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Research Paper

Herbicidal effects of *Prosopis juliflora* (Sw.) DC. (Mesquite) leaf powder on seed germination and seedling growth of the weed species *Tribulus terrestris* L.

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Abstract. Herbicidal effects of *Prosopis juliflora* (Sw.) (mesquite) leaf extract on seed germination and seedling development of the weed species *Tribulus terrestris* L. was investigated as a potential tool to control this widespread weed in the agricultural system of Tabuk region and many areas around the world. 5 *T. terrerestris* spiny seed-containing fruits were germinated in 998, 995, 990 and 985 g soil mixed with 2 .00, 5.00, 10.0 and 15.00 g mesquite leaf powder respectively with three replicates in addition to control. The experimental units were set outdoors under tree shade. Irrigation in the morning continued for 15 days, then analysis of variance was carried out to test significance of difference in number of germinated seeds, the germination percentage and germination speed were calculated; coefficient of variation in seedling length and seedling fresh weight was maintained between different treatments. Results showed that number of germinated seeds differed significantly between treatments; both germination % and speed decreased with increased quantity of mesquite leaf powder in the soil; seedling length and seedling fresh weight also differed significantly among the treatments. It has been concluded that *P. juliflora* leaf powder is effective if introduced to the conventional weed control methods to the control of *T. terrestris* in particular.

Keywords: Herbicidal, effects, *Prosopis juliflora*, weed, control, *Tribulus terrestris*.

INTRODUCTION

Allelopathic properties of *Prosopis juliflora* (Sw.) DC are well known and documented (Al-Humaid and Warrag, 1998; Getachew *et al*., 2012; El-Shabasy, 2017; Damasceno *et al.*, 2018) and allelochemicals isolated, identified and tested (Nakano *et al*., 2002, 2003; Damasceno *et al.*, 2018). The problem of weeds in the agricultural systems is experienced worldwide. Weeds are part of the natural vegetation; monocots or dicots; are of different life forms (trees, shrubs, herbs or grasses); endogenous or invaders. They compete with crop plants and deprive them from limited available nutrients (Jabran *et al.*, 2015). Some weed species are very successful competitors as they have the ability to send their roots deep into the soil; some are of dense growth, having broad leaf areas to maximize absorbed light, some are successful in terms of seed and fruit dispersion strategies and some are able to survive long dry seasons. Weeds cause losses of varying extents in crop yield depending on weed species composition, crop species and ecological conditions (Lacey, 1985; Moody, 1991; Appleby *et al*., 2000; Hartzler, 2009). In addition, plant ecology theory on niche relationships and interspecific competition predicts that subordinate species mixtures (i.e. weed species) will affect dominant (i.e. crop species)

