Physiological Response of *Alhagi pseudoalhagi* to Root Exhausting Management During Fallow Season

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ABSTRACT

A series of experiments were conducted in Khorasan Agricultural and Natural Resources Research Center (Mashhad, Iran) to evaluate potential germination ability of detached rhizomatous roots as an index of recovery after mechanical management during 2005-2006. Microscopic cross sections were prepared to study the rhizomatous nature of the roots. Effects of the *in situ* root detaching were examined. Three depths of plough *i.e.* 10, 20 and 30cm were applied at a field highly infected with camelthorn (*Alhagi pseudoalhagi*) during fallow season. Samples were taken to record the number of germinated detached roots 20, 30 and 50 days after treatment. To quantify revival of mechanically treated rhizomes undetached from root bases, further experiments were performed during the fallow season of 2005. Camelthorn was cut off from 4 different soil depth i.e. 0, 10, 20 and 30 cm at an infected field with natural distribution. Date of germination, plant height, canopy shading area, number of shoots and dry matter were recorded at 7, 10,17, 24, 34, 41 and 58 days after treatment (DAT). Various physiological indices including plant growth rate and germination rate were determined. The results revealed that roots with various length of detachment at the field differ significantly in ability to recover. However, no germination in all pot experiments

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was recorded. Soil depth for cutting off roots could make significant differences on plant growth characteristics. Final shoot height was significantly reduced by depth of cutting. Almost the same pattern was recorded in case of canopy shading area and single plant dry matter. In conclusion, the deeper plow depth the more suppressed plants are, and as a consequence, we have better camelthorn management.

چکیده

بمنظور ارزیابی توان جوانه زنی بالقوه ریشه‌های ریزومی قطع شده خارشتر به‌عنوان شاخصی از امکان رشد مجدد آن پس از اعمال مدیریت مکانیکی، آزمایش‌های متعددی در مرکز تحقیقات کشاورزی و منابع طبیعی خراسان رضوی طی سال های 1384-85 به اجرا درآمد. مقاطع میکروسکپی ریشه تهیه گردید تا ماهیت ریزومی آن مشخص گردد. اثرات قطع ریشه در مزرعه مورد آزمون قرار گرفت. بدین منظور در یک مزرعه کاملا پوشیده از خارشتر، سه عمق 10، 20 و 30 سانتیمتری شخم در طی فصل آیش اعمال گردید. 20، 30 و50 روز بعد از اعمال تیمارها تعداد ریشه های قطع شده ای که مجددا جوانه زده بودند ثبت گردید. توان رویش مجدد بخش پایینی ریشه‌های تیمار شده در عمق خاک نیز مورد بررسی قرار گرفت. بدین منظور ریشه خارشتر از 4 عمق 0، 10، 20 و 30 سانتیمتری از سطح خاک در یک مزرعه با توزیع طبیعی گیاه قطع گردید. تاریخ جوانه زنی، ارتفاع گیاه، سطح سایه انداز کانوپی، تعداد شاخه ها و ماده خشک در رویش‌های مجدد 7، 10، 17، 24، 34، 41و 58 روز پس از اعمال تیمار ها یادداشت گردیدند. شاخص‌های رشد ازجمله سرعت رشد گیاه و سرعت جوانه زنی نیز محاسبه گردیدند. نتایج نشان دادند که تفاوت معنی داری در توان جوانه زنی ریشه ها با طول قطع متفاوت در مزرعه وجود دارد..در عین حال هیچیک از ریزوم های کاشت شده در گلدان ها قادر به جوانه زنی نبودند. عمق قطع تاثیر معنی‌داری بر ویژگی های رشد این گیاه داشت. ارتفاع نهایی، سطح سایه اندازو وزن خشک تک بوته توسط افزایش عمق به شدت کاهش یافتند. می‌توان نتیجه گرفت که با افزایش عمق قطع تا 30 سانتیمتر امکان مدیریت موفق تر خارشتر وجود خواهد داشت.

واژه‌های کلیدی: انتقال مواد، علف های هرز، گیاهان چند ساله، خارشتر

.INTRODUCTION

The genus *Alhagi* is classified under the Fabaceae family. Cytological studies have shown that there are 16 chromosomes in somatic cells i.e. 2n=2x=16 (Simay, 1992). Camel thorn roots may develop vertically and horizontally up to 8 m and 2 m, respectively. It's new shoots originate from root bearing buds (Rashed, 2001).

