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Interspecific variations in the habitats of *Rhus tripartitum* L. populations in Saudi Arabia leading to changes in morphological traits and allelopathic activity

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SILVICULTURE

ABSTRACT

Background: The objectives of this study are to (i) determine the variations in the soil composition among six different habitats of six *Rhus tripartita* populations, (ii) identify and compare the variation in the fruit and seeds parameters of these populations, and (iii) evaluate the differences in *Rhus tripartita* allelopathic activities among populations on the Chenopodium album weed on it as biological control method.

Results: The soils analysis of the six habitats of *Rhus tripartita* populations revealed a significant variation in the soil variables, while salinity, organic matter, and macro-elements (Cl^-, HCO^{3-}, Na^+, K^+, Ca^+ and Mg^{2+}) were the most controlling factor. *Rhus tripartita* fruits and seeds showed that there is an inter-site variability observed between populations. Morphological study indicating a large-scale diversity among the provenances. It is related to the phenotypic characteristics which may be due to the genetic effect. The *Rhus tripartita* extract concentration, especially population 4 (P4), showed potential allelopathic activity against Chenopodium album, where the germination was strongly inhibited at a concentration of 10 g l^{-1}. Under same concnetration, seedling root length and shoot lenght were seriously affected.

Conclusion: These extracts could be used as green source, eco-friendly bioherbicide and to be integrated into the weed control program of weeds. However, further study is needed for characterization of essential oil of Rhus tripartita and their potential allelopathic activities against the *Chenopodium* album weed or maybe other weeds, and evaluate its valuable economic use on a large scale.

Keywords: *Rhus tripartita*; Edaphic factors; Population; Morphological traits; Allelopathic activity

HIGHLIGHTS

Changes in soil characteristics, morphological traits and the effect of allelopathic activity depend on population habitats of *Rhus tripartitum* L.
Soils analysis revealed a significant variation in the physico-chemical parameters of population habitats.
Morphological traits indicating a large-scale diversity among the populations.
The *Rhus tripartita* extract concentration, especially population 4 (P4), showed potential allelopathic activity against *Chenopodium* album
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INTRODUCTION

The Rhus (Anacardiaceae) species distributed in different temperate zones (Giovanelli et al. 2017). Rhus species have a wide array of pharmacological activities such as anti-inflammatory, antinephritic, antimicrobial (Abbassi and Hani 2012), antioxidant and breast cancer preventive properties (Amin et al. 2007; Wang et al. 2005). The products of secondary metabolism of *Rhus tripartita*, in particular the phenolic compounds, have anti-carcinogenic, anti-thrombotic and anti-inflammatory (Chung et al. 1998; Barka et al. 2019), anti-nephritic, antimicrobial (Abbassi and Hani 2012) activities; antioxidants and preventive properties of breast cancer (Wang et al. 2005; Amin et al. 2007; Shahat et al. 2016). Baraka et al. (2019) found that *Rhus tripartita* as dietary source of natural antioxidants and might be appropriate for the development of reliable biotechnologic methods to identify and extract the antimicrobial and anti-inflammatory biomolecules. These authors showed that showed the presence of high concentrations of polyphenols, flavonoids and tannins (which is the major compound for the leaf). Baraka et al. (2019) showed that *Rhus tripartita* extracts exhibited interesting antioxidant, antimicrobial and anti-inflammatory activities due to their high polyphenols contents. *Rhus tripartita* fruits are consumed fresh, soaked in sour milk or added to drinking water to offer an acceptable taste (Mahjoub et al. 2010). *Rhus tripartita* and other Rhus species are widely used in food, and in modern and traditional medicine. They have been used for the treatment of diarrhea, colitis, diseases, inflammatory diseases, diabetes, dysentery, haemoptysis, conjunctivitis, animal bites and poisons, hemorrhoids, sexual disease, fever, pain and various cancers (Wu et al. 2013; Giancarlo et al. 2006). The antioxidant, anti-inflammatory, antiulcerogenic, antimalarial, antimicrobial, antitumor, antiviral, anticonvulsant and hypoglycaemic activities of *Rhus tripartita* have been investigated (Mahjoub et al. 2010, Giancarlo et al. 2006; Alimi et al. 2013). In particular, *Rhus tripartita* (Ucria) Grande is largely located in North Africa and in northeastern part of Saudi Arabia (Shahat et al. 2016). In Arabian traditional medicine, this plant has been used for the treatment of cardiovascular and gastrointestinal disorders along with inflammatory conditions (Shahat et al. 2016; El-Mokasabi 2014) its other reported biological activities also include antioxidant, antidiarrheal, and antiulcer effects (Itidel et al., 2013). *Rhus tripartita* fruits were recently shown to contain a wide array of phytochemicals but were remarkably rich in flavones and betulinic acid (Zhang et al. 2005). Interestingly, flavones were previously reported to ameliorate induced cardiac injury (Tlili et al. 2014) and hyperlipidemia (Lu et al. 2013).

