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Structure and diversity of weed communities associated with *Cucurbita pepo* L. cv. Scarlette “Zucchini” in the Eastern Province of Saudi Arabia

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Weed communities constitute an important component of any agro-ecosystem. Weeds are widespread among different crop cultivars and usually cause many changes. *Cucurbita pepo* is a common vegetable cultivated around the world. Additionally, there is a significant increase in the cultivation of *Cucurbita pepo* in Saudi Arabia. During the 2015 and 2017 growing seasons of *Cucurbita pepo* “zucchini,” weed communities were investigated in five regions of the Eastern Province of Saudi Arabia. Fifty-four weed species belonging to 20 plant families that occurred within the *Cucurbita pepo* fields in the studied areas were investigated. Community structure, frequency, presence and species diversity were evaluated. In addition, relative abundance and phi-coefficient of association was calculated. The diversity and functional complex of weed communities can help to sustain biodiversity, ecosystem amenities and maintain crop performance.

Key words: Abundance, *Cucurbita pepo,* species diversity, weed community.

INTRODUCTION

As a result of the wide ecological amplitude of weed communities, weeds have become widespread among all different crop cultivars causing many alterations. Evaluations of crop systems divulge a general negative correlation between weed diversity and crop yield (Syswerda and Robertson, 2014), but tallying of a particular weed species does not really necessarily impact crop yield (Epperlein et al., 2014). Although weed communities often affect major constraints to resource-efficient crop production, changing weed communities can also support performance directly or indirectly by providing shelter and food for the beneficial insects and birds (Isbell et al., 2011; Kohler et al., 2011; Marshall et al., 2003). Moreover, weed communities can positively affect ecosystem purpose and stability, like reducing soil erosion, and nitrogen leaching (Carlesi et al., 2013), pest control (Donald, 2004), and pollination (Kremen et al., 2002). Weed communities constitute a highly dynamic collection of plants adapted to frequently disturbed habitats (Stenchly et al., 2017).

The plants of *Cucurbitaceae* family are grown within the tropics and temperate areas, where those with edible fruits were among the earliest cultivated plants in both the Old and New Worlds. The *Cucurbitaceae* family ranks

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among the highest of plant families for the number and the percentage of species that have been used as human food (Lira and Montes, 2013). *Cucurbita pepo* is a common vegetable cultivated in vast and different areas of Saudi Arabia; and in other countries of the world. It is called zucchini in America, courgette in the UK, and kusa in Arabic speaking countries. The geographic origin of *C. pepo* is commonly determined to be between Mexico and eastern North America (Smith, 1992).

One of the important challenges to improve the weed control methods is their identification (Tuo et al., 2013). Studying the composition of the weed flora and its evolution, abundance, diversity and fidelity under the impact of environmental and phytotechnic factors is actually a basic criterion for any advance of weed control methods. Nonetheless, some weed species are more damaging than others; also changes in weed communities may influence the impact of weeds, so it is relevant to determine the structure and diversity of weed communities associated with the crops. Therefore, this work aims to investigate the weed communities associated with *Cucurbita pepo*, their composition, abundance and diversity.

MATERIALS AND METHODS

The study area

This study was done in the Eastern Province of Saudi Arabia, which has an area of approximately 672,500 km^2. This region is one of the country's main vegetable suppliers. Five selected localities with 17 *Cucurbita pepo* fields were investigated. The selected localities from which data were collected are as follows:

Dammam

It is the capital of the Eastern Province, about 800 km^2 area. Dammam has a hot desert climate according to the Köppen climate classification. The winter temperatures range from mild to warm, but regularly decrease to as low as approximately 8°C some days (Table 1). Summer temperatures are extremely hot, typical of most of West Asia and usually exceed 40°C for approximately five months. Rainfall in Dammam is generally sparse, and usually occurs in December. However, some winter rainfall has been comparatively heavy, resulting in filling of water-reservoirs at desert Wadies. The mean annual precipitation is approximately 85 mm (RCC, 2010). Two fields were studied in this region (Table 1).