Alhagi pseudoalhagi(M.B) Dest. (camelthorn) is an invasive perennial weed, originated from Irano-Touranian region (Hickman, 1993; Kerr *et al*., 1965). The species is well adapted to a wide range of climatic conditions. It can grow under semi-arid hot environments as well as irrigated systems, highly carbonated soils with different textures in various ecological systems including rangelands and forest (Rashed *et al*., 2001). Germination may occur even in rigid physical surfaces such as rocks, cement and even may results in asphalt apertures (Kassas, 1952). The species has been extended to other parts of the world, including South Africa and America most probably through impurity in alfalfa seed or camel dung used as packing material around date plants from the Mediterranean region (Monier & Abd El-Ghani, 2000; Kerr *et al*., 1965). Early actions to control camelthorn weed during mid-1920s in USA was not successful (Bottel, 1933).

Due to hard seed coat of seed and relatively high 1000 seed weight (5-5.5 g), the species does not easily propagate and spread by seed (Sazvari, 2006). Once the plant was established, the predominant method of spread distribution is through vegetative reproduction. Lateral growth of the extensive root system is an important method of distribution, which the radius of a patch extends by up to 7.4 m per year. Seeds and shoot pieces can distribute by water and strong winds, which may blow balls of entangled aerial parts (including seeds) for long distances (Richardson, 1953). If roots are cut by cultivation equipment, small pieces can be transported elsewhere to produce new plants.

Camelthorn interferes in various cropping systems such as wheat, cotton and sugar beet. It has also been reported from different parts of Iran (Bazoobandi *et al*., 2005). It can grow in pastures, rangeland, and irrigated croplands such as date plantings, alfalfa fields, and citrus groves (Parsons, 1992).

Frequent vegetation of the species over marginal parts of deserts was related to occurrence of upstanding water tables (Rashed *et al*., 2001). Its ability to tolerate saline soils is attributed to its higher photosynthetic activities compared to other metabolic processes (Halila *et al.,* 1999). Camelthorn's rapid and aggressive growth allows it to emerge in both native vegetation and cultivated crops. Because of its rhizomatous growth habit, dense stands of the weed may be formed, that are impenetrable due to their spiny stems. It is especially troublesome in cereal and horticultural croplands, where repeated cultivation aids its distribution (Parsons, 1992).

Successful weed management may be achieved when it's life cycle and population dynamics are well investigated (Mortimer, 1987) and could predict the weeds physiological responses to environmental variations (Ghersa, 1995).

Vegetative growth is the most important mean for distribution. Small portions of the rootstock have been reported to be capable of giving rise to new plants (Richardson, 1953). This allows camelthorn to thrive in situations of intensive erosion (such as along riverbanks) by re-sprouting from underground buds (Kassas, 1952). Camelthorn has a vigorous root system that is able to tap into a water table down to fifteen meters below the soil surface. This allows camelthorn to thrive in areas of little rainfall and high deep water tables, such as saline meadows, sandbars, playas, riverbanks, irrigation canals, and irrigated croplands (Kerr, 1965). The fast-growing rhizomes can enlarge stands up to 7.4 m per year. Many infestations of this plant have been described as circular pattern. Camelthorn can send its roots underneath asphalt roads and then produce shoots over 6.5 m from the parent plant. Shoots can also break through asphalt roads to produce new plants (Parsons, 1992).

Although the stems are somewhat woody, in cooler environments camel thorn is deciduous and dies back to the ground each winter, remaining dormant until spring (Kassas, 1952; Rahimian, 1999).

Camelthorn's growth form may vary with habitat conditions. Plants can be either prostrate (in areas of prevailing winds) or, more typically, erect (Kassas, 1952). This variable morphology may exist within a single clone growing in different microhabitats. In moist habitats, leaves are broader and spins are smaller than one of plants growing in hot and dry habitats, In hot and dry areas, the ratio of spins to leaves increases, slowing water losses. Spins have less transpiring surface than leaves, they are structurally more capable of withstanding water loss, and they have chlorophyllous tissues that can continue photosynthesis in the absence of leaves (Rahimian, 1999).