Allelopathy is important ecological mechanism that influences the presence of vegetation in an ecosystem, the biodiversity of the flora and the management and productivity of crops Chou 1999). Recent reports have proved allelopathic effects revealed by forest trees on vegetation suppression and soil sickness (Baltzinger et al. 2012; Hegab et al. 2016). Allelopathy plays a key role in the dynamics of vegetation in natural ecosytems. Understanding this biological phenomenon could help in the development of applications in both natural and agricultural systems (Wardle et al. 2011). Environmental factors of any habitat can directly or indirectly affect the allelopathic potential of a plant. The most critical ecological factors that influence allelopathy include temperature, water content, salinity, nutrient availability and competition stress (Elshamy et al. 2019; Meiners et al. 2012). *Chenopodium album* L. (Amaranthaceae) is a broad leaved and annual herb. It is known among local farmers in Saudi Arabia by the name « *Aldhorbaih* » and has been described as one of the worst weeds in many places in Saudi Arabia and elsewhere (Chaudhary and Akram 1987; Gomaa 2012; El-ghazali and Al-soqeer 2013; Alshallash 2018; Majrashi and Khandaker 2020; Alharthi et al. 2021). It is listed as the world's 10^{th} most serious weed and is found in Asia, Europe and North America; it is adapted to grow vigorously in many different climates and soils (Holm et al. 1977). Its presence has also been recorded in Denmark, as a summer, annual weed, usually growing on wasteland and in cultivated areas (Eslami 2011). Seeds of *chenopodium* germinate readily in light at warm temperatures between 15 and 25 °C and at even warmer ones at 25–35 °C (Altenhofen 2009). According to Alshallash (2018), *chenopodium album* which occur commonly in cereal fields in the north of Saudi Arabia and have a important rate compared to *Bromus catharticus* and *Avena fatua*. Germination of *Chenopodium album* favoured alternating temperatures (10/20 °C or 5/25 °C) over a constant (15 °C), in a light/dark (16/8 h) regime. Knowledge of ecology of *Chenopodium album* L. would the development of effective weed control programs and help in designing suitable weed management programs.

The specific objectives of this study were to (i) determine the variations in the soil composition among six different habitats of six *Rhus tripartita* populations, (ii) identify and compare the variation in the fruit and seeds parameters of populations of *Rhus tripartita* from these six habitats, and (iii) evaluate the differences in *Rhus tripartita* allelopathic activity among six populations on the *Chenopodium album* weed on it as biological control method. The effect of allelopathic control and its interaction with root and seedling of species was also assessed. Our hypothesis that allelopathic, as an environmental signal, would modify the germination characteristic and growth of *Chenopodium album*.

MATERIALS AND METHODS

The study area

The location of Hail region is found in the northern central part of Saudi Arabia (Figure 1). The Hail–region of Saudi Arabia, located between 25°35′ and 29°00′ N longitudes and 39° 01′ and 44°45′ E latitudes. It covers an area of 118,322 sq km and represents 6% of the total area of the kingdom of Saudi Arabia. Hail is bordered to the north by Al-Jouf and the Northern Frontier regions, to the west by Tabouk and Al-Madinah regions, to the south by Al-Qassim and to the east by the Central and Eastern regions (El-Ghanim et al. 2010). Hail region is characterized

Fig. 1 Study area, Hail provenace in Saudi Arabia.

by its variation in topography and geomorphology. The weather system in the Hail regions is general arid to extra arid. The study area is marked by a mean minimum temperature of 10.8 °C in January and a mean maximum temperature of 34.1°C in August with an annual mean temperature of 25.6 °C. The rainfall in the region is erratic and irregular; it is mainly winter fall, the high precipitation occurs in November (32.0 mm per day) and the average annual rainfall is 104.4 mm/year, however in the summer months no rain has been detected. The relative humidity is extremely low in summer as it reached 15.0% in July and relatively high January (53.0%); the mean annual average is 31.0%. The average annual wind velocity in the study area is 68.4 km/h and the mean number of stormy days may reach 25 per year, storms are more frequent in the spring from the North East direction. The rate of evaporation in the area is generally low; it ranges between 6.6 mm in January and 8.7 mm in November (El-Ghanim et al. 2010).

Soil analysis

Soil samples were collected from each site from six populations of *Rhus tripartita* (triplicates) (Table 1), representing a profile at a depth of 0–50 cm (Abd El-Gawad, 2014). Soil texture, porosity, organic carbon, and sulfate were determined according to Piper (1946). Calcium carbonate was determined by titration against 1 N NaOH and expressed as percentage (Jackson, 1962). A soil solution (1:5) was prepared for each soil sample. The electrical conductivity (EC), pH, and chloride were determined according to Jackson (1962). Carbonate and bicarbonate were determined by titration method using 0.1 N HCl (Pierce et al., 1958). The extractable cations Na^+ and K^+ were determined using a flame photometer, while Ca^{++} and Mg^{++} were estimated according to Allen et al. (1974) using an atomic absorption spectrometer.

Tab. 1 Location and main ecological traits of six populations of *Rhus tripartita* in Hail region (Saudi Arabia).

