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# ALLELOPATHIC INTERACTION OF PEPPER (*Capsicum annuum*) AND PEARL MILLET (*Pennisetum glaucum*) INTERCROPPED

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**Abstract**

Intercropping is common practice in many regions of Tunisia, particularly in Cap-Bon where different crops such as tomato, pepper, cucumber, peanut, corn, pearl millet and sorghum are grown together in the same field and at the same time for self-sufficiency. A number of these crops and vegetables are known for their allelopathic activities. The interaction between plants could be within the individuals of the same species (intraspecific interaction or autotoxicity) or between different species (interspecific interaction or teletotoxicity). Little is known about allelopathic interaction of some of these intercropped plants in mixed farming systems in our local conditions. Therefore, the objectives of the present investigation are to evaluate, under laboratory condition, the allelopathic effect of mixed crops, which interacted positively or negatively when cultivated together in the same field. Two plant species were used to study the effects of their aqueous extract on germination and growth of each other (pepper and pearl millet). The results suggested that aqueous extracts from shoots and roots significantly inhibited germination and seedling growth and the inhibitory effects were increased proportionally with the extract concentration. The shoot and root aqueous extract also exhibited intraspecific and interspecific allelopathy. Generally, it was observed that roots were more toxic than shoots. For root extract, the highest inhibition percentage was gained from the effect of pearl millet on pepper (40%) and highest autotoxicity was observed from pearl millet (36%). The effect of shoot extract on germination indicated that the highest reduction (55%) was obtained from pepper shoot extract on pearl millet and highest autotoxicity was observed from pepper which reached (45%). In most cases autotoxicity appeared to be more severe than teletotoxicity, on seed germination of the two intercropped plant species.

Keywords: Allelopathy, Pearl millet, Pepper, Aqueous extract, Germination.

## Introduction

Allelopathy has been increasingly recognized as an important ecological mechanism that plays an appreciable role in plants dominance, plant succession, formation of communities and climax vegetation and crop productivity (Chou, 1999). Allelopathy is the interaction of plants as influenced by the chemical substances that they release into the environment (Machado, 2007) and (Dayan *et al.*, 2009). Allelopathy can enhance the competitive success of the invader plants, since the release of phytotoxins in the environment may affect the growth and life processes of other community species (Callaway *et al.*, 2002). The world is still in search of and in the process of developing farming techniques, which are sustainable for environment, crop production and protection as well as socio-economic points of view. Integrated weed management is one of such approaches where allelopathy can play its eco-friendly role in weed management (Hussain *et al.*, 2007). The allelopathic properties of plants can be exploited successfully as tool for pathogens and weed reduction (Xaun *et al.*, 2005). In fact, allelochemicals have been shown to be less toxic, environmentally safer, conserve the resources and also their potential biodegradability would nullify the problems raised by synthetic chemicals (Rizvi *et al.*,1992). Allelopathic crops, when used as cover crops, mulch, smother crops, intercrops or green manures, or grown in rotational sequences, can combat biotic stresses such as weed infestation, insect pests and disease pathogens (Khanh *et al.*, 2005) and additionally build up fertility and organic matter status of soil, thereby reducing soil erosion, and improve farm yields (Jabran *et al.*, 2007). Nevertheless, damaging consequences of an allelopathic crop in rotation have also been observed. In fact, in some rotation, allelochemicals exuded from some crops affected the development of the subsequent crop (Roth *et al.*, 2000). The toxic effects of these allelochemicals are species specific and dependent on stage of plant, growth conditions, mass added into the soil, their movement and their persistence in soil (Inderjit, 2001).

The allelochemicals may be produced by any part of plant although stems and leaves are most important source of allelochemicals (Rice, 1984). Several crops are known for their allelopathic activities such as alfalfa (Miller, 1983), corn (Almezori, 1996), rice (Ebana et al., 2001), tomato (Saied and Saied, 2001), sorghum (Cheema *et al.*, 2004), Ficus (Rsaissi *et al.*, 2013) and many of which have been chemically characterized (Pereda-Miranda *et al.*, 1993) and (Inderjit, 1996). The idea of exploiting these compounds as natural herbicides is therefore very attractive (Weston, 1996) and (Duke *et al.*, 2000).