MATERIALS AND METHODS

The experiments were conducted in Khorasan Agricultural and Natural Resources Research Center (Mashhad, Iran), located in a semi-arid climate with a sum of 260 mm annual rainfall, during 2005-2006. Preliminary tests were conducted to evaluate potential germination ability of fresh and stored detached rhizomatous roots as an index of recovery after mechanical management. One-year aged camelthorn roots were collected from fields during late summer and early spring, sliced to four different lengths i.e. 5, 10, 20 and 30cm, washed with benomil 5% for 15min and were rinsed three times with distilled water to ensure exclusion of possible infective diseases. Each treatment was replicated 5 times. Chopped rhizomes were sown in pots with 30 x 30 x 30cm dimensions. Vessels were filled with silty-loam soil. Pots were transferred to a germinator, where under temperature conditions of 25℃ and 70% humidity, as the optimum germination conditions for most of perennial species. Daily germination percentage was recorded during the first 30 days after sowing. The experiment was laid out in a completely randomized design

In a separate experiment, effects of *in situ* root detaching were examined. Three depths of plow *i.e.* 10, 20 and 30 cm were applied at a field highly infested with camelthorn on 20 April during the fallow season when camelthorn almost attains its potential emergence rate and plant height is about 10cm as a criteria of whole single plant size ready for mechanical control (30 days after first emerging shoots). The experiment was laid out in a randomized complete block design (RCBD) with four replicates for each depth. Sampling was conducted using a 1m x 1m quadrate to record numbers of germinated detached roots 20, 30 and 50 days after treatment (DAT). Ten samples were collected from each plot (3m x 20m) according to W movement pattern.

To quantify revival of mechanically treated rhizomes of undetached root bases, a further experiment was performed during the fallow season of 2005. Camelthorn was cut off from 4 different soil depths i.e. 0, 10, 20 and 30cm at an infected field with natural distribution (Average density=1.2 plant m^{-2}). Randomized complete block design was applied for analysis of variance. Twenty five plants with average 10cm height were devoted to each treatment to provide enough material for destructive sampling method. Date of germination, plant height, canopy shading area, number of shoots and dry matter (DM) weight were recorded 7, 10, 17, 24, 34, 41 and 58 DAT. Various physiological indices were calculated and fitted by proper regression models. Relative growth rate (RGR) was calculated through derivation of dry matter 2nd order equations:

$DM = a + b.GDD + c.GDD^2$,

$RGR = b + 2c.GDD$.

GDD stands for growing degree days. Base temperature was set to 7.5 ^{o}C according to Sazvari (2006). Maximum day temperature did not exceed 48 ^{o}C which is reported to be the maximum tolerable temperature for camelthorn (Sazvari, 2006). SPSS Ver.13, Sigmaplot Ver.7 and MSTATC softwares were used to fit the regression models and analysis of variance, respectively.

To confirm rhizomatous nature of roots, microscopic cross sections were prepared. Root cellulosed textures and lignin (woody) parts were stained by incubating in KARMAN dye (red) for 15 minutes and methyl dye (blue) for 1 minute, respectively.

RESULTS AND DISCUSSION

Germination Characteristics

No germination of detached roots were observed in all pot experiments. Reports on the same species by Hesari (2007) confirms this result. However, other species as for *Calystegia sepium* may behave differently. Rask and Andreasen (2007) in their studies *on C. sepium* observed rhizome fragment's regrowth in pot experiments.

The results revealed that there are significant differences among depths of plough (length of detached root), concerning the ability of recovery i.e. germination percent. None of the root segments with less than 30[cm] could germinate, while 5.5% germination was observed in case of root pieces with at least 30[cm] length, including residues of root hairs which probably have been formed before plowing. All rhizomes undetached from root bases germinated fully. With respect to the above mentioned findings, it may be concluded that detached roots are not able to germinate due to insufficient carbohydrate reservoirs, water and nutrient uptake failure, and or probably distressed growth regulator balance.

Studies on roots tissues revealed the occurrence of central parenchyma tissue at the central point of the cross section, followed by xylem vessels (meta-xylem next to proto-xylem) and epidermis at the external layer. Fibrous roots were observed in biennial root samples. Such anatomical constitution matches best with rhizomatous nature of roots.

