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Allelopathic effect of *Casuarina equisetifolia* L. on wheat, associated weeds and nutrient content in the soil

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Allelopathy is an ecological phenomenon that recently attracted researchers' attention as a new approach in weed control. Pot and field experiments were conducted to study the allelopathic effect of *Casuarina equisetifolia* L. leaf litter, one of three most common Casuarina species in Egypt. The influence was studied during two successive seasons (2012-2014) on wheat and associated weeds through foliar application of the aqueous extract and incorporating Casuarina leaf litter in the soil. In pot experiment, the results showed remarkable improvement in the growth of wheat under screen house conditions at the different rates of incorporation (15, 30 and 45 g dry L/kg soil). On the contrary, associated weed (that is, canary grass) was adversely affected and recorded up to 62% inhibition over the control. Germination was less affected both for crop and weed. Slight increases in macro (N, P, K, Ca and Mg) and micro (Fe, Mn, Zn and Cu) elements were recorded in the shoots of wheat, 21 days after sowing, compared to the control. Good response otherwise was noted in increasing soil content of the different nutrients. Under field conditions, the incorporation of dry leaf litter at a rate of 1 ton/fed (fed = 0.42 ha) caused increases in wheat biomass (65 days after sowing) by up to 27.5% in comparison with the untreated control. On the other hand, weed biomass was significantly reduced by up to 27%. Foliar application (twice) of water extract was most effective. Wheat biomass increased by up to 42.9% versus 51.2% reduction in weed biomass compared to the untreated control. Hand pulling treatment for weeds was the best regarding the increase of wheat yield (up to 66.9%) and its components (from 24.4% to >100%) followed by foliar application of the extract and then incorporation of leaf litter in the soil. From these results it can be concluded that spraying water extract of Casuarina leaf litter (comparing to incorporation the litter in the soil) has a high degree of effectiveness which ensures safe use in controlling weeds in wheat fields.

Key words: Allelopathy, cannary grass, casuarina leaf litter, nutrients, weed, wheat.

INTRODUCTION

Chemical pesticides cost the world a lot. Water, air and soil contaminations and natural ecological balance upsetting are of the most harmful aspects of pesticides. Herbicides are the main class of pesticides worldwide.

The world consumption of herbicide is about 48% of the total manufactured pesticides in the world (Gupta, 2011). Herbicides cause a great damage to the environment if compared with the other groups. Searching for the alternatives is then necessary. Allelopathy is the harmful or beneficial effect of an organism upon another, including plants and microorganisms, through the release of one or more bioactive agents (e.g., allelochemicals) into the environment. As the world's attention tends to search for new alternatives to herbicides, the natural products from plants and microbes received the greatest attention. Plants produce a wide array of secondary metabolites that can be used directly in controlling weeds or as a skeleton for new synthetic herbicides (Duke and Lydon, 1987; Duke et al., 2002). Aside from being safer and economically sounder than commercial herbicides, they might open the door for new discoveries related to new sites of action (Duke, 1990).

Various aspects of the allelopathy phenomenon have been studied. Crops affect crops, crops affect weeds, weeds affect weeds, weeds affect crops and microorganisms affect crops have been studied extensively (Mandava, 1985). *Casuarina equisetifolia* L. is one of the important trees in Egypt. It is a fast growing, evergreen, nitrogen fixing multipurpose tree. Casuarina wood is widely used as a source of energy. It is also grown along rivers for the purpose of fixation and reduction of evaporation. In the new reclaimed lands it is grown in rows along field boundaries as windbreaks. It is also being grown in the neglected wasteland/poor lands with the aim of reclaim soils (Pahwa, 1988). The roots of *C. equisetifolia* harbor nitrogen-fixing microbial assemblages that allow the host tree to colonize and thrive in low nutrient soil conditions that many other species cannot tolerate (Swearingen, 1997). Casuarina species are strongly suspected to have allelopathic properties, as evidenced by the total or near absence of the understory species which are otherwise present around it (Batish and Singh, 1998; Batish et al., 2001). The leaf leachates collected under canopy of Casuarina trees were found to have a deleterious effect on species like *Medicago sativa* L., and *Ageratum conyzoides* L. (Batish et al., 2001). Extracts from fresh and brown (dead when collected) Casuarina needles were also effective against duckweed plants (Sutton and Portier, 1989). Phenolics, terpenoids and organic cyamides were identified as allelopathic agents in the different parts of the tree including fresh needles, female cones and even leaf litters (June, 1976; Batish and Singh, 1998; Buehler, 2010). Quercetin-3-α-araboside and quercetin-3-β-glucoside were recognized as biologically active allelochmicals in *C. equisetifolia* that are responsible for the autotoxicity in Casuarina plantations (Jian et al., 2013). Kaempferol-3-α-rhamnoside and luteolin-3,4-dimethoxy-7-β-rhamnoside were also isolated and identified as autotoxins in *C. equisetifolia* (Deng et al., 1996). Thus, the aim of the present work is to study the allelopathic potential of Casuarina leaf litter on the growth and development of wheat and associated weeds as well as on the nutrient content both in soil and in wheat plants.

