Effect of hydroseeding on grass yield and water use efficiency on forest road artificial soil slopes

AIDIN PARSAKHOO 1* , Mohammad JAJOUZADEH 2 , Ayoob REZAEE MOTLAGH 1

¹Department of Forestry, Faculty of Forest Science, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

²Department of Silviculture and Forest Ecology, Faculty of Forest Science, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

Abstract

Parsakhoo A., Jajouzadeh M., Rezaee Motlagh A. (2018): Effect of hydroseeding on grass yield and water use efficiency on forest road artificial soil slopes. J. For. Sci., 64: 157–163.

Hydroseeding treatments are increasingly being used as a feasible alternative for soil erosion control after forest road construction. This study investigated the germination and biomass production of two hydroseed mixes and assessed the effectiveness of these treatments to reduce the water consumption of grass. Hydroseed mix 1 (water + seed + organic tackifier + starter fertilizer + superabsorbent) and hydroseed mix 2 (mentioned materials in mix 1 + biohumus + cellulose fibre mulch + natural yarn) were compared to a control (prevalent mix including seed + animal fertilizer) during the study period (30 days in July). Hydroseed mix 2 significantly favoured both seed germination parameters and grass biomass production. Hydroseed mix 2 significantly reduced the quantity of irrigation water via producing an absorbent layer. The results from this study could help managers to select and apply more appropriate hydroseeding treatments for slope stabilization of forest road embankments.

Keywords: hydroseed mixes; grass germination; fibre mulch; stabilization; consumption

Created artificial slopes during the topographic change by road construction are susceptible to water erosion and are commonly stabilized by revegetation (WAGENBRENNER et al. 2006; RIVERA et al. 2014). Different effective road slope stabilization methods such as hydroseeding, topsoil spreading, geotextile installation and planting have been developed and used around the world (AKBARZADEH et al. 2009; RIVERA et al. 2014). Over the past decade, the use of hydroseeded grasses has greatly increased because of their restoration and habitat advantages as well as their beauty (MARQUES et al. 2007; RIVERA et al. 2014).

Some grasses can reduce runoff and sediment concentrations by 65–70 and 80–95%, respectively (LI et al. 2011). Their cover also consists of numerous grass stems that enhance the trap sediment

and slow down surface runoff. Grasses are also capable of forming root mats in the soil that act as mechanical barriers to sediment loss (Gyasi-Agyei 2004; Fox et al. 2010). Plant roots significantly affect soil erosion (Pan, Shangguan 2006). The establishment of grass will require a detailed analysis of the site in terms of access to irrigation water, established weeds and other ground covers as well as soil erosion process (Babcock, McLaughlin 2011).

Seeding is the distribution of seeds for the purpose of establishing vegetation at a desired density and species composition to minimize the soil erosion (Sheldon, Bradshaw 1977; Grace 2002). These old soil conservation and stabilization techniques have been rediscovered and improved. Recently ground covers such as grasses have usually

^{*}Corresponding author: Aidinparsakhoo@yahoo.com

been applied on soil slopes by hydroseeding or other techniques (Liu et al. 2010). Hydroseeding is an important and popular treatment to stabilize steep slopes (ADEKALU et al. 2007). A hydroseed binder can decrease sediment production by providing cover on bare soil, reducing raindrop impact erosion, reducing runoff during precipitation events by increasing infiltration into the soil and increasing soil water-holding capacity by decreasing soil evaporation (ALBALADEJO MONTORO et al. 2000; GROEN, WOODS 2008).

Hydroseeding is a process by which seed, water, fertilizer, and sometimes fibre mulch and binders are blended together in a tank and applied onto bare soil surfaces through hydroseeder equipment (Wagenbrenner et al. 2006; Dodson, Peterson 2009). When sprayed, the cellulose fibre mulch together with fertilizer and grass seed will act as an absorbent mat, holding enough moisture to allow the proper and rapid germination of grass seeds and at the same time forming a cover to prevent soil erosion (FAUCETTE et al. 2004; Holt et al. 2005; Вавсоск, McLaughlin 2013). However, information regarding the effectiveness of these techniques in erosion control, irrigation requirement and vegetative parameters of grasses is scarce (Enriquez et al. 2004; Dodson, Peterson 2009). Hydroseeding can achieve dense grass cover in the short term by stabilizing the soil, thus controlling erosion (Robichaud et al. 2000). This technique was widely used for grass establishment on road cuts and fills (Muzzi et al. 1997; BOCHET, GARCÍA-FAYOS 2004). Grass rapidly develops a fine, extensive root system that stabilizes soil particles. In this study a grass species (Poa annua Linnaeus) was used to establish steep slopes. The objectives of this study were to examine the vegetative parameters of grass associated with different mixtures, and assess the effects of hydroseed mixes on water requirements for irrigation.