Many researchers investigated the effect of plant extracts on the germination and growth of other plants (Ben Hammouda *et al.*, 2001) and (Saied, 2004). These aspects become particularly interesting when plants are intercropped. In fact, intercropping is common practice in many regions of Tunisia, particularly in Cap-Bon where different crops such as tomato, pepper, cucumber, peanut, corn, pearl millet and sorghum are grown together in the same field and at the same time for self-sufficiency. A number of these crops and vegetables are known for their allelopathic activities. The interaction between plants could be within the individuals of the same species (intraspecific interaction or autotoxicity) or between different species (interspecific interaction or teletotoxicity). However, little is known about allelopathic interaction of some of these intercropped plants in mixed farming systems in our local conditions. Therefore, the objectives of the present investigation are to evaluate, under laboratory condition, the allelopathic effect of mixed crops, which interacted positively or negatively when cultivated together in the same field. Two plant species were used to study the effects of their aqueous extract on germination and growth of each other (pepper and pearl millet).

## Materials and methods

In field conditions, the problem of toxicity arises with rains or irrigations; therefore, only aqueous extracts of pearl millet and pepper roots and shoots were taken. The root and shoot residues were collected after harvest, from Tunisian Research Institute.

A study has been undertaken on the effect of aqueous extracts of autochthonous pearl millet ecotype (KS) and local variety of pepper on seed germination and on plant growth of pearl millet and pepper.

### *Preparation of aqueous extracts of pearl millet and pepper*

Roots and shoots of KS pearl millet ecotype and pepper were separated, cleaned, dried at (80°C) for 48 hours and mixed with warm distilled water for 3 days. The mixtures were passed through cheesecloth and filtered by filter paper. The concentrations of aqueous extract used were respectively 3% for roots and 10% for shoot.

### *Effect of aqueous extracts of pearl millet and pepper on seed germination*

5 ml of the extracts were added to each Petri dish planted with 25 seeds. 4 replicates of each treatment were randomly distributed in a growth germinator at 30°C. The germination percentages were recorded after 7 days of cultivation. It corresponded at the maximum number of seedlings that germinated during the experiment.

### *Effect of aqueous extracts of pearl millet and pepper on plant growth*

Experiment was carried out in plastic pots. Each pot was planted with 4 seeds and 50 ml of extracts were added to each pot. Throughout the duration of the experiment, the pots were alternatively irrigated with equal quantities of nutrient solution and aqueous extracts. The pots were distributed randomly in a green house, in three replications. After two months, the length of root and shoot system was recorded, then dried at 80°C for 48 h.

### *Statistics Analyse*

Average counts for each of replicates were pooled and subjected to standard statistical analysis. Data were statistically analyzed using analysis of variance techniques appropriate for randomized complete block design. Main and interaction effects were separated by LSD test at 0.05 level of probability, if the F-values were significant

## Results

### *Effect on germination*

For root extract (table 1), the highest inhibition percentage was gained from the effect of pearl millet on pepper (40%) and highest autotoxicity was observed from pearl millet (36%).

**Table 1. Effect of root aqueous extract of pearl millet and pepper on pepper and on pearl millet germination**

| Plant type | Concentration (%) | Pepper germination (%) | Pearl millet germination (%) |
|---|---|---|---|
| Pepper | 0 | 100 a | 100 a |

| | | | |
|---|---|---|---|
| | 3 | 84 b | 96 a |
| (%) Inhibition | - | 16 | 4 |
| Pearl millet | 0<br>3 | 100 a<br>60 b | 100 a<br>64 b |
| (%) Inhibition | - | 40 | 36 |

Means with different letters in a column differed significantly (5% level).

The effect of shoot extract on germination (Table 2) indicated that the highest reduction (55%) was obtained from pearl millet shoot extract on pepper and highest autotoxicity was observed from pepper which reached (45%). In most cases autotoxicity appeared to be more severe than teletotoxicity, on seed germination of the two intercropped plant species.

Generally, it was observed that roots were more toxic than shoots. Indeed, with a lesser concentration (3% vs 10%), effect of root on germination reductions was greater or equal than those obtained with shoot aqueous extract.