There was a high significant correlation (r^2=0.9702) between rhizome re-growth and growing degree days (GDD) (Figure 1b). Average daily growth (length increment) was 1.82 cm d^{-1} during the recovery period (Figure 1a).

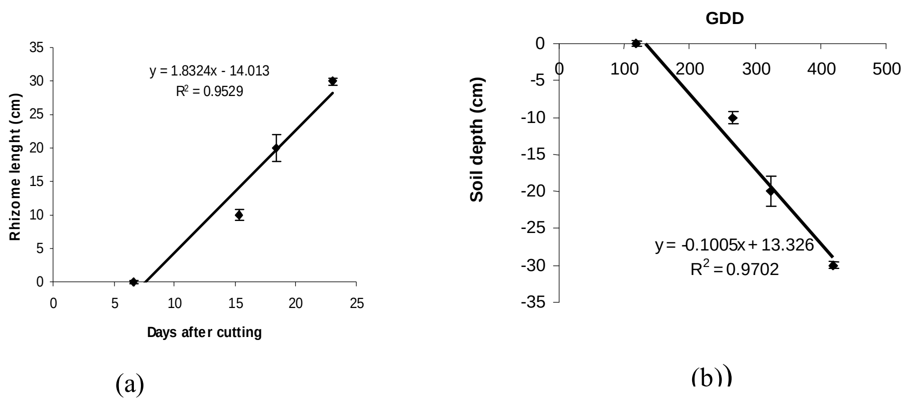

Figure 1. Days to emergence (a) and thermal requirements (GDD) of rhizome for re-growth (b) Error bars represents ±SEM.

It can be observed that a minimum thermal unit (118 GDD) is necessary for root-born buds for activation. Rask and Andreasen (2007) also observed that burial and fragmentation delayed the emergence time of *Calystegi asepium*.

Growth Characteristics

Soil depth of root cutting caused significant differences on plant growth characteristics. Final shoot height was significantly ($P<0.01$) reduced by depth of root cutting (Figure 2). A fast increase in plant height was observed during the first 41 days after treatment while reducing during the remained short span of the growing season. There were no significant difference between 0 and 10 cm plow depth concerning final plant height while the two other depths were classified in separate groups based on Duncan's multiple range test (DMRT), stating necessity of at least 20^{cm} plow depth for minimum significant impact on the species (Figure 2 and Table 3). A minimum of cutting off depth and/or deep burial was reported to be met to suppress plant recovery. As reported by Rask and Andreasen (2007) at least 25cm deep burial was necessary to reduce regrowth of *C. asepium*. The same pattern was also recorded in case of canopy shading area (Figure 3) and single plant dry matter (Figure 4), with minor differences between the first, two levels of treatment. The deeper the plow depth, the more suppressed plants were and, as a consequence, a more effective camelthorn control. Fitting parameters of growth indices have been shown in details in Tables 1 and 2.

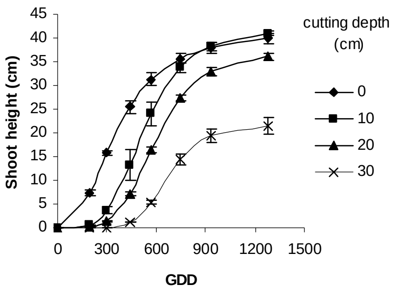

Figure 2 . Final shoot height as affected by by depth of cutting. Error bars represent ± SEM

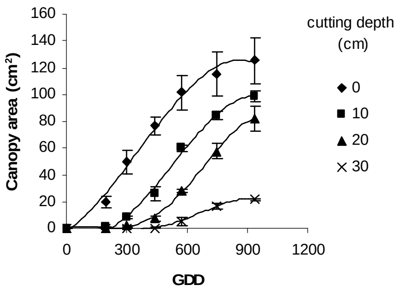

Figure3. Canopy area as affected cutting. Error bars

Marrs *et al.*, (1998) used regression analysis to investigate the relationship between frond production and rhizome characteristics of bracken. Their results show that the response of the rhizome to the cutting treatment is not linear through longer period of time. This is because the impacts of the treatments reduce through time.