Code of population	Bioclimatic zone	Latitude	Longitude	Altitude (m)	Rainfall $m.yr^{-1}$
P1	arid to extra arid	25°46′N	40°21′E	750	100 - 250
P1		26°08′N	41°14′E	700	
P2		26°51′N	42°12′E	850	
P3		27°34′N	42°44′E	900	
P4		27°023′N	43°27′E	850	
P5		28°24′N	40°49′E	820	

Physical properties of *Rhus tripartita* fruits and seeds

Fruits and seeds of *Rhus tripartita* were obtained from wild tree which were collected from six populations (Table 1 and Figure 2). Fruits were collected from nine trees from each population: 100 fruits per tree and 100 seeds per tree. The length, width, and area (mm^2) of fruits and seeds were individually measured to the nearest 0.01 mm using strero-microscope (leica DM 205-C). Fruit and seed thickness (mm) are measured by calipher with a sensitivity of 0.01 mm. The average weight of 100 fruits (g) is measured with a precision balance.

Allelopathy activities

The seeds of *Chenopodium album* were collected from agricultural area. Seeds were sterilized with 0.3% calcium hypochlorite, rinsed in distilled water, and dried on fiter paper in the laboratory at room temperature for 7 days. Six *Rhus tripartita* populations were harvested in Hail region in Saudi Arabia (Table 1). For bioassay tests, extracts were prepared from the leaves of Six *Rhus tripartita* populations as various concentrations (2, 4, 6, 8 and 10% w/v) and 0

Fig. 2 *Rhus tripartita* species.

(control). For each population of *Rhus tripartita* mixtures of leaves are prepared (1 : 1 v/v). The solutions were fitered through double layers of muslin cloth followed by fiter paper. The pH of the mixtures was adjusted to 7 with 1 M HCl, and then mixtures were stored in a refrigerator at 4°C until further use. For germination bioassays, two layers of fiter papers were placed in 90-mm-diameter glass petri dishes. Twenty seeds of *Chenopodium album* were placed in each petri dish, followed by 10 ml of plant extract of each population of *Rhus tripartita*. A control sample was assigned with distilled water. Germination is maintained in a growth chamber under controlled room temperature (20ºC ± 2) and photoperiod of 16–08 h (light/Dark). Starting from the first day after the experiment began, germinated seeds were counted and removed daily. The experimental design was carried out as a randomized complete block (RCB) with 5 replications (Nagmouchi and Alsubeie 2020). The percentage of germination was calculated. For growth bioassays, the seeds of *Chenopodium album* were germinated on fiter paper at room temperature for 2 days. Fiften germinated seeds were transferred to petri dishes, which were filed with 25 g of sterilized quartz sand, and 10 ml of tested extract (2, 4, 6, 8 and 10% w/v) and 0 control was added of each population. In addition, control sample was added to the experiment without any treatment. Root lengths and seedlings height were measured 14 days after treatment (DAT) (Nagmouchi and Alsubeie 2020).

Statistical analysis

All data were subjected to analysis of variance (ANOVA) for a randomized complete block design, after testing for homogeneity of error variances and Student-Newman-Keuls test were analysis, using the SPSS software 23.0. All data were expressed as mean ± standard deviation (SD).

RESULTS

Soil analysis

As shown in Table 2, all physico-chemical characteristics (sand, silt, clay, OC, OM, $CaCO_3^-$, EC, Cl^-, HCO_3^-, Na^+, K^+, Ca^{++} and Mg^{++}) of soil under each population of *Rhus tripartita*. Table 2 illustrated that sand varied between 79.45 and 9.12%, silt varied between 6.42 and 18.52%, organic carbon varied between 1.25 and 3.19%. Soil under population 1 (P1) have the most important content of Na^+ (114.25 mg/100 g) and the lowest content of Ca^{++} (9.12 mg/100 g). Under the six populations soil content of Mg^{++} and K^+ varied between 18.24 (Population 4) and 36.45 (Population 6) mg/100 g, 22.35 (Population 1) and 80.12 (Population 5) mg/100 g, respectively. Figure 3 shows the principal component analysis and dendrogram based on trait variation using UPGMA method of six sites of *Rhus tripartita* populations according to the soil characters. The dendrogram shows differences between the studied populations. We found that there is a important variability among site populations. There are two groups of site which are distinguished according to the soil parameters. First group composed by population 4, population 5 and population 3 and second group composed by popumation 1, population 2 and population 6, respectivelly.

Morphology of fruits and seeds of *Rhus tripartita* populations

As shown in Table 3, all morphological parameters (lenght, widh, thickness, surface and weight) of the fruits and seeds of six populations of *Rhus tripartita* in Saudi Arabia. Data in Table 3 show that the fruit of P5 have the most important morphological parameters by 6.46 mm of lenght, 5.88 mm of widh, 3.68 mm of thickness, 79.12 mm^2 of surface and 8.87 g of weight of 100 fruits. As well seeds of P5 have the most important lenght (4.44 mm), widh

Tab. 2 The physico-chemical parameters of the soil under each population of *Rhus tripartita*.