**Table 2. Effect of shoot aqueous extract of pearl millet and pepper on pepper and on pearl millet germination**

| Plant type | Concentration (%) | Pepper germination (%) | Pearl millet germination (%) |
|---|---|---|---|
| Pepper | 0<br>10 | 100 a<br>55 b | 100 a<br>90 b |
| (%) Inhibition | - | 45 | 10 |
| Pearl millet | 0<br>10 | 100 a<br>45 b | 100 a<br>92 b |
| (%) Inhibition | - | 55 | 8 |

Means with different letters in a column differed significantly (5% level).

***Effect on seedling growth***

Aqueous extract of pepper shoot on pepper growth caused reduction only in shoot, root and intact plant dry weights (Table 3).The influence of shoot extracts on lengths of different plant types was, however, not significant.

For pearl millet, application of 10 % of pepper shoot extract concentrations resulted in decrease in lengths and weight of all parameters except for root dry weight. The reduction is more important for total length (76%) than total dry weight (25%).

**Table 3.** The effect of pepper shoot aqueous extract on the growth and dry weight of pearl millet and pepper

| Plant type | Concentration (%) | Shoot length (cm) | Root length (cm) | Intact plant length (cm) | Shoot dry weight (mg/plant) | Root dry weight (mg/plant) | Intact plant dry weight (mg/plant) |
|---|---|---|---|---|---|---|---|
| **Pepper** | 0<br>10 | 9 a<br>10 a | 11 a<br>8 a | 20 a<br>18 a | 95 a<br>65 b | 95 a<br>65 b | 190 a<br>130 b |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Pearl millet** | 0 | 28 a | 23 a | 51 a | 190 a | 130 a | 320 a |
| | 10 | 5 b | 7 b | 12 b | 130 b | 110 a | 240 b |

Means with different letters in a column differed significantly (5% level).

Shoot extract of pearl millet decreased significantly the root and intact plant lengths of pearl millet and also diminished shoot and intact plant dry weights (Table 4). Instead, pearl millet shoot extract has only a low effect on length and dry weight of pepper.

**Table 4. The effect of KS pearl millet ecotype shoot aqueous extract on the growth and dry weight of pearl millet and pepper**

| Plant type | Concentration (%) | Shoot length (cm) | Root length (cm) | Intact plant length (cm) | Shoot dry weight (mg/plant) | Root dry weight (mg/plant) | Intact plant dry weight (mg/plant) |
|---|---|---|---|---|---|---|---|
| **Pepper** | 0 | 9 a | 10 a | 19 a | 90 a | 90 a | 180 a |
| | 10 | 9 a | 9 a | 18 a | 90 a | 80 b | 170 b |
| **Pearl millet** | 0 | 27 a | 22 a | 49 a | 183 a | 130 a | 313 a |
| | 10 | 27 a | 16 b | 43 b | 120 b | 125 a | 245 b |

Means with different letters in a column differed significantly (5% level).

The effect of root extract of pepper was not significant on root, shoot and intact plant lengths of pepper, while significant differences were obtained from root, shoot and intact plant lengths and weights of pearl millet (Table 5).

**Table 5. The effect of pepper root aqueous extract on the growth and dry weight of pearl millet and pepper**

| Plant type | Concentration (%) | Shoot length (cm) | Root length (cm) | Intact plant length (cm) | Shoot dry weight (mg/plant) | Root dry weight (mg/plant) | Intact plant dry weight (mg/plant) |
|---|---|---|---|---|---|---|---|
| **Pepper** | 0 | 9 a | 10 a | 19 a | 90 a | 90 a | 180 a |
| | 3 | 10 a | 6 a | 16 a | 60 b | 60 b | 120 b |
| **Pearl millet** | 0 | 27 a | 22 a | 50 a | 180 a | 130 a | 310 a |
| | 3 | 6 b | 6 b | 12 b | 130 b | 100 b | 230 b |

Means with different letters in a column differed significantly (5% level).

Root extract of pearl millet significantly affected lengths and weights of different parts of the plant of pearl millet. Whereas the same extract had not effect on pepper. Pearl millet appeared more susceptible than pepper (Table 6). Autotoxicity appeared to be more severe than teletotoxicity.