MATERIALS AND METHODS

Pot experiment

The allelopathic effect of dry leaf litter of *C. equisetifolia* was studied under screen house conditions on wheat (*Triticum aestivum* L., cv. Sakha-93) and one of the most common weeds in wheat fields in Egypt namely canary grass (*Phalaris minor* L.). The effect on soil properties and nutrient content in wheat shoots was also studied. Casuarina content of the different macro- and micronutrients was also investigated using methods of Cottenie et al. (1982).

Material preparation

The dry leaf litter of Casuarina was collected under the tree in the Experimental Research and Production Station of the National Research Centre, Al-Emam Malek Village, Nubaria District, Al-Behaira Governorate, Egypt. The dry materials was chopped into 1 to 5 cm pieces with an electric fodder cutter, then grounded to pass a two-mesh (4.48 mm) screen in a laboratory grinder. The ground material was mixed with loamy sand soil (88.2% sand, 4% silt and 7.8% clay according to the methods of Black et al. (1981) at rate of 15, 30 and 45 g/kg soil (equivalent to 0.5, 1.0 and 1.5 ton/fed, resp.; fed=feddan= 0.42 ha). Plastic pots (12 cm in diameter x 8 cm depth) were filled with 1 kg of soil/Casuarina ground leaves, while control pots were filled only with loamy sand soil.

Cultivation methods

Twenty grains of wheat and thirty five seeds of canary grass were sown per pot. Water was added as required to avoid water stress. Recommended NPK fertilizers were applied throughout the period of experiment (21 days after sowing). The experiment was applied in completely randomized design with three replications for each treatment.

Data collection

Germination took place 5 days after sowing; the number of emerged seedlings (wheat and weeds) was recorded until emergence ceases. At 21 days after sowing (DAS), data on vegetative growth including shoot and root lengths (cm), fresh and dry weights (g/plant) as well as dry root/shoot ratios were estimated for both wheat and weeds. Soil chemical analysis (that is, organic matter, OM; Electric conductivity, EC; pH; $CaCo_3$) was realized according to the procedure described by Jackson (1973). Macro- (that is, K, Mg, Ca and Na) and micro-elements (that is, Fe, Mn and Zn) concentrations were determined in wheat shoots 21 DAS as mentioned by Cottenie et al. (1982).

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Table 1. Physical and chemical properties of experimental soil at Numbaria District.

Physical properties				
Particle size distribution	**Sand**	**Silt**	**Clay**	**Texture**
	68.70	24.50	6.80	Silty loam
Chemical properties				
	pH*	**EC** dS/m**	**Ca CO_3 (%)**	**OM (%)**
	7.80	0.18	7.07	0.16
Soluble cations (meq/L)	**Ca^{++}**	**Mg^{++}**	**K^{+}**	**Na^{+}**
	3.00	2.00	0.32	2.09
Soluble anions (meq/L)	$CO^{=}_{3}$	HCO^{-}_{3}	Cl^{-}	$SO^{=}_{4}$
	-	1.41	0.70	5.30
Available macronutrients (mg/100 g soil)	**Total N**	**K**	**P**	**..**
	15.00	9.40	16.00	..
Available micronutrients (ppm)	Fe	Mn	Zn	Cu
	7.80	3.30	1.86	4.00

*Soil pH was measured in 1.25 L soil - water suspension. ** EC was measured as dS/m in soil paste extract.