Parameters	Population 1 (P1)	Population 2 (P2)	Population 3 (P3)	Population 4 (P4)	Population 5 (P5)	Population 6 (P6)
Sand (%)	81.53±2.25c	79.45±4.68d	84.34±1.79bc	87.39±2.73bc	92.12±8.12a	84.24±6.12b
Silt (%)	12.52±4.16bc	18.52±3.02a	12.79±4.19bc	9.82±1.34e	6.42±4.79cd	14.69±4.13b
Clay (%)	5.95±1.05a	2.03±1.79c	2.87±2.84b	2.79±6.24bc	1.46±3.49cd	1.07±2.43e
pH	7.49±1.43c	7.12±2.95cd	7.81±7.19b	7.53±1.78bc	7.05±3.58e	7.95±6.75a
OC (%)	1.25±0.45c	2.67±0.23ab	2.16±0.98bc	3.19±1.04a	1.78±6.12d	2.56±3.12ab
CaCO3 (%)	14.52±4.52b	18.45±6.45a	8.57±8.75cd	10.48±1.32c	14.45±2.71bc	18.32±3.36ab
EC (µmhos/cm)	3.25±3.21b	4.29±2.23b	5.16±4.26a	4.25±6.25b	5.75±0.96a	3.52±0.26bc
Cl^- (%)	72.15±4.25d	87.79±15.42b	112.87±18.35a	88.34±4.15b	91.76±12.34ab	80.12±12.48bc
HCO^{3-} (%)	8.26 ±3.69	7.46 ±2.18	9.53±2.78	6.41±6.35	8.63±2.15	7.44 ±1.25
Na^+ (mg/100 g dry soil)	114.25±12.35ab	86.15±11.02d	115.34±8.19b	90.42±18.64bc	89.76±14.26c	122.61±3.52a
K^+ (mg/100 g dry soil)	22.35±9.35d	32.16±12.03cd	60.24±12.35b	55.64±21.2c	80.12±13.26a	24.75 ±6.15d
Ca^{++} (mg/100 g dry soil)	9.12±4.28c	18.64±8.47b	22.76±9.85a	19.54±6.35ab	12.42±3.91bc	10.43±3.77d
Mg^{++} (mg/100 g dry soil)	28.34±3.12b	25.17±9.34b	31.42±4.16ab	18.24±4.12bc	24.19±5.83c	36.45±6.52a

OC = organic carbon, EC = electrical conductivity. Different letters indicated a significant difference at $P \leq 0.05$, according to the Student-Newman-Keuls test when the ANOVA is significant. Values are means ± SD.

(2.66 mm), thickness (1.71 mm), surface (21.84 mm^2) and weight of 100 seeds 5.36 g. P5 have lowest fruit and seeds dimensions between the six populations by fruit lenght (5.03 mm), fruit widh (4.02 mm), fruit thickness (3.05 mm), fruit surface (66.37 mm^2), weight of 100 fruits (6.24 g) and by seeds lenght (3.26 mm), seeds widh (2.01 mm), seeds thickness (1.62 mm), seeds surface (18.42 mm^2), weight of 100 seeds (3.16 g). We have noted significant increases in morphological parameters of P5 compared to P1, P2, P3, P4 and P6. There are positive correlation between fruit trait and seed trait (Figure 4). There are a positive correlation between fruit lenght and seeds lenght, seeds surface and seeds weight (Figure 4). There are positive correlation between seeds weight and seeds surface and seeds lenght (Figure 4). Figure 5 showed the principal component analysis and dendrogram based on trait variation using UPGMA method of six *Rhus tripartita* populations (P) according to the fruit and seeds characters . The dendrogram shows differences between the studied populations. We concluded that there is a important variability among fruit and seeds populations. There are two groups of population are distinguished according to the fruit ans seeds parameters. First group composed by P1, P3 and P4 and second group composed by P2, P5 and P6, respectivelly.

Allelopathy activity

As shown in Table 4, all germination and growth characteristics (germination capacity, seedling root length and seedling height) of *Chenopodium album* weed significantly decreased with application of all extract concentrations (2, 4, 6, 8 and 10 g l^{-1}) of six populations of *Rhus tripartita* compared to the control. Minimum values of germination percentage, seedling root lenght and seedling height were obtained with 10 g l^{-1} of concentration of the extract of both provanances: P1, P2, P3, P4, P5 and P6. Under this concentration of the extract (10 g l^{-1}), germination capacity range from 2.35 to 8.65%, seedling root lenght varied from 1.14 to 1.58 cm and seedling height oscillated from 4.13 to 5.25 cm, respectivelly. Table 4 also show that under extract concentration of P4 had significant decreased germination capacity and growth characteristics of *Chenopodium album* weed compared to extract concentrations of P1, P2, P3, P5 and P4. All extract concentrations levels (2, 4, 6, 8 and 10 g l^{-1}) significantly decreased of garmination capacity and growth characteristics of *Chenopodium album* weed compared to control. Figure 6 showed the principal component analysis and dendrogram based on germination and growth trait of *Chenopodium album* weed under

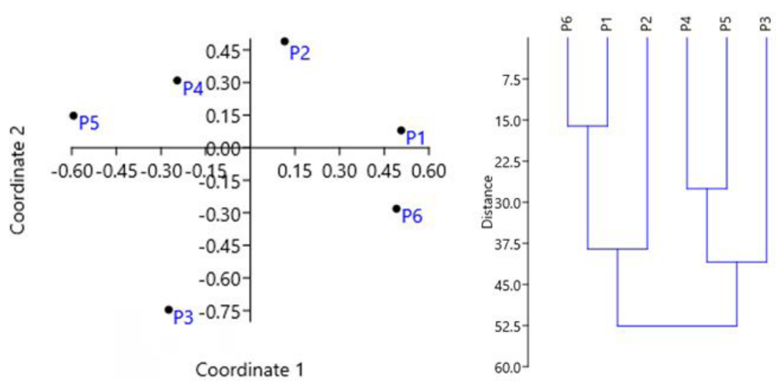


Fig. 3 Principal component analysis and dendrogram based on trait variation using UPGMA method of six sites of *Rhus tripartita* populations (P) according to the soil characters.

