

Commune	Localities	Crop area (ha)	TFI Farm average	PPI Locality	Pressure Level	PPI Locality/ Commune	Pressure Level
Ain Naga	Ghemoug	0.28	14.43	0.03	Low	0.00	Low
	Methnane	0.32	5.41	0.01	Low	0.00	Low
	Bel M'rimet	0.4	0.16	0.00	Low	0.00	Low
	Dhibia	0.4	0.19	0.00	Low	0.00	Low
	Zemoura	0.72	0.08	0.00	Low	0.00	Low
	Choucha	1	0.19	0.00	Low	0.00	Low
	Mabdouaa	2.04	0.11	0.00	Low	0.00	Low
	Elhamra	3.5	5.84	0.14	Low	0.01	Low
	AlbGhenim	4.88	1.43	0.05	Low	0.00	Low
	Djalaya	5	10.32	0.36	Low	0.02	Low
	Feidh Sala	5.8	25.47	1.02	Moderate	0.06	Low
	Sidi Salah	7.16	2.42	0.12	Low	0.01	Low
	TabetChanouf	7.78	8.82	0.48	Low	0.03	Low
	Lamnisaf	8.04	2.58	0.14	Low	0.01	Low
	SaflTadjdid	12.8	10.25	0.91	Moderate	0.05	Low
	Horraya	12.96	1.14	0.10	Low	0.01	Low
	Nebka	19.6	39.00	5.30	Very High	0.31	Low
	Mansoria	51.62	42.06	15.04	Very High	0.87	Moderate
Doucen	Elmalah	0.16	0.20	0.00	Low	0.00	Low
	Louzen	0.28	1.81	0.01	Low	0.00	Low
	Elguetaa	0.4	0.43	0.00	Low	0.00	Low
	Megadersoltane	0.4	0.04	0.00	Low	0.00	Low
	Draa belamri	0.4	0.05	0.00	Low	0.00	Low
	Douisse	0.48	1.96	0.02	Low	0.00	Low
	Khafoura	0.52	1.02	0.01	Low	0.00	Low
	Hai elgamer	0.64	0.03	0.00	Low	0.00	Low
	MatbakhK'dar	1.48	2.32	0.06	Low	0.00	Low
	Draa R'mal	2.13	3.19	0.12	Low	0.01	Low
	Chouiter	2.16	3.47	0.13	Low	0.01	Low
	Mhissar	2.36	2.18	0.09	Low	0.00	Low
	MaatherKhira	2.7	9.42	0.46	Low	0.02	Low
	Noumer	3.5	19.13	1.20	Moderate	0.05	Low
	Elmarhoum	3.98	11.39	0.81	Low	0.04	Low
	ELamri	5.1	6.74	0.62	Low	0.03	Low
	Tamda	10.42	16.13	3.02	Very High	0.14	Low
	Berouth	18.54	21.47	7.15	Very High	0.33	Low

DISCUSSION

The assessment of phytosanitary practices for vegetables revealed extensive use of pesticides. Most of these products are insecticides, followed by fungicides. However, herbicides are rarely used. So, this can be explained by the fact that farmers use other alternatives to chemical control in order to control weeds. The persistence of herbicides and their broad spectrum of action encourages farmers to manage weeds in greenhouses manually. Our study findings are consistent with those reported in Benin (Ahouangninou *et al.,* 2019).

For the frequency of treatment per season, both communes showed a very high spray frequency, mainly during dry season. This can be justified by market garden crops' vulnerability to pests (Toumi *et al.,* 2018). Also, intensive farming or monoculture systems require frequent use of pesticides. This uncontrolled application can lead to undesirable effects on the environment (Ruiz-Martinez *et al.,* 2015).

The heavy use of pesticides in the market gardening system could be explained by the absence and ignorance of pesticide application schedules throughout the year. However, these schedules tend to be more necessary to manage the frequency of pesticide use and limit peak periods in agricultural lands (Didoné *et al.,* 2021). Also, it allows for matching the biology of the pests, which can ensure the effectiveness of pesticide application (Epstein and Bassein, 2003; FAO, 2006), over years of pest pressure.

The TFI computation showed that some species of vegetables were more demanding (so-called consumers) of PPPs, particularly Solanaceae (tomato and pepper) and Cucurbitaceae (eggplant) families. For these same crops and for both communes, the total TFI values registered were not reflecting a significant difference, which expresses that farmers are following similar patterns. The tomato crop recorded the highest TFI value (154.9). our finding obtained is 14 and 29 times higher than those previously reported by Leung *et al.* (2016) and Deslandes *et al.* (2019) in France for open fields (TFI = 11.3) and for soilless shelters (TFI = 4).

For average TFI, the highest values are mostly obtained for tomato (7.72) and chili (5.86) crops in the Ain Naga commune and chilli pepper(30.45), eggplant (14.08), melon (13.45), tomato (8.66) and cucumber (6.22) crops in Doucen commune. These findings are consistent with a series of surveys performed on different vegetables crops and fruits grown in El-Oued region, Southeastern Algeria. Surveys such as that conducted by Ben Abdelhamid (2016) has found very high average TFI values in tomato crop (around 10.16) and in pepper (15.16).

In 2017, Hamdi and Djaoudi have recorded average TFI values higher than 15 in several species including pepper (15.26), watermelon (16.21), strawberry (16.30), and faba beans (22.89). While Ben Thamer and Seghieri (2018) have shown values ranging from 2.70, 6.08 and 8.50 for potato, tomato, and pepper crops, respectively.