Al Jubail

It is the host of the largest industrial city in the Middle East, approximately 100 km from Dammam. The average annual temperature here is 26.3°C and average rainfall is 73 mm (RCC, 2010). Here, five fields have been investigated.

Ras Tanur

It is a city in the Eastern Province of Saudi Arabia located on a peninsula extending into the Arabian Gulf within 80 km distance from Dammam (RCC, 2010). The average annual temperature is 25.6°C and about 82 mm of rainfall annually (Table 1). Two fields of *Cucurbita pepo* were studied.

Al-Ahsa (Al Hofuf)

It is a traditional oasis region in eastern Saudi Arabia and it is located about 60 km inland from the coast of the Arabian Gulf. Hofuf climate is a desert climate, without actual precipitation during the year (RCC, 2010). Natural fresh-water springs are scattered at oases, encouraging human habitation and agricultural efforts. Five fields were studied.

Salasel

It is a small community located at 49.449 E and 26.075 N, approximately 70 km from Dammam. The environment more or less varies in this region (RCC, 2010), with sand dunes, sandy plains, gravel valleys, dense vegetation areas and mountains. Three *Cucurbita pepo* fields were studied.

Collection of data

Before cover crop demolition, weed species were collected and weed density and diversity were evaluated in the middle of each cover crop plot and in the weedy fallow by cutting the plants at ground level in a quadrat 100 cm × 100 cm (1 m^2) placed randomly four times over each plot. Weed samples were investigated inside and outside the *Cucurbita pepo* rows. To evaluate weed community structure and composition in the *Cucurbita pepo* crop, weed species density and diversity was assessed at 30 days after *Cucurbita pepo* planting, and finally in all weedy plots when cucurbits were harvested. Additionally, the phi-coefficient of association was calculated according to Chytrý et al. (2002a), where its values ranged between "-1" for least association and "1" for maximum association.

An exhaustive floristic survey was conducted with a whole field browsing technique. This method consists of an integral floristic survey of all weed species present by browsing the whole field until no new species were found. Using this method allows the inclusion of species even if they are heterogeneously distributed within the field (Chicouene, 2000). Weed species were identified according to Chaudhary (2000 and 2001), and native versus exotic status was assigned, and growth form and life history (annual versus perennial) were recorded. For each locality, each species was assigned a qualitative abundance score on a scale of zero to five (0 to V): 0 (if the species was absent), I (if present but rare; 1-5%), II (if frequent; 6-20%), III (if abundant; 21-40%), IV (if common; 41-80%) and V (if the species was very common; 81-100%). We then used the abundance score values and fidelity for clustering recognized weeds species into groups, and examined the relationship between sites as to their abundance of these weeds. Thus, five clusters were initiated. The diversity was calculated by using the species richness and abundance index.

Statistical analysis

All the characteristics were analyzed by ANOVA using JMP statistical software (SAS, 1996). All descriptive statistics were reported as figures (graphs) or as tables.

RESULTS

We investigated fifty –four weed species belonging to 20

Table 1. Climatic data of the study areas according RCC (2010).