Tab. 3 The morphological parameters of the fruits and seeds of the population of *Rhus tripartita*.

	Parameters	Population 1 (P1)	Population 2 (P2)	Population 3 (P3)	Population 4 (P4)	Population 5 (P5)	Population 6 (P6)
Fruit	Lenght (mm)	5.03±1.22b	6.32±2.46a	5.26±2.19b	5.12±2.12bc	6.46±3.56a	5.85±1.86ab
	Widh (mm)	4.02±1.24d	5.64±3.24a	4.12±2.14c	4.75±1.06b	5.88±2.03ab	4.33±1.02bc
	Thickness (mm)	3.05±2.14bc	3.10±1.23e	3.42±0.32ab	3.66±0.68a	3.68±1.43b	3.14±0.85cd
	Surface (mm^2)	66.37±12.52d	78.45±16.38a	70.24±9.85bc	72.45±14.65b	79.12±18.25a	77.29±12.39b
	Weight of 100 fruits (g)	6.24±3.42ab	8.35±3.49a	6.68 ±1.75d	7.15±2.37d	8.87±1.46b	7.99±3.98bc
Seeds	Lenght (mm)	3.26±1.02c	4.21±1.09a	3.42±0.47bc	3.89±1.19b	4.44±2.31a	3.87±1.43b
	Widh (mm)	2.01±1.41bc	2.12±1.24c	2.34±0.98ab	2.45±0.81a	2.66±0.97b	2.54±1.08a
	Thickness (mm)	1.62±0.59a	0.95±0.42d	1.12±0.46bc	0.99±0.23bc	1.71±0.36a	1.23±0.24ab
	Surface (mm^2)	18.42±4.26c	21.32±9.44ab	18.52±8.33d	19.85±2.98bc	21.84±8.64ab	21.45±4.59a
	Weight of 100 seeds (g)	3.16±0.99d	4.27±1.22b	3.49±0.87d	4.12±1.03bc	5.36±1.55a	4.98±2.43a

Different letters indicated a significant difference at P ≤ 0.05, according to the Student-Newman-Keuls test when the ANOVA is significant. Values are means ± SD.

different extracts (allelopathy activity) of six *Rhus tripartita* population using UPGMA method. The dendrogram shows differences between the on germination and growth trait of *Chenopodium album* weed under different extracts of *Rhus tripartita* populations. We found important variability among allelopathy activity of populations. There are two groups of population are distinguished according to allelopathy activity effect. First group composed by P2 and second group composed by P1, P3, P4, P5 and P6, respectivelly.

DISCUSSION

Soil analysis

The environment of the populations of *Rhus tripartita* is characterized by sandy soils. This reflects that *Rhus tripartita* dominates in sandy habitats in desert environments under harsh xeric conditions (Furth 1985). In North Africa, plants grow in the semi-arid, arid and Saharan regions including the rocky valleys in the south and mountains in the center (Saadaoui et al. 2017). Although *Rhus tripartita* requires calcareous soil, it can grow in a variety of edaphic situations, from rather deep clay-textured soil to fissures in hard limestone, dolomite rock, or granite, where some soil has accumulated (Furth 1985). *Rhus tripartita* grow mainly on eroded substrates and saharan site, under a rainfall ranging from 100 to 600 mm yr^{-1} and at altitudes ranging from 10 to 500 m (Itidel et al. 2013; Tlili et al. 2014; Tlili et al. 2019; Alimi et al. 2013). According to Barroso et al. (2003), this species relieve sand movement. *Rhus tripartita* can grow in a variety of types of soil from deep clay-textured soil to fissures in hard limestone, dolomite rock, or granite, where soil has accumulated (Gamoun and Louhaichi 2019). However, it can be used successfully on marginal and poor soils and in the rehabilitation process of degraded environments (Ferchichi 1999).