Field experiments

In this trial we studied the allelopathic effects of the aqueous extract or dry leaf litter of *C. equisetifolia* leaves on wheat growth and yield as well as on associated weeds under field conditions. The study was conducted during two successive seasons (2012/2013 and 2013/2014) at Experimental Research and Production Station of the National Research Centre, Al-Emam Malek Village, Al-Nubaria District, Al-Behaira Governorate, Egypt. The physical and chemical soil properties of the experimental site are presented in Table 1.

The aqueous extract of Casuarina leaf litter were prepared by soaking 1 kg of the ground tissues in 5 L of distilled water under lab conditions (20 to 25°C) for 24 h in darkness. The extract was filtered and used immediately under field conditions. The Casuarina extract was applied as post-emergence (30 and 45 day DAS). Spraying was done by Knapsak hand sprayer. The treatments were then: hand pulling of weeds (twice at 30 and 45 DAS); foliar application (twice at 30 and 45 DAS) of aqueous extract of Casuarina leaf litter at a rate of 200 L/fed (20% based on dry leaf matter); incorporation of dry ground tissues of Casuarina leaf litter (1 ton/fed) into the soil at sowing time and control (unweeded).

The treatments were arranged in a randomized complete block design with three replicates for each treatment. The experimental unit consisted of 20 rows of wheat, each 15 cm apart by 3.50 meters long (10.5 m^2). Soil was prepared for cultivation by removing the residue of the previous crop, plowing twice and dividing into rows. Wheat grains cv. Sakha-93 were sown by drilling seeds manually in the rows at a rate of 60 kg/fed. Sowing date was in mid November in both seasons. Potassium sulphate fertilizer (50 K kg/fed) in the form of K_2O (48%) was added 30 days after wheat sowing. Nitrogen fertilizer (120 kg N/fed) was added as ammonium sulphate (20.6% N) in six equal supplies after complete germination and over a two weeks period till spike emergence stage. Sprinkler irrigation was applied as needed by plants. All others standard agronomic practices for wheat cultivation were done.

Data collection

Wheat and weeds dry weight

During both seasons the dry weight of weed and wheat plants (g) was recorded in 1 m^2 from each plot at 65 days after sowing. The weight was determined after drying in a forced oven at 70°C until constant weight.

Yield and its components

Wheat plants were manually harvested in the first week of May in both seasons. The tillers in 0.25 m^2 from each plot were cut and counted to determine number of spikes/0.25 m^2. The plant height (cm), No. of spikelets/spike, No. of grains/spike, length of spike (cm), weight of spike (g) and grains weight of spike (g) were also determined from 20 randomly selected tillers. Wheat was threshed manually to determine grain, straw and biological yields per plot (3 x 3.5 m) and then per fed. Harvest and crop indexes were calculated by dividing seed yield by biological yield and straw yield, respectively.

Statistical analysis

All data were subjected to analysis using M-STAT-C statistical analysis program (MSTAT, 1988). LSD test were used to compare between means.

RESULTS

Pot experiment

Germination and seedling growth

The results showed an appreciable effect of Casuarina leaf litter in improving growth of wheat under screen house conditions with a marked decline in the growth of associated canary grass weed (Tables 2, 3 and Figures 1 to 3). Generally, the data recorded an increase of 16.8% to >100% and 18% to >100% for the fresh and dry weights of wheat respectively unlike the effect on weed growth which inhibited by up to 62% in the two

Table 2. Effects of *C. equisetifolia* leaf litter incorporated in soil on wheat growth 21 days after sowing under screen house conditions.