Area	Parameter	January	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Damm.	Mean Temp.	15.7	17.1	20.6	25.5	30.4	33.4	34.9	34.4	32.4	27.8	22.5	17.9	26.05
	Min. Temp.	11.5	12.3	15.3	20.3	25.3	28.7	30.6	30.1	27.7	23	17.9	13.2	21.33
	Max. Temp.	19.9	21.9	25.9	30.8	35.6	38.1	39.3	38.7	37.1	32.7	27.1	22.6	30.80
	Mean PPT	17	18	17	8	0	0	0	0	0	0	8	9	**77**
Hofo	Mean Temp.	15.7	17.5	21	25.9	31.1	33.9	35	34.2	32.1	27.8	22.4	17.5	26.17
	Min. Temp.	11.1	12.4	15.5	20.1	25	27.8	29.1	28	26	21.8	17.2	12.6	20.55
	Max. Temp.	20.4	22.6	26.6	31.7	37.2	40.1	41	40.5	38.3	33.9	27.7	22.5	31.875
	Mean PPT	14	14	18	12	2	0	0	0	0	1	5	8	**74**
Ras Tan.	Mean Temp.	15.6	16.9	20.4	25	29.8	32.5	34.3	33.7	31.9	27.6	22.3	17.7	25.64
	Min. Temp.	11.7	12.3	15.2	20.1	25	28.3	30.6	30.1	27.8	23.3	17.9	13.2	21.29
	Max. Temp.	19.6	21.6	25.6	30	34.6	36.8	38.1	37.4	36.1	31.9	26.7	22.2	30.05
	Mean PPT	18	20	16	9	0	0	0	0	0	0	9	10	**82**
Jubail	Mean Temp.	14.9	16.2	19.9	24.5	29.6	32.7	34.3	33.6	31.7	27	21.5	16.8	25.23
	Min. Temp.	10.7	11.3	14.5	19.4	24.6	28.2	30.4	29.6	27.2	22.4	16.9	12	20.60
	Max. Temp.	19.1	21.2	25.3	29.7	34.6	37.2	38.3	37.6	36.2	31.7	26.1	21.6	29.88
	Mean PPT	21	19	15	10	0	0	0	0	0	1	13	9	**73**
Salasel	Mean Temp.	15.3	16.9	20.5	25.6	30.7	33.8	35.2	34.3	32.2	27.5	22	17.1	25.93
	Min. Temp.	10.7	11.7	14.9	19.9	25	28.2	29.9	28.8	26.6	21.9	16.9	12.1	20.55
	Max. Temp.	19.9	22.1	26.2	31.3	36.5	39.4	40.5	39.8	37.8	33.2	27.1	22.2	31.33
	Mean PPT	16	15	18	11	1	0	0	0	0	1	8	8	**78**

Temp. = temperature; PPT= precipitation.

plant families that occurred within the *Cucurbita pepo* fields in the studied areas (Table 2). The set of species is very similar to those in tropical regions of Africa or Asia, with the same species or genera being the most common (Kent et al., 2001; Rodenburg and Johnson, 2009).

Weed community structure

Among the studied sites, species richness ranged from 10 to 36 species with a median value of 25 species (Table 2). The most abundant and diverse family is Poaceae (represented by 13 species), followed by Fabaceae (8 species).

The recorded species can be grouped in 5 clusters (Figures 1 and 2) according to the abundance class and the presence percentage of the species (Legendre and Legendre, 2012).

Cluster one

Abundance class V (above 70% presence), five species were recorded (representing 9.3% of the total recorded species). The prevailing families are Chenopodiaceae, Amaranthaceae, Convolvulaceae, Portulacaceae and Malvaceae.

Cluster two

Nine species comprise 16.7% of the total recorded species. Abundance is in class IV, with presence ranging from 35.5 to 47%.

Cluster three

Fourteen species were recorded here (26% of the total recorded species), with presence values between 20 and 30%.

Cluster four

Ten species were recorded here (18.4% of the total recorded species), with presence values between 6 and 20%.

Cluster five

Here, abundance values were less than 6%, and 16

Table 2. Characteristic of weed species associated with Cucarbita pepo in the studied areas of eastern region of Saudi Arabia.