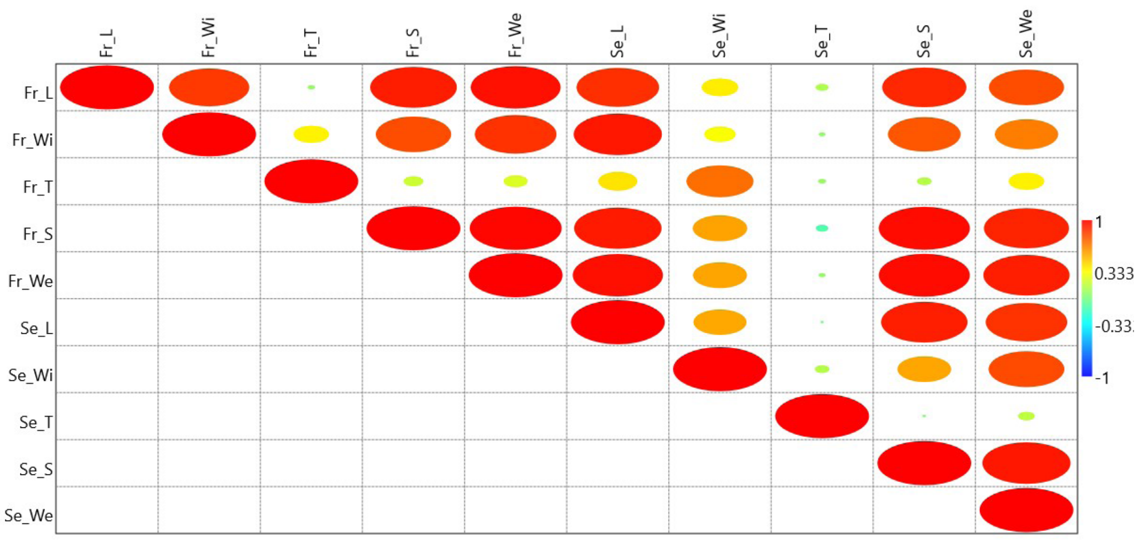


Fig. 4 Correlation matrice between morphological trait of fruit and seeds (Fr: fruit; Se: seeds; L: Plant lenght; Wi: widht; T : thickness; S: surface, We: weight of 100 seeds) (P< 0.05).

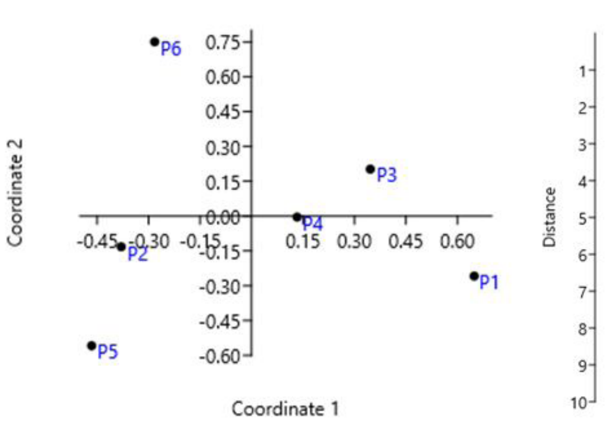


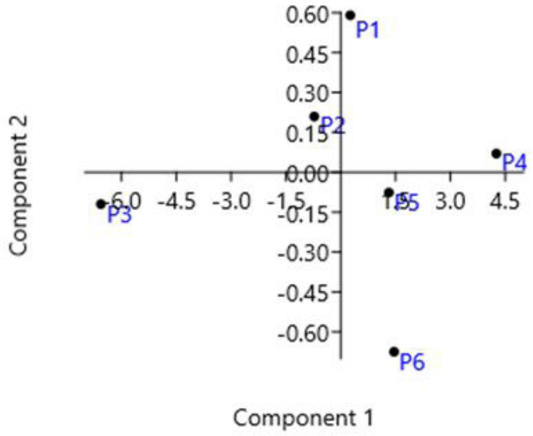
Fig. 5 Principal component analysis and dendrogram based on trait variation using UPGMA method of six *Rhus tripartita* populations (P) according to the fruit and seeds characters.

Morphology of fruits and seeds of *Rhus tripartita* populations

Fruits play a key role in providing nutritious minerals and vitamins (Serville 1984). These elements are essential to the proper functioning of the body and are among the main sources of micronutrients to food balance in the body. The specificity of a nutritious fruit is related to its composition depends on the species, variety, degree of maturity and factors environment (Zouaoui et al. 2014). Morphological seed characters, such as shape and size can be used to distinguish species, ecotypes and varieties (Arman and Gholipour 2013). The analysis of seed diversity will be a necessity to improve the germinative bahavior of the species and aims at the rehabilitation of the natural populations (Saadaoui et al. 2017). The mean lenght of fruit of six poupulations of *Rhus tripartita* in Saudi Arabia varied between 5.12 and 6.46 mm, the mean widh of fruit oscillated between 4.02 and 5.88 mm, the mean thickness of fruit ranged between 3.05 and 3.68 mm. The mean surface of fruit varied between 66.37 and 79.12 mm^2. The mean weight of 100 fruits ranged between 6.24 and 8.84 g. In Tunisia (North Africa), according to Zouaoui et al. (2014), the fruit of *Rhus tripartita* were between 4.770 and 6.920 mm in length, between 3.63 and 6.10 mm in width and between 3.080 and 4.240 mm mm in thickness. Mean weight of the 100 fruit was 6.619 g. The range of variation of the average oscillated between 4.370 and 9.060 g. The surface area ranged between 48.540 and 88.990 mm^2. The mean lenght of seeds of six poupulations in Saudi Arabia oscillated between 3.26 and 4.44 mm, the mean widh

Tab. 4 Allelopathy activity, the effect of different extracts of six *Rhus tripartita* population on the germination percentage (%) (at 5 DAT), on the seedling root length (mm) and on the seedling length (mm) of *Chenopodium album* weed at 14 DAT (Means ± SD).