Treatment		Casuarina leaf litter incorporation rate (g/kg soil)				LSD at 5%
Character		0.0	15	30	45	
			Season 2012/2013			
Germination (%)		58.33	63.33	95.83	65.00	13.92
Shoot weight (g/pot)	Fresh	1.31	2.86	4.50	1.53	0.25
	Dry	0.22	0.38	0.49	0.31	0.03
			Season 2013/2014			
Germination (%)		63.33	66.73	76.703	73.33	8.30
Length (cm)	Shoot	11.80	13.25	15.35	13.75	1.59
	Root	3.70	5.75	6.40	6.00	0.40
	Total	15.50	19.00	21.75	19.75	1.45
Fresh weight (g/pot)	Shoot	2.05	3.00	3.08	2.57	0.22
	Root	1.59	1.92	3.65	2.79	0.28
	Total	3.64	4.92	6.73	5.36	0.45
Dry weight (g/pot)	Shoot	0.61	0.72	0.86	0.74	0.08
	Root	0.68	0.83	2.00	1.20	0.07
	Total	1.29	1.55	2.86	1.94	0.12
Root/Shoot dry ratio		1.13	1.15	2.34	1.63	0.32

Table 3. Effects of *C. equisetifolia* leaf litter incorporated in soil on growth of canary grass weed 21 days after sowing under screen house conditions (Combined analysis of two seasons).

Treatment		Casuarina leaf litter incorporation rate (g/kg soil)				LSD at 5%
Character		0.0	15	30	45	
Germination (%)		42.90	62.90	35.20	32.40	8.78
Length (cm)	Shoot	16.67	17.00	14.00	13.00	1.60
	Root	20.33	21.00	16.00	15.33	1.54
	Total	37.00	38.00	30.00	28.33	2.88
Fresh weight (g/pot)	Shoot	2.29	2.60	1.78	1.69	0.16
	Root	7.87	7.25	3.05	2.99	0.25
	Total	10.16	9.85	4.83	4.68	0.20
Dry weight (g/pot)	Shoot	0.89	1.01	0.69	0.66	0.06
	Root	3.54	3.26	1.37	1.35	0.11
	Total	4.43	4.28	2.07	2.00	0.09
Root/Shoot dry ratio		3.97	3.22	1.98	2.05	0.30

successive seasons. The germination responded to a lesser extent. It recorded an increase of between 8.5 to 64.1% for wheat (Table 2 and Figures 1, 2) and up to 24.5% reductions for canary grass weed (Table 3 and Figure 3). It should be noted that the effect on wheat decreased in general with higher doses of incorporated leaf litter compared to low and moderate doses (Figures 1 and 2). Good response was also recorded for shoot and root lengths either for canary grass or wheat.

Macro- and microelements in Casuarina leaf litter, wheat shoots and soil

Analyzing Casuarina leaf litter revealed good composition of macro- and micronutrients including N,P,K, Ca, Mg and Fe, Mn, Zn, Cu respectively (Table 4). The chemical analysis of the macro- and microelements in treated plants of wheat showed a moderate impact of Casuarina leaf litter incorporation on increasing N, P, K, Ca, Mg, Fe,