S/N	Families/species	Life form	Origin	Frequency					Total presence %	Abundance
				Damm.	Huf.	Sala.	Jub.	R. Tun		
1	**Aizoaceae**									
1	*Mesembryanthemum nodiflorum*	A herbs	N	0	0	33.3	0	0	5.9	R
2	**Amaranthaceae**									
2	*Amaranthus gracizans*	A herbs	Native	50	100	100	50	80	82.4	V. Ab.
3	**Asteraceae**									
3	*Ifloga spicata*	A herbs	Native	0	0	33.3	0	0	5.9	R
4	*Launaea capitata*	B herbs	Native	0	0	100	10	0	23.5	F
5	*Launaea cassiniana*	A / B herb	Native	0	60	100	0	0	35.3	Ab.
6	*Launaea nudicaulis*	P herbs	Native	50	80	33.3	40	0	47	V. Ab.
7	*Senecio desfontainei*	A herbs	Native	0	0	33.3	60	0	23.5	R
8	*Sonchus oleraceus*	A / B herb	Cosmop	0	60	66.7	0	0	29.5	F
4	**Boraginaceae**									
9	*Heliotropium bacciferum*	P shrublet	Native	50	20	66.7	20	0	29.5	F
10	*Moltkiopsis ciliata*	P shrublet	Native	0	0	66.7	0	0	11.7	O
5	**Brassicaceae**									
11	*Diplotaxis acris*	A herb	Native	0	0	100	40	0	29.5	F
12	*Eremobium aegyptiacum*	A/P herb	Native	0	0	33.3	0	0	5.9	R
13	*Farsetia aegyptia*	P shrub	Native	0	0	33.3	0	0	5.9	R
6	**Caryophyllaceae**									
14	*Arenaria serpyllifolia*	A herb	Cosmop	0	0	33.3	20	0	11.7	O
15	*Silene Arabica*	A herb	Native	0	0	100	20	0	23.5	F
7	**Chenopodeaceae**									
16	*Beta vulgaris*	A / B herb	Native	0	0	0	0	50	5.9	O
17	*Chenopodium album*	A herb	Cosmop	50	80	0	20	0	35.5	Ab.
18	*Chenopodium ambrosioides*	A herb	Native	100	80	100	100	0	82.4	V. Ab.
19	*Salsola baryosma*	A herb	Native	0	0	33.3	0	0	5.9	R
20	*Suaeda vermiculata*	P shrub	Native	0	0	0	20	0	5.9	O
8	**Convolvulaceae**									
21	*Convolvulus arvensis*	A herb	Cosmop	0	80	100	50	80	70.6	F
9	**Cyperaceae**									
22	*Cyperus conglomeratus*	P herb	Native	50	0	33.3	0	50	17.6	F
10	**Euphorbiaceae**									
23	*Euphorbia heterophylla*	A herb	Native	0	0	0	50	0	5.9	O
24	*Euphorbia prostrate*	A herb	Exotic	0	0	33.3	0	0	5.9	R
11	**Fabaceae**									
25	*Alhagi maurorum*	P shrublet	Native	0	20	0	0	0	5.9	R
26	*Astragalus asterias*	A shrublet	Native	0	0	33.3	0	0	5.9	R
27	*Astragalus corrugatus*	A herb	Native	0	0	33.3	0	0	5.9	R
28	*Hippocrepis bicontorta*	A herb	Native	0	0	33.3	0	0	5.9	R
29	*Lotus garcini*	A shrublet	Native	0	0	33.3	0	0	5.9	R
30	*Melilotus indica*	A herb	Native	50	20	100	20	80	41	V Ab
31	*Trifolium fragiferum*	A herb	Native	0	0	66.7	0	60	29.5	F

Table 2. Contd.