Parameters of *Chenopodium album* weed	Concentration of the extract	Extracts of six *Rhus tripartita* populations					
		P1	P2	P3	P4	P5	P6
Germination capacity (%)	Control	96±2.35a	89±3.65a	98±6.34a	91±3.82a	86±6.44a	95±1.25a
	2 g L^{-1}	82.34±3.35ab	79.65±1.23b	85.34±6.25ab	70.34±2.33ab	81.25±6.22ab	86.34±5.26ab
	4 g L^{-1}	59.37±5.26bc	46.78±2.31c	44.19±3.26bc	41.32±1.22c	65.32±2.12bc	50.34±4.15c
	6 g L^{-1}	42.25±2.35d	38.65±0.54d	23.54±1.25de	22.26±1.45d	39.75±2.03de	33.89±3.68cd
	8 g L^{-1}	20.35±1.25e	18.65±0.68e	14.35±3.25e	10.65±2.03e	26.54±2.10e	13.56±2.02e
	10	8.65±3.21f	5.68±0.12ef	6.87±1.02ef	2.25±0.15ef	2.35±0.48f	4.55±2.15f
Seedling root length (cm)	Control	9.25±1.24a	8.68±1.02a	10.24±1.23a	9.88±0.35a	7.25±1.09a	6.89±1.45a
	2 g L^{-1}	7.28±2.54ab	6.35±1.12b	8.64±0.85b	4.88±0.65ab	6.21±1.22ab	5.24±2.13ab
	4 g L^{-1}	6.34±3.48c	5.66±2.34cd	5.12±2.31c	3.12±0.49c	5.34±0.87c	4.24±0.54c
	6 g L^{-1}	4.25±2.56cd	4.33±1.02d	3.15±0.54cd	2.11±1.05de	4.18±0.45de	3.99±0.68d
	8 g L^{-1}	2.99±4.21e	2.97±0.45e	2.95±0.68e	3.56±0.17e	3.24±0.63e	3.44±0.75e
	10 g L^{-1}	1.32±1.2ef	1.25±0.85ef	1.22±1.49ef	1.14±1.02f	1.58±0.85f	1.42±0.78ef
Seedling shoot (height) (cm)	Control	11.25±2.41a	12.25±4.15a	13.29±1.37a	10.25±2.15a	9.68±1.08a	8.76±0.95a
	2 g L^{-1}	9.65±1.26b	8.42±2.35b	9.85±1.28b	6.28±1.06ab	7.15±0.42ab	7.35±0.45ab
	4 g L^{-1}	7.19±0.88c	7.15±3.45c	8.25±0.86bc	6.02±2.15bc	6.19±0.87cd	6.44±0.18c
	6 g L^{-1}	5.62±1.06de	6.48±2.65de	7.47±0.32de	5.75±1.02d	5.99±0.96d	5.13±0.44d
	8 g L^{-1}	5.09±1.03e	4.38±4.15e	6.29±0.45e	5.19±0.42de	5.24±0.42e	4.45±0.63de
	10 g L^{-1}	4.22±0.58f	5.25±6.35ef	5.21±1.20ef	4.13±0.33f	4.88±0.48f	4.35±0.77ef



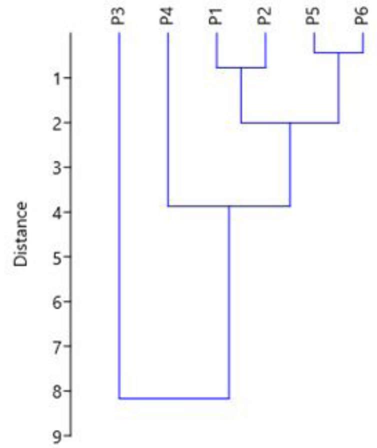


Fig. 6 Principal component analysis and dendrogram based on germination and growth trait of *Chenopodium album* weed under different extracts (allelopathy activity) of six *Rhus tripartita* population using UPGMA method.

of seeds ranged between 2.01 and 2.66 mm, the mean thickness of seeds oscillated between 1.62 and 1.72 mm. The mean surface of seeds ranged between 18.42 and 21.84 mm^2. The mean weight of 100 seeds varied between 3.16 and 5.36 g. Zouaoui et al. (2014) showed that in Tunisie, the seed were between 3.310 and 4.91 mm in length, between 2,430 and 3,340 mm in width and between entre 0.710 and 1.910 mm in thickness. While mean seed length was 4.175 mm, seed width was 2.905 mm and thickness was 1.325 mm. Mean weight of the 100 seed was 4.874 g. The range of variation of the average varies between 3.180 and 7.120 g. Seed areas of *Rhus tripartita* oscillated between 19.4 and 25.3 mm^2 and seeds were larger in lower semi-arid climate and smaller in upper arid climate (Saadaoui et al. 2017). Our results confirms the high variability in seed and fruit. Similar results were obtained for *Rhus tripartita* by Zouaoui et al. (2014) and Saadaoui et al. (2017) explained phenotypic variability of *Rhus tripartita* by genetic effects and ecological conditions. This is confirmed by Brittaine and Lutaladio (2010). In addition, seed size affects plant germination, growth and physiology (Pesendorfer 2015); the large seed size can contribute to a better survival and growth of its seedlings (Vera, 1997). Mtambalika et al. (2014) registered the highest seedlings height and largest root collar diameter with large seeds; in fact, seed size is a component of seed quality which has impact on the performance of crop (Adebisi et al. 2013). Generally, large seed has better field performance than small seed (Ambika et al. 2014). In Saudi arabia, *Rhus tripartita* fruits and seeds shows that there is an inter-site variability observed between populations. It is related to the phenotypic characteristics which may be due to the genetic factors and environmental conditions.