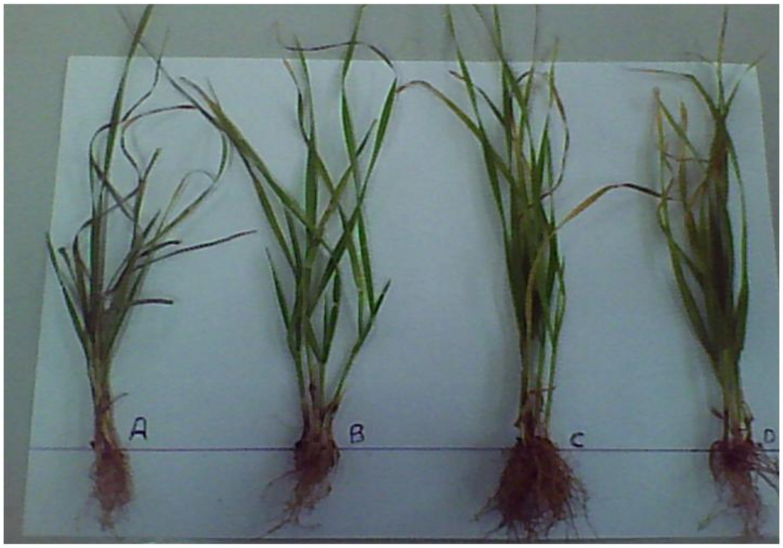

Figure 1. Effect of *C. equisetifolia* leaf litter incorporated in soil at different rates on wheat growth 21 days after sowing under screen house conditions. A, B, C, D= 0, 15, 30, and 45 g/kg soil, respectively.

Control 15 g/kg soil 30 g/kg soil 45 g/kg soil

Figure 2. Effect of *C. equisetifolia* leaf litter incorporated in soil at different rates (15, 30 and 45 g/kg soil) on wheat aerial growth.

Control 15 g/kg soil 30 g/kg soil 45 g/kg soil

Figure 3. Effect of *C. equisetifolia* leaf litter incorporated in soil at different rates (15, 30 and 45 g/kg soil) on aerial growth of canary grass weed.

Table 4. Casuarina content of macro- and micronutrients.

Character	Macronutrients (%)					Micronutrients (ppm)			
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
Casuarina chemical composition	1.40	0.14	0.68	1.55	0.24	126.00	96.00	14.90	6.00

Table 5. Wheat content of macro- and micronutrients at 21 days after sowing of wheat and incorporation of Casuarina leaf litter in soil under screen house conditions.

Character		Macronutrients (%)					Micronutrients (ppm)			
Treatment		N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
Casuarina leaf litter incorporation rate (g/kg soil)	0.0	3.02	0.09	1.12	0.33	0.15	135.50	8.80	2.21	1.10
	15	3.25	0.12	1.13	0.42	0.15	178.50	9.00	2.47	1.38
	30	3.44	0.16	1.17	0.48	0.15	209.00	12.30	2.72	1.38
	45	3.88	0.17	1.20	0.51	0.15	220.00	13.20	6.46	1.93
LSD at 5%		**0.10**	**0.04**	**0.01**	**0.02**	**ns**	**3.40**	**1.00**	**0.67**	**0.53**

Table 6. Soil content of macro- and micronutrients at 21 days after sowing of wheat and incorporation of Casuarina leaf litter in soil under screen house conditions.

Character		Macronutrients (mg/100 g soil)					Micronutrients (ppm)			
Treatment		P	K	Mg	Na	Ca	Fe	Mn	Zn	Cu
Casuarina leaf litter incorporation rate (g/kg soil)	0.0	1.10	4.30	3.96	4.10	174.00	1.10	2.21	0.56	0.18
	15	2.01	4.80	4.66	6.10	187.50	1.50	3.09	0.89	0.09
	30	2.10	7.40	5.28	9.20	185.00	2.50	3.96	1.03	0.10
	45	2.30	7.10	5.04	9.80	208.00	3.00	4.80	1.88	0.14
LSD at 5%		**0.01**	**0.62**	**0.36**	**0.71**	**9.55**	**0.55**	**0.20**	**0.21**	**ns**

Table 7. Chemical analysis of soil 21 days after wheat sowing and incorporation of Casuarina leaf litter in soil.

Character		Chemical proprieties (%)			
Treatment		$CaCo_3$	OM	EC(dS/m)	pH
Casuarina leaf litter incorporation rate (g/kg)	0.0	2.61	0.20	0.33	8.87
	15	1.73	0.23	0.21	8.76
	30	1.71	0.19	0.33	8.80
	45	1.52	0.19	0.42	8.81
LSD at 5%		**0.12**	**ns**	**0.07**	**0.06**

Mn, Zn and Cu nutrients (Table 5). The chemical analysis of soil regarding its content of macro- and micro-nutrients 21 DAS otherwise showed high efficiency in increasing P, K, Mg, Na, Ca, Fe, Mn and Zn components under treatments supplied with Casuarina leaf litter compared to untreated treatment (Table 6). Some variations regarding soil pH, E.C, OMand calcium carbonate content were recorded (Table 7).