In Mauritius, Le Bellec *et al.* (2017) have recorded high TFI values on eggplant and tomato crops, low TFI values on beans, and medium to high TFI values on pepper crops. As a consequence, a relationship exists between crop diversity and the increase of pest pressure on farms

(Le Bellec *et al.,* 2017). Therefore, according to Brunet *et al.,* (2008), the kind of vegetables grown, the production systems and the cropped surface are the main criteria influencing the extent of phytosanitary pressure more than the pesticide use intensity.

The investigations showed that three vegetable species (tomato, pepper, and eggplant) were grown on large surfaces within the studied communes. This marks a very high intensity of phytosanitary pressure and a tremendous amount of PPPs are being used intensively to control pests and diseases.

In addition, the high intensity of PPP used on the seven species identified in Doucen seems more important and worrying, despite that its total treated surface areas were three times lower than Ain Naga's, but its applied dosages were exceeded the prescribed standards. Therefore, surveys and the use of simple and manageable tools, such as the Danish indicator can provide understandable and efficient results to measure the annual evolution of the phytosanitary pressure at the national level as well as to evaluate the general policy of reducing the risks linked to the use of pesticides (Pingault, 2007; Brunet *et al.,* 2008; Dessaint *et al.,* 2014).

A number of causal factors have been found to lead to increase pest pressure, adverse health effects, and environmental problems in the long and/or short term. These factors are mainly the changes in the ambient environment (humidity, temperature, and lighting), farmers' erroneous and sometimes hazardous phytosanitary practices, such as incorrect selection of PPPs, non-respect for the recommended dosage and its application (Soudani *et al.,* 2020a).

Corresponding to Hashemi and Damalas (2010), farmers' mindsets and understanding of the nature and properties of the pesticides greatly influence their behavior and their use of these chemicals, as does their willingness to accept alternative methods like Integrated Pest Management (IPM). Thus, it is necessary to provide more and ongoing guidance to farmers regarding pesticide hazards, the benefit of the use of good agricultural practices (El Bouzaidi *et al.,* 2020), the safe use of pesticides, and the effectiveness of the IPM. In addition, advisory support given by the actors concerned with the agricultural sector to farmers, along with monitoring and understanding long-term changes in their farming practices, can ease the transition into sustainable practices (Hashemi and Damalas, 2010 ; Chantre and Cardona, 2014 ; Hantchi *et al.,* 2022).

CONCLUSION

In this study, the TFI and PPI indicators measurements revealed extensive use of PPPs and bad phytosanitary practices by the market gardeners. Both study communes (Ain Naga and Doucen) are experiencing an intense phytosanitary pressure, which may have serious effects on all ecosystem compartments, as well as on human health. So far, very little attention has been paid to the role of indicators measurements. Consequently, integrating this kind of assessment tool into intensive agriculture can help public policy authorities in managing pesticide use, making comparisons between crop types, production systems, and geographical areas. This could be achieved by conducting regular investigations and inciting farmers to register and follow up on their practices, over several farming seasons (a long-term time period) in order to assess the errors, and then correct them if occurred. Furthermore, supporting studies on farming systems will contribute to collecting relevant data for setting regional, national and Mediterranean baseline values. Moreover, it is recommended to create a national cell for support, and monitoring to ensure the sustainability and safety of agriculture, and optimal selection of phytopharmaceutical products with a minimal danger for both human health and environment. Also, training of trainers (TOT) and providing courses to farmers at the Farmer Field Schools (FFS) can contribute to taking steps to minimize arbitrary usage of PPPs on various crops and cropping systems.

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تقدير ضغط الصحة النباتية والأثر البيئي المرتبط باستخدام المبيدات

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الملخص

تعد الخضروات من المحاصيل الشديدة الحساسية لهجمات الآفات وانتشار الأمراض و الحشائش الضارة. و لمكافحة هذه الآفات يلجأ المزارعون إلى الاسراف في استخدام المبيدات الكيميائية المختلفة. لذلك، يهدف هذا العمل إلى قياس شدة استخدام المنتجات الكيمائية الزراعية و إلى تقدير ضغط الصحة النباتية وفقًا لممارسات مزارعي الخضروات في منطقة بسكرة، جنوب شرق الجزائر. من خلال استبيان تم إجراؤه على 96 من مزارعي الخضروات المختارين عشوائياً في بسكرة خلال دورتين زراعيتين 2017/2016 و 2018/2017. أظهرت النتائج بأنه من بين 70 مادة فعالة مختلفة، ثمانية عشر مادة يتم استخدامها غالبا على سبع أنواع نباتية تم جردها، و بأن المبيدات الحشرية ومبيدات الفطريات هي الأكثر انتشارً. يتراوح متوسط قيم مؤشر تكرار العلاج المحسوب من 0.80 إلى 30.45. أما مؤشر ضغط الصحة النباتية فينذر بالخطر بشكل خاص لمحاصيل الطماطم والباذنجان والفلفل الحار، كما تتراوح القيم بين 4.03 و 4.29 و 8.25 على التوالي. والخلاصة، وجد أن المناطق التي شملتها هاته الدراسة تشهد ضغطا كبير على الصحة النباتية مما سيأثر سلبيا على البيئة وصحة الإنسان.

الكلمات المفتاحية: منتجات وقاية النبات، ضغط الصحة النباتية، المخاطر البيئية، محاصيل الخضر