32	*Trigonella stellate*	A herb	Native	0	0	66.7	0	0	11.7	O
12	**Geraniaceace**									
33	*Erodium glaucophyllum*	A herb		0	0	66.7	0	0	11.7	O
13	**Juncaceae**									
34	*Juncus rigidus*	P herb	Native	0	20	0	0	0	5.9	R
14	**Malvaveae**									
35	*Malva parviflora*	A herb	Native	50	100	100	50	80	82.4	V. Ab.
15	Plantagenaceae									
36	*Plantago cylindrical*	A/P herb	Native	0	0	100	20	0	23.5	Ab.
16	**Poaeaceae**									
37	*Aeluropus massauensis*	P. grass	Native	0	60	0	0	60	35.5	F
38	*Chrysopogon aucheri*	A. grass	Native	0	40	0	0	0	11.7	O
39	*Cenchrus ciliaris*	P. grass	Native	0	20	66.7	0	40	29.5	F
40	*Cynodon dactylon*	P. grass	Native	50	80	0	0	20	35.5	Ab.
41	*Dactyloctenium aegyptium*	A. grass	Native	0	40	0	20	0	17.6	O
42	*Lasiurus hirsutus*	P. grass	Native	0	0	33.3	0	0	5.9	R
43	*Phalaris minor*	A. grass	Native	0	60	66.7	0	0	29.5	F
44	*Phragmites australis*	P. grass	Cosmo.	0	20	33.4	20	0	17.6	F
45	*Poa annua*	A. grass	Cosmo.	0	60	100	0	20	41	Ab.
46	*Polypogon monospeliensis*	A. grass	Native	50	0	0	0	50	11.7	O
47	*Promus tectorum*	A. grass	Native	0	40	0	40	0	23.5	F
48	*Setaria viridis*	A. grass	Native	50	0	33.7	60	0	35.5	Ab.
49	*Stipagrostis obtusa*	P. grass	Native	0	60	0	40	0	29.5	F
17	**Polygonaceae**									
50	*Emex spinosus*	A. herb	Native	0	40	0	0	0	11.7	O
18	**Portulacaceae**									
51	*Portulaca oleracea*	A. herb	Exotic	100	80	0	0	100	47	Ab.
19	**Solanaceae**									
52	*Solanum nigrum*	A. herb	Exotic	0	0	0	40	100	23.5	Ab.
20	**Zygophyllaceae**									
53	*Tribulus terrestris*	A. herb	Exotic	0	80	0	40	0	35.3	F
54	*Zygophyllum coccineum*	P. Shrublet	Native	50	20	50	20	50	23.5	Ab.

Life form (A: annual, B: biennial, P: perennial); origin (N: native, E: exotic, C: cosmopolitan), abundance (R: rare, O: Occasional, F: frequent, Ab.: abundant, V. Ab: very abundant), frequency of Fidelity, total presence and abundant.

species represented this cluster (29.6% of the total recorded species).

Weed species richness and abundance

The cumulative number of species recorded in the studied areas with different distributions ranged from 4 to 27 among the studied fields (Table 2) and varied significantly among the investigated areas.

Among the studied areas, Salasel had the highest species richness, frequency abundance and phi-coefficient values (Figures 1 and 2). On the other hand, the lowest values of the studied parameters were

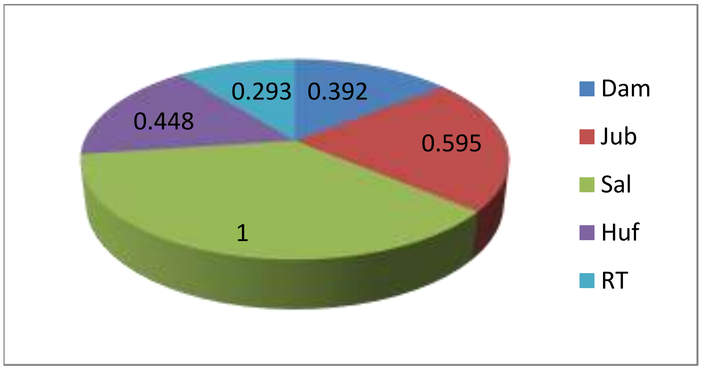
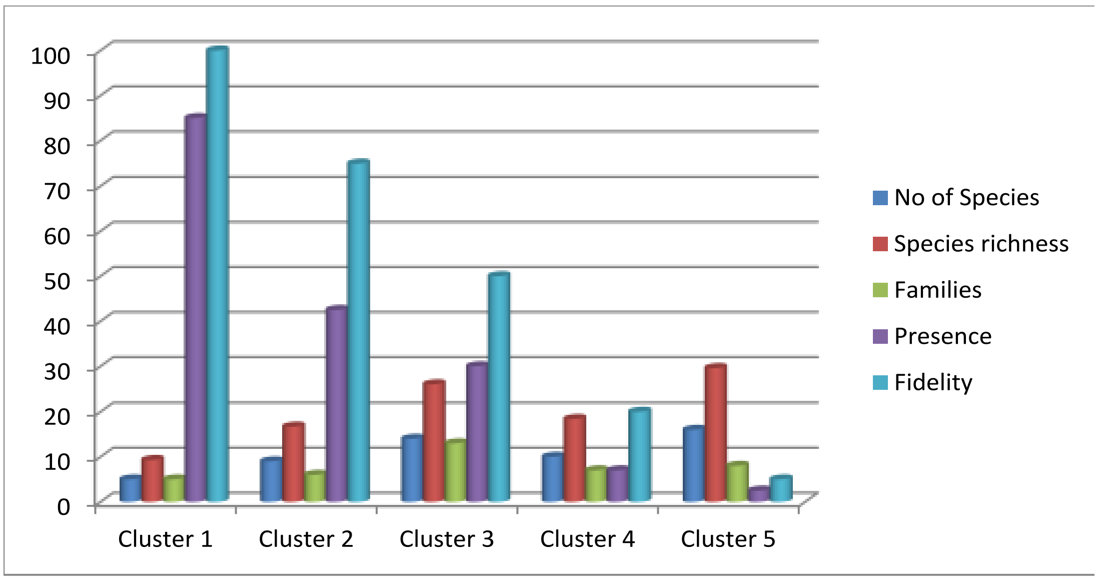