(Gibson *et al*., 2017). Weed control measures are numerous and being practiced all over the world including hand weeding, mechanical weeding, herbicide applications, grazing, prescribed fire and biological control (Tu *et al.*, 2001; Griepentrog and Dedousis, 2010; Bergin, 2011; Chauvel *et al.*, 2012). Hand weeding and mechanical weeding are costly and time consuming. Repeated burning has strong negative effects on litter C and N contents (Jones *et al.*, 2015). Herbicides are the chemical substances that are used to selectively kill plants (Tu *et al.*, 2001), these chemicals can accumulate in crops, seep into the ground water, leach into the neighboring water bodies and eventually affect human health and the ecological system as a whole (Khahn *et al.*, 2005) in addition to the appearance of herbicide-resistant weeds; There are currently 514 unique cases (species × site of action) of herbicide resistant weeds globally, with 262 species (152 dicots and 110 monocots). Weeds have evolved resistance to 23 of the 26 known herbicide sites of action and to 167 different herbicides. Herbicide resistant weeds have been reported in 93 crops in 70 countries. (Heap, 2020), which warrants the development of new herbicides, and increasing doses of synthetic herbicides in practice (Khahn *et al.*, 2013). *Tribulus terrestris* is widely spread in Tabuk region (Moawed *et al*., 2015; Moawed, 2016; Al-Mutari *et al*., 2016). It is one of the most successful weeds and invaders due to its ability to grow everywhere, extract water from deep soils, produce multiple prostrate stems that grow in all directions and to long distances, in addition, it produces copious spiny and hard fruits that can easily adhere to animal and human feet and disperse. A wide range of adverse effects caused by *T. terrestris* have been documented by many authors including its effects on biodiversity (Van Vleet, 2005); on agricultural production of so many crops and in many parts of the world (Boyston, 1990; Holm *et al.*, 1991; Scott and Morrison, 1996; Geier and Stahlman, 1999; Kostov and Pacanoski, 2007). *T. terrestris* is widely known as a noxious weed because of its small woody fruit – the bur – having long sharp and strong spines which easily penetrate surfaces such as the bare feet or thin shoes of crop workers and other pedestrians, the rubber of bicycle tires, and the mouth and fur of grazing animals. It has been shown that allelopathy plays a major role in various disciplines of agricultural and biological sciences and could be used for pests (weeds, insects, nematodes, pathogens) management (Narwal *et al.*, 2013). Allelopathy, being an important phenomenon in agriculture, is also important in sustainable agriculture (Bruisma, 2003; Ramakudzibga, 1991; Farooq *et al.*, 2011). Thus, for sustainability, future weed control practices must minimize the use of herbicides and use allelopathic strategies and other practices for weed management (Farooq *et al.*, 2011). Allelopathic property of some plants is a promising, environment friendly tool and an alternative to other time and money consuming and environment polluting measures for achieving sustainable weed management (Abu-Romman *et al*., 2010; Salhi *et al.*, 2012). The allelopathic compounds can be used as natural herbicides; they are less disruptive of the global ecosystem than are synthetic agrochemicals; parallel approaches in control of weeds may be possible by finding compounds that inhibit seed germination, plant growth or prevent propagule production.

MATERIALS AND METHODS

Collection and preparation of plant materials

Prosopis juliflora (Sw.) DC (Mesquite) leaves

Green branches were collected from an old tree growing in a farm in Damaj area (Tabuk), transferred to the laboratory for drying in shade. After drying the leaves were ground into fine powder using an electric grinder and the powder kept in tightly closed plastic bags for further use.

T. terrestris seeds

T. terrestris spiny fruit (bur) were collected from a transferred bulk of soil in the main campus of Tabuk University using a coarse sieve and hand sorting, then kept in a plastic bag in the laboratory.

Collection and preparation of soil samples

Soil samples (fine sand) were collected from a seasonal stream in Al-Wadi Al-Akhdhar (the green valley) of Tabuk region, transferred to and kept in the laboratory. A sufficient quantity of soil was heated in the oven at 100°C for 1 hour to kill viable seeds of other plant species.

Germinating *T. terrestris* seeds

2, 5, 10 and 15 g of the fine mesquite leaf powder were weighed thrice using a sensitive balance and kept in labeled dry plastic bags. Clean and dry plastic pots were prepared and 998, 995, 990 and 985 g soil were taken in each pot and the pots were labeled as 0.2%, 0.5%, 1.0%, 1.5% and control; then each of the leaf powder samples was mixed thoroughly and carefully with its corresponding soil sample to make 0.2%, 0.5%, 1.0% and 1.5% of leaf powder in the soil (weight per weight). All pots with their contents were transferred to the Faculty front garden. 5 *T. terrestris* spiny fruits were placed into the soil in each pot to about 1.5 cm depth and they were evenly spaced. The experimental units were laid in a completely randomized design with 4 treatments and 3

Table 1. Test for equal means (no. of germinated seeds).