**Table 6.** The effect of KS pearl millet ecotype root aqueous extract on the growth and dry weight of pearl millet and pepper

| Plant type | Concentration (%) | Shoot length (cm) | Root length (cm) | Intact plant length (cm) | Shoot dry weight (mg/plant) | Root dry weight (mg/plant) | Intact plant dry weight (mg/plant) |
|---|---|---|---|---|---|---|---|
| **Pepper** | 0 | 9 a | 10 a | 19 a | 90 a | 90 a | 180 a |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 8 a | 12 a | 20 a | 80 a | 80 a | 160 a |
| **Pearl millet** | 0<br>3 | 27 a<br>23 b | 22 a<br>21 a | 49 a<br>44 b | 183 a<br>123 b | 129 a<br>125 a | 312 a<br>248 b |

Means with different letters in a column differed significantly (5% level).

**Discussion**

Some crop and weed plants are able to release some exudates into the environment, suppressing the growth of plants of their own kind, other plants or weeds. This is called the allelopathic effect (Narwall and Willis, 2006). Allelopathy plays an eminent role in the intraspecific and interspecific competition and may determine the type of interspecific association.

Mixed cropping is practiced particularly in Cap-Bon and in Kairouan where different vegetables and other crops are cultivated together in the same field at the same time. Among these crops, particular attention is given for pepper and pearl millet intercropped and for allelopathic effect of mixed crops.

The results of seed germination indicated that autotoxicity is present for the two species. This suggests that pearl millet and pepper are allelopathic plants, which are capable of suppressing their own germination and growth. Allelopathic pepper effects is supported by several authors such Siddiqui and Uzzaman (2005), ZhongQun *et al.* (2012), Valcheva and Popov (2013).

For pearl millet, the capability of *P. glaucum* to release allelopathic substances through water is cited by many authors (Saxena *et al.* (1996) and Radhouane (2012).
Allelophathic effects depended upon the parts assayed, test species and physiological process involved (Reigosa *et al.*, 1999). In fact, inhibition effect is more severe for pepper under pepper shoot aqueous extract (45%) than under pepper root extract (16%). These data suggest that stimulatory and inhibitory effects of a given plant extract are a function of concentration **(**Saxena *et al.* 1996) and (Hussain and Ilahi, 2009). That difference was present between shoot and root extracts of the same plant concerning their effect on others (Ben-Hamouda *et al.*, 2001). This can be explained by the differences of plant parts in accumulation of phytotoxin (Gonzalez *et al.*, 1997).

Further higher concentrations of aqueous extracts bioassayed caused decline in total dry matter per seedling. The results suggest that the growth inhibition due to an autotoxic principle contained in the root and shoot tissue of both plants is concentration–dependent. It implies that the phytotoxic compounds will have to accumulate in sufficient quantity in the soil to cause autotoxicity.

Inderjit and Duke (2003) stated that plants release phytochemicals from dead tissues, and their incorporation to the soil could be accelerated by leaching thus facilitating their harmful effects in the field. The mode of action of allelochemicals spans over a wide range of actions including cell lysis, blistering or growth inhibition (Wu *et al.*, 2003).

The allelochemicals present in the two plants root and shoot aqueous extracts might have inhibited root growth by at least two mechanisms. The first possible target is cell division in roots (Bhowmik and Doll, 1982). Phenolics represent one of the largest groups of allelochemicals and Avers and Goodwin (1956) have shown that various phenolic compounds inhibited cell division. It is also possible that the cell elongation was affected by extracts of plants residues. Tomaszewski and Thimann (1966) found many allelochemicals inhibited gibberellin and indole acetic acid-induced growth. Su and Fang (1981) and Hegde and Miller (1992) also reported the adverse effects of phytotoxins from crop residues on the seedling growth of succeeding crops.

This study leads us to avoid practicing intercropping pepper with pearl millet and also to avoid monoculture. This study also shows the importance of crop rotation in improving crop yields.

## Conclusion

Autochthonous pearl millet ecotype and local pepper have strong allelopathic potentials in mixed cropping. But, in most cases autotoxicity appeared to be more severe than teletotoxicity, on seed germination of the two intercropped plant species. So, they might be candidates for biological control of weeds and insects. They may be used in different ways to influence weeds such as surface mulch, incorporation in to the soil, spray of aqueous extracts, rotation, smothering or mix cropping. However, further studies are required to see their allelopathic behavior under field condition against others species and to identify the toxic principle, their quantification and their efficacy in the soil.

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