Allelopathy activities

Our study found that the extracts concentrations of *Rhus tripartita* populations signifiantly decreased the germination capacity, seedling root lenght and seedling height of *Chenopodium album* weed. In general, *Rhus tripartita* extracts from all populations significantly (P<0.05) reduced the germination of *Chenopodium album.* The seed germination of *Chenopodium album* was inhibited at a concentration varied from 2 to 10 g l^{-1}. It is worth mentioning herer that *Chenopodium* is considered as winrer weed in the cultivated crops as well as the road sides habitat. It is imported to the cultivated land as contaminants with the seeds and it has cabability to compete with the crops via allelopathy (Al-Johani et al. 2012). Corsato et al. (2010) found that the allelopathic effect is a natural interference in which the plant produces substances and metabolites that may benefit or harm other plants/organisms when released. Inhibition of germination comparing to control could be explained by the presence of glycol alkaloids and tannins in the studied extracts (Serafimov et al. 2005). The roots of *Chenopodium album* were more sensitive to the allelopathic effect than shoots. This sensitivity could be correlated to the direct contact with the allelochemicals as well as the membrane permeability of the root cells. (Abd El-Gawad 2014; El-Shora and Abd El-Gawad 2015; Abd El-Gawad 2016; Abd El-Gawad et al. 2019; Abd El-Gawad et al. 2020; Nagmouchi and Alsubeie 2020). The results of the present study are in harmony with those of (Mardani et al. 2012), who found that root length is more affected than shoot growth. Our results revealed promising allelopathic activities against weeds, at least the *Chenopodium album* compared to other extracts reported from other wild plants. Therefore, the extract from *Rhus tripartita* parts could be integrated into the control tools of The *Chenopodium album* as green, biodegradable, and eco-friendly resource. Generally, the extracts from the population 4 (P4) of *Rhus tripartita* revealed more allelopathic effect against the tested plants than the samples from other populations. These results could be attributed to the presence of many allelochemicals, which enhance the defense system in the plant at low concentrations (Liu et al. 2011). Most allelopathic activities are due to the presence of several compounds in the mixture, where the concentration of each compound in a mixture might be signifiantly less than the concentration of individual compounds needed to cause growth inhibition. This is related to the inactivation of the enzymatic and nonenzymatic systems in the plant by diffrent allelochemicals (Einhellig 1996). The allelopathic activities might be attributed to the higher concentrations of phenolics and flavonoids reported in this sample. Phenolic compounds, especially quercetin, ellagic acid, gallic acid, chlorogenic acid, caffeic acid, and naringenin have been reported to possess various biological activities (Abd El-Gawed et al. 2020). Moreover, the bioactive ingredients enable the plant to face or survive in the variable stressful conditions, and they are considered as an important part of the plant defense system against pathogenic attacks and environmental stresses (Yang et al. 2018). In addition, most of the identified compounds in this sample were reported as allelochemicals (Inderjit, 1996; Li et al. 2010). Phenolics and flavonoids were reported as defense compounds against herbivores and pathogens such as bacteria and fungi (Agrawal 2007). Quercetin and naringenin were reported as the most often cited allelopathic flavonoids (Berhow and Vaughn 1999). Naringenin was reported to inhibit the growth of soybean (Bido et al. 2010). According to Abd El-Gawed et al. (2020b) *Chenopodium* has been reported to have various allelochemicals such as benzoic acid, *p*-coumaric acid, ferulic acid, and vanillic acid. (Batish et al. 2007) *Chenopodium murale* is a noxious weed as it interferes negatively with wheat, (Batish et al. 2007; Majeed et al. 2012) barley, (Al-Johani et al. 2012) rice, (Alam and Shaikh 2007) pea, and chickpea (Batish et al. 2007) through its allelopathic activities. Abd elmigid and Morsi (2017) showed that allelopathic interactions of allelochemicals plant extraction include variable genetic effects on plant weed. These authors revealed that the high accumulation of *Eucalyptus* leaves on the soil surface may be responsible for retardation of growth of understory plants and consequently reduces the plant yield.

CONCLUSIONS

In conclusion, this paper represents the important study of populations diversity of *Rhus tripartita* in Saudi Arabia. In this study we concluded that the variability in the physico-chemical properties of the soil between localities influenced variability in the morphological fruit and seeds. The present study revealed that extracts concentration from six *Rhus tripartita* populations has potential allelopathic activities against the weed *Chenopodium album* and the germination was strongly inhibited at a concentration of 10 g l^{-1}. Therefore, this extracts could be a promising food supplement and natural, green, eco-friendly resource to control this weed. However, further studies are required to study the chemical compounds from the Essential oils of *Rhus tripartita*, and evaluate their allelopathic activities individually or in combination against *Chenopodium album* or maybe other weeds, and evaluate its valuable economic use on a large scale.

Disclosure statement

No potential conflict of interest was reported by the authors.

AUTHORSHIP CONTRIBUTION

Project Idea: ASA

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Analysis: ASA, NS

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