	Sum of squares	df	Mean square	F	p (same)
Between groups	220	3	73.3333	19.13	0.0005236
Within groups	30.6667	8	3.83333	Permutation p (n = 99999)	
Total	250.667	11	0.0048		
Components of variance (only for random effects)					
Var(group)	23.1667	Var (error):	3.83333	ICC:	0.858025
Omega2	0.8193				
Levene´s test for homogeneity of variance, from means	p (same):	0.3338			
Levene´s test, from medians	p (same):	0.6288			

Welch F test in the case of unequal variances: F = 41.74, df = 3.778, p = 0.00231

replicates in addition to control. All units were irrigated every day in the morning for 15 days. After 15 days the pots were transferred to the laboratory and the following measurements were carried out.

Calculating germination percentage (%)

Germination % was calculated according to Aravind *et al.* (2019) as under:

$$GP = \frac{Ng}{Nt} \times 100$$

Where Ng is the Number of germinated seeds.
Nt is the total number of seeds.

Seedling length and seedling fresh weight

Seedling lengths and seedling fresh weights of all seedlings in each pot were taken using a calibrated ruler (by stretching the seedling along the ruler starting from zero) and a sensitive balance respectively and recorded and the average values were maintained.

Coefficient of velocity

Number of seedlings emerged everyday was recorded for each pot for 15 days. Coefficient of velocity was calculated according to Jones and Sanders (1987) as under:

$$COV = \frac{A1 + A2 + A3 + \cdots An}{A1T1 + A2T2 + A3T3 + \cdots AnTn} \times 100$$

Where:
A = number of seedlings that emerge at a particular number of days
T = number of days involved.

Statistical analysis

Number of germinated seeds were recorded for each experimental unit and entered to the Paleontological Statistics (PAST) version 326b, analysis of variance (ANOVA) to test significance of difference among the means for number of germinated seeds and Kruskal-Wallis test for equal medians result were maintained. Germination percentages and coefficients of velocities of different treatments in addition to control were calculated and plotted; Coefficient of variation in seedling length and seedling fresh weight were computed using the same statistical package. Least significant difference (LSD) test was used for mean separation.

RESULTS AND DISCUSSION

Generally significance of effects observed rejects the null hypothesis and accepts the alternative hypothesis that decreased number of germinated seeds (Tables 1 and 2), suppressing seedling development (Table 3) is a result of treatment with mesquite leaf powder and, consequently allelochemical contents of leaves. The data in Figure 1 show that seeds germinated in soil with 0.2% leaf powder exhibited the highest germination percentage and those germinated in soil with1.5%

Table 2. Kruskal-Wallis test for equal medians (no. of germinated seeds).

H (chi2):	8.077
Hc (tie corrected):	8.462
p (same):	0.03738

There is a significant difference between sample medians

Table 3. Means seedling length and seedling fresh weight with coefficients of variation.

Treatments	Mean values	
	SL (cm)	SFW (g)
Control	11.8	0.209
2%	8.7	0.126
5%	7.9	0.094
10%	7.1	0.089
15%	5.9	0.064
±SE	0.994	0.025
Coeff. Var.	26.84	48.34

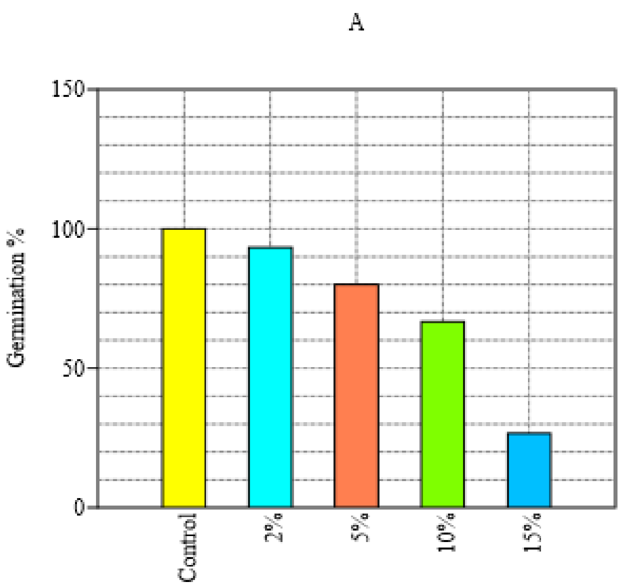

Figure 1. Germination percentage of *Tribulus terrestris* L. seeds in different concentrations of *Prosopis juliflora* (Sw.) leaf powder in the soil.