Figure 1. The Phi-Coefficient of Association of weed species within the study areas. According to Chytrý et al. (2002a).



Figures 2. Features of the recognized clusters: number of species, species richness, families, presence % and Fidelity.

recorded within the Ras Tanura region.

DISCUSSION

The study of vegetables around the world is revealing increasing evidence of the fact that different plants have many unexpected ties connecting them with each other (Vivaldo et al., 2016). *Cucurbita pepo* causes novel canopy and sub-canopy microhabitats that enhance the structural diversity of weed and may alter the composition and abundance of associated weed species. The set of associated weed species is very similar to those in tropical regions of Africa or Asia, with the same species or genera being the most common (Kent et al., 2001; Rodenburg and Johnson, 2009).

More broadly, the families Poaceae followed by Fabaceae and Asteraceae were the dominant weed families found within weed communities of *Cucurbita pepo* cultivation fields, as emphasized by Marnotte et al. (2006). The predominance of Poaceae is explained by the metabolic advantages of C4 plants, which are well adapted to hot and dry climates (Stenchly, 2017). Rodenburg and Johnson (2009) suggested more or less the same consistency of the weed flora of Cucurbita pepo as reported here.

Weed communities of Cucurbita pepo are strongly influenced by the cropping practices and water management (Kent et al., 2001) as well as altitude, soil characteristics (including fertility), and weed control techniques (Smith, 1983). Different research showed that squash (*Cucurbita pepo* L. cv. Scarlette) is of an allelopathic potential on some common weed species (Qasem and Issa, 2010). Definitely, factors other than soil and climate share in determining weed community composition and structure. To take these other factors into consideration, we controlled statistically for the effect of geographical position on our measures of community similarity because more proximate sites are likely to be more similar for general factors. After controlling for geographic position, we detected a significant influence of abundance on weed communities, suggesting that it influences weed communities independent of, over and above, a general effect of geography (Houngbédji et al., 2016). Five clusters were recognized according to the presence percentage and fidelity; thus, particular weed management methods were suitable for each group. Each floristic group was characterized by the percentage of coverage of its constituting species. The results of the internal fidelity analysis reveals that the more heterogeneous a syntaxon is, the higher are the phi-coefficient values of association in the Salasel area (Figure 1). The use of fidelity measures supports and improves the results of phytosociological classification based on comparing more or less numerous sets of species that are nevertheless always limited by the ecological and the geographical contexts (Legendre and Legendre, 2012; Nawaza and Farooq, 2016). The results endorse the requirement of removing the early and frequent weeds, even after long period (reaching four years) to reduce weed infestations and improve crop growth.

Conclusion

The weeds are one of the most limiting factors affecting *Cucarbita* crop yield according to the weed species composition, density and diversity. Crop type, soil and climatic aspects can affect weed community's variation. Improvement of crop yield requires integrated weed studies and management strategies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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