Root exhausting management could have also significantly affected number of emerging shoots. Since observations per unit of area usually do not follow normal distribution and show skewness, therefore, to minimize bias in estimations, these data were transformed to their second roots and analyzed, as it was found to be also necessary in our calculations. On the average, 2.3 shoots were emerged when they were cut off from the soil surface while only 1 new shoot could be observed when plants were cut off from 20 and 30 cm soil depth (Table 3). Differences were significant at 95% confidence interval. The traditional technique of mechanical cutting was shown to be effective in reducing plant reproductive success and the concentration of nutrients (Kluth *et al.*, 2003).

Table 1. The equations coefficients of regression analysis for various traits of camel thorn at different depths of cutting

Depth cm	Shoot Height	Canopy Area	Dry Matter	Shoot Height	Canopy Area	Dry Matter	Shoot Height	Canopy Area	Dry Matter
0	41.71	131.97	48.80	-2.48	-3.22	-2.48	365.70	515.00	365.61
10	42.01	103.00	49.04	-4.11	-5.22	-4.12	530.00	701.00	533.60
20	37.11	89.05	43.43	-4.65	-6.08	-4.65	597.76	847.00	597.80
30	21.70	21.77	25.44	-6.48	-10.26	-6.47	673.90	831.60	673.90

$Y=a/[1+(x/x_0)^b]$ where x= GDD, a=Max(y), $x_0=x_{50}$

Table 2. Determination coefficients of growth equations for various traits of camelthorn at different depths of cutting

Depth cm	Shoot Height	Canopy Area	Dry Matter
0	0.9966	0.9965	0.9983
10	0.9992	0.9970	0.9988
20	0.9988	0.9996	0.9988
30	0.9981	0.9909	0.9981

Table 3. Means of plant growth characteristics of camelthorn plant at different depths of cutting

	Root cut off depth (cm)			
	0	10	20	30
Height (cm)	40.50 a*	41.73 a	35.83 b	21.33 c
Canopy Area (cm^2)	121.83 a	100.00 a	82.30 a	21.50 b
Single plant DM (g)	48.09 a	45.04 ab	39.83 b	24.8 c
Shoot number**	1.52 a	1.38 ab	1.00 b	1.00 b

* Means with the same letter in each row are not significantly different based on LSD test (α =0.05) * * Transferred data

Maximum RGR (0.0098 g $g^{-1}d^{-1}$) was obtained for the deepest cutting depth. It reveals that plants struggle for rapid recovery after emergence (Figure 5). Such high RGR results in carbohydrates reservoirs and further general plant weakness.

Further studies should be conducted to investigate the effects of several other factors influencing root exhausting management including: number and time (phonological stage) of cutting and their interactions with depth of cutting, density and spatial pattern of distribution as a consequence of rhizome interconnecting network. Combining the cutting off (as a mechanical measure) with other methods, especially with biological ones have been reported to increase the efficacy of perennial species management (Hatcher & Melander, 2003; Kluth *et.al* 2003; Zaller, 2004).

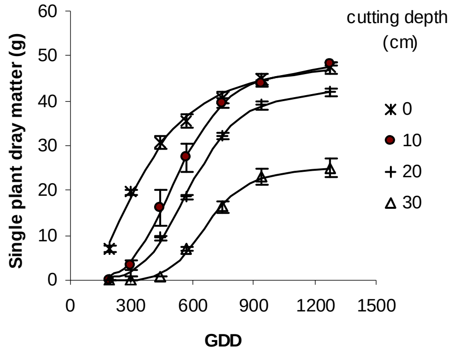

Figure 4. Dry matter changes of camelthorn as affected by depth of cutting. Error bars represents± SEM

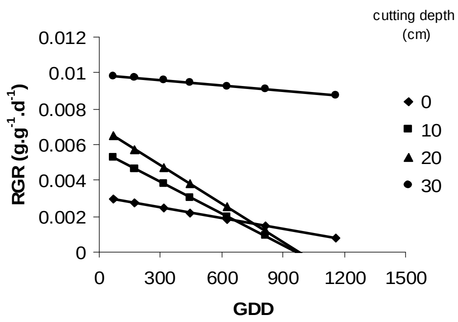

Figure 5. Relative growth rate of camelthorn under different soil cutting depth

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