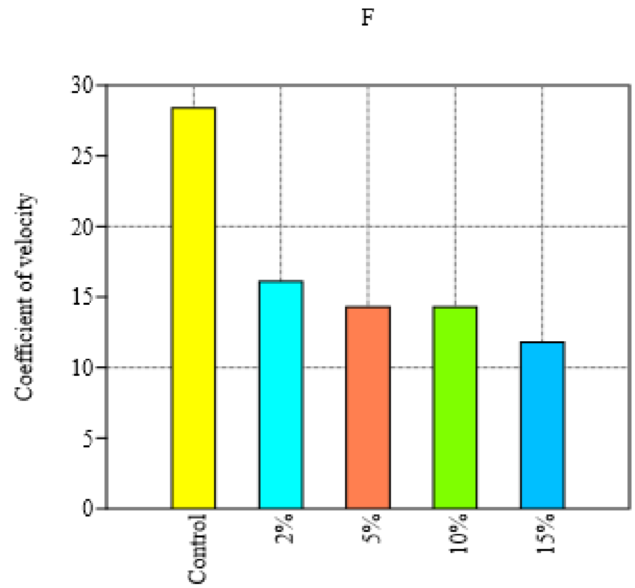

Figure 2. Coefficient of velocity of *Tribulus terrestris* seed germination in different amounts of *Prosopis juliflora* leaf powder in the soil.

leaf powder showed the lowest one compared to control. It was previously stated by Getachew *et al*. (2012) that shoot and root growth of the study species were inhibited by leaf and root at higher concentrations and seed germination was inhibited by soil amended with decaying plant parts and under canopy soil. They also reported that Leaf seems to contain greater number/amount of inhibitors than does root and bark. Getahun *et al.* (2017) also found that the effect of leaf extract was the highest, followed by litter fall, root extracts and soils respectively. Germination percentage generally decreased with increased amount of mesquite leaf powder. This result clearly indicates that *T. terrestris* seeds can tolerate low amounts of mesquite leaf powder and germination inhibition magnitude is directly proportional to leaf powder ratio in the soil. This observation is in line with Sen and Chawan, (1970) who reported that the effect of growth inhibiting substance becomes more evident at its higher concentrations. Effect of mesquite leaf powder on seed germination percentage almost coincide their effect on coefficient of velocity (measure of germination speed) (Figure 2) which showed a similar trend (decreased with increased amount of leaf powder) (Table 1) as a significant consequence of allelochemicals from *P. juliflora* leaves on *T. terrestris* seedling length and seedling fresh weight. LSD further showed (Table 3) that among all variables measured, differences between means according to the LSD test were significant only between the two treatments 2 and 15%. This means that effective inhibition of seed germination and seedling growth might be achieved in higher concentrations of mesquite leaf powder in the soil and mesquite leaf powder (up to 15% in the soil) do not completely prevent *T. terrestris* seeds to germinate, but they weaken them, delay their germination and lessen the number of germinated seeds. This finding suggests that introducing mesquite powder with this ratio as a control method for the aggressive weed *T. terrestris* does not guarantee complete avoidance of this weed species; however it is better to be a part of other measurements. Further studies that involve increasing the amount of mesquite leaf powder in the soil, extraction, identification and application of allelochemicals from mesquite leaves and manipulating other weed species and other parts of mesquite (roots, bark and fruits) is suggested. *P. juliflora* itself is a well-known weed species and one of the top 100 invaders worldwide, it has a range of negative effects on biodiversity and agricultural systems and an incredible ability to invade new areas with varying ecological conditions. It also owns a set of surviving, spreading and competing strategies; it enhances the soil nutrients for the sake of its own. In addition it is difficult to eradicate. On the other hand, the allelopathic properties of mesquite can balance its negative effects if properly exploited in the field of allelopathy based weed management.

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