Field experiment

Wheat and weed growth

The results of using dry litter and aqueous extract of Casuarina leaf litter under field conditions were promising either in increasing wheat growth or suppressing associated weeds (Table 8). Foliar application of the

Table 8. Effect of *C. equisetifolia* leaf litter incorporated in soil in comparison with foliar application of the aqueous extract of the litter on growth of wheat and associated weeds 65 days after sowing under field conditions**.**

Character	Wheat dry weight (g/m^2)		Weeds dry weight (g/m^2)	
Treatment	**2012/2013**	**2013/2014**	**2012/2013**	**2013/2014**
T^1	164.00	104.00	29.13	18.20
T^2	116.00	88.00	34.20	27.44
T^3	94.00	78.67	46.00	41.08
T^4	81.13	68.99	58.16	56.33
LSD at 5%	5.51	9.62	6.09	9.39

T^1: Hand pulling (twice at 30 and 45 DAS), T^2: Post-emergence application of aqueous extract of Casuarina leaf litter (20%) at a rate of 200L/fed (sprayed twice 30 and 45 days after sowing), T^3: Incroporation of 1 ton of ground leaf litter of Casuarina per fed at wheat sowing time,T^4: Unweeded (control).

Table 9. Effect of *C. equisetifolia* leaf litter incorporated in soil in comparison with foliar application of the aqueous extract of the litter on yield components of wheat under filed conditions.

Treatment		**T^1**	**T^2**	**T^3**	**T^4**	**LSD at 5%**
Character		**Season 2012/2013**				
Plant height (cm)		85.00	77.33	71.33	65.67	8.03
Spike characteristics	Number/0.25 m^2	100.00	81.33	76.00	61.33	7.05
	Length (cm)	12.50	11.33	10.33	9.33	1.15
	Weight (g)	1.00	0.89	0.70	0.51	0.15
	Grains weight (g)	0.80	0.58	0.54	0.47	0.11
Spikelet's no/spike		17.33	16.33	15.00	13.67	1.37
		Season 2013/2014				
Plant height (cm)		79.33	73.00	65.00	58.00	6.82
Spike characteristics	number/0.25 m^2	120.00	116.00	104.00	86.33	11.79
	Length (cm)	12.33	11.33	10.67	9.50	1.07
	Weight (g)	1.10	0.83	0.61	0.50	0.12
	grains weight (g)	0.70	0.63	0.51	0.40	0.07
Spikelet's no/spike		17.00	15.67	15.00	13.67	1.45

T^1: Hand pulling (twice at 30 and 45 DAS), T^2: Post-emergence application of aqueous extract of Casuarina leaf litter (20%) at a rate of 200L/fed (sprayed twice 30 and 45 days after sowing), T^3: Incroporation of 1 ton of ground leaf litter of Casuarina per fed at wheat sowing time,T^4: Unweeded (control).

aqueous extract at a rate of 200 L/fed was more effective than soil incorporation treatment (1 ton/fed). Incorporation of dry leaf litter increased wheat growth (plant biomass) by up to 27.5% and reduced weed growth by up to 27% in comparison with the untreated control. Foliar treatment caused wheat growth to increase by 27.55 and 42.98% and weed growth to decrease by 41.19 and 51.28% during the two successive seasons. As expected hand pulling of weeds was the best technique as far as wheat and weed growth is concerned; an increment of >100% was estimated in the first season versus 50.7% in the second seasons for wheat growth, meanwhile a reduction in weed growth was estimated in between 49.9% in the first season and 67.7% in the second season on this treatment (Table 8).

Wheat yield and its components

Wheat yield and different other parameters including spike attributes, plant height, straw yield and biological yield were also significantly affected by Casuarina leaf litter used (Tables 9 and 10). Post-emergence application treatment was still in the lead compared to adding leaf litter to the soil. The foliar treatment achieved up to 47.79% increases in grain yield, compared to soil incorporation treatment which recorded only 33% increases as compared with untreated control. Hand

Table 10. Effect of *C. equisetifolia* leaf litter incorporated in soil in comparison with foliar application of the aqueous extract of the litter on wheat yield under filed conditions.

Treatment		T1	T2	T3	T4	LSD at 5%
Character			**Season 2012/2013**			
Yield (ton/fed)	Grain	2.27	2.01	1.81	1.36	0.04
	Straw	7.31	6.49	5.32	4.49	0.31
	Biological	9.58	8.50	7.14	5.85	0.31
Harvest index (%)		23.7	23.7	25.4	23.3	0.82
Crop index (%)		31.1	31.0	34.1	30.3	1.41
			Season 2013/2014			
Yield (ton/fed)	Grain	1.97	1.59	1.51	1.33	0.03
	Straw	6.18	4.79	4.49	3.99	0.59
	Biological	8.15	6.38	6.00	5.32	0.61
Harvest index (%)		24.23	24.89	25.19	24.93	ns
Crop index (%)		32.03	33.15	33.67	33.21	ns

T^1: Hand pulling (twice at 30 and 45 DAS), T^2: Post-emergence application of aqueous extract of Casuarina leaf litter (20%) at a rate of 200L/fed (sprayed twice 30 and 45 days after sowing), T^3: Incroporation of 1 ton of ground leaf litter of Casuarina per fed at wheat sowing time, T^4: Unweeded (control).

pulling treatment was most effective. It caused an increase in wheat grain yield by up to 66.9% and different other characteristics in a range of 24.4% to >100%.

DISCUSSION

Casuarina is a widespread tree. Its allelopathic effect is well established (Singh, 1993; Jadhav and Gaynar, 1995; Patil and Hunshal, 2004; Wu-xing, 2010). Both fresh parts and litters are involved. In our current study wheat growth was well improved in contrast to weeds (e.g., canary grass) which were negatively affected in this regard. Of the many experiments comparable with our current results is the work by Leela et al. (2014) who referred to the good allelopathic effect of *C. equisetifolia* leaf extracts. Researchers believe that Casuarina trees employ allelopathy to eliminate competing plant species, as evidenced by the absence of the nearby species around and under the tree (Batish and Singh, 1998; Batish et al., 2001). Self-inhibitory effect is also commonly observed in Casuarina colonies as many autotoxins are released suppressing root growth of its own seedlings (Liu et al., 2007). Phenolics, terpenoids and organic cyamides were reported as active allelochemicals in Casuarina trees (June, 1976; Batish and Singh, 1998; Buehler, 2010). These researches provide evidences on supporting our findings in many places regarding the allelopathic effect of Casuarina leaf litters on wheat (positively) and associated weeds (negatively).

Regarding the effect of Casuarina leaf litter on the macro- and micronutrients, the results were not consistent between the plants and soil. The treatment with Casuarina had a good impact in increasing the soil content of the different micro- and macronutrients while a poor effect was noted on wheat plants. *C. equisetifolia* litter is rich in the different nutrients as we reported earlier and this may explain in a positive way what has been obtained from results on increasing the soil content of the different element. *C. equisetifolia* leaf litter may works in enriching the soil of the different elements that could benefit wheat plants. However, some researchers believe that *Casuarina* debris is able to decrease soil pH and that has a dramatic effect on the capacity of the soil to retain nutrients (Ussiri, 2006). Barritt and Facelli (2001) demonstrated emphatically that Casuarina spp. litter has both physical and chemical effects.

Increasing yield and its components is a normal situation due to suppressing weed growth and increasing chemical soil fertility. The good effects of post-emergence application of the extract compared to adding leaf litter into the soil could be due to the absence of many of the biotic and abiotic factors that interfere with the phytotoxic action of Casuarina leaf litter in the soil. From the above results we can note the beneficial effect of Casuarina leaf litter on both wheat and weed growth, positively and negatively respectively. However, the economic side remains the crucial point in judging the reliability of using these natural products in the effective weed control in various crops. May be the advances in biotechnology and chemistry could solve many of our problems related to develop natural products as herbicides.

Conflict of Interest

The authors have not declared any conflict of interest.

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