MATERIAL AND METHODS

The study site was located in the forest engineering laboratory at the Gorgan University of Agricultural Sciences and Natural Resources (36°50'32"N and 54°26'22"E) in the Golestan Province, Iran. The experiments were conducted in July 2017 on artificial soil slopes with obvious bare and eroded surfaces. Climate records as measured at a Gorgan weather station show that the mean annual air temperature during the study was 32°C, with a maximum daily temperature of 39°C for the hottest day, and a daily minimum of 27°C for the coldest day (Монаммарі et al. 2017). The soil texture was clay (14% sands, 40% silts, 46% clays). Soil bulk density was 1.2 g·cm⁻³ with a pH of 7.7. Hydroseed binders in this study were produced based on the native materials and hydroseeding Protocol Options. To establish these binders, it is important to prepare the site and remove weeds. The site must be cleared of trash to ensure maximum contact of the hydroseed slurry to the soil. Formulations applied to produce seed mixes are shown in Table 1.

Grass (P. annua) seeds are enclosed by sets of bracts, called the lemma and the palea. These structures provide a protective covering and are believed to reduce seed breakage during seeding agitation and application. Organic tackifiers are sticking agents that bind soil particles together and protect the surface from wind and water erosion. They are derived from plant materials which include natural polysaccharide (ionic starch) and agar. Seed Starter Fertilizer 20-20-20 formulation (fortified amino acids + gibberellic acid + microelements) is ideal for hydroseeding (Babcock, McLaughlin 2013). Adding a fertilizer to the slurry can reduce germination of certain species due to the effects of fertilizer salts on seed imbibition, or uptake of water. This is not just a problem when seeds and fertilizers are mixed together in the slurry tank; it can also negatively impact the seeds after they are ap-

Table 1. Formulation of seed mixtures used in soil erosion control experiments

	Hydroseed mix 1	Hydroseed mix 2	Prevalent mix
Water (l)	5	5	5
Seed (g)	30	30	30
Organic tackifier (g)	20	20	0
Starter fertilizer (g)	30	30	0
Biohumus (g)	0	30	0
Cellulose fibre mulch (g)	0	100	0
Superabsorbent (g)	10	10	0
Natural yarn (g)	0	10	0
Animal fertilizer (g)	0	0	30

plied to the soil surface and before the first rains dilute the surrounding salts. Effects of fertilizer salts will be more detrimental on sites with low rainfall. Cellulose fibre mulch (saw dust) together with the biohumus will act as an absorbent mat, holding enough moisture to allow the proper germination of grass seeds. Natural yarn will hold materials together as a sheet and is referred to as a bonded matrix. The length of the yarn is an important characteristic in creating a matrix sheet. The length of goat yarn in this study was 2 cm. Seed that is sown on the surface and pressed into the soil increases germination rates over broadcast sowing. Seeds are dropped from a seeder mounted in front of the imprinter and then pressed into the soil (Fig. 1).

Experimental design. The erosion control treatments examined in the present study are: (i) hydroseed mix 1, (ii) hydroseed mix 2, (iii) prevalent mix. Treatments were conducted in 5 replications on artificial soil slopes (soil boxes). The soil box had variable slopes (20, 45 and 70°) with dimensions of 0.40 m length, 0.2 m depth and 0.25 m width (Fig. 2). The bottom of the soil box was filled with 10 cm of sand covered with a layer of gauze to keep the water drainage conditions close to those of the test soil; thus, water can easily infiltrate into the soil during the test. Irrigation was carried out once or twice per day after sunset for as long as it takes the surface soil to start to glisten. Most grasses will germinate in 5 to 10 days at optimal temperatures. The experimental design consisted of randomized blocks with 3 × 3 factorial arrangement and five replications. Totally 45 soil boxes or samples were used in this study.







Fig. 1. Erosion control treatments used in the present study: hydroseed mix 1 (a), hydroseed mix 2 (b), prevalent mix (c)



Fig. 2. The test condition and boxes in an open-top laboratory

Grass biomass and irrigation quantity measurements. Seed germination in each soil box was observed daily and the germinated seeds were counted. Seeds were considered germinated when the radicle was 5 mm long (Sosa et al. 2005). Final germination percentage (FG) and mean daily germination (MDG) were calculated by Eqs 1 and 2 (Hossain et al. 2005; Li et al. 2006):

$$FG = \frac{n}{N} \times 100 \tag{1}$$

where

n – number of germinated seeds,

N – total number of seeds.

$$MDG = \frac{FG}{D}$$
 (2)

where:

D – number of days to final germination percentage.

To assess the germination rate (GR), the mean germination time was calculated by Eq. 3:

$$GR = \sum_{i=1}^{n} \frac{n_i}{t_i}$$
 (3)

where:

 n_i – number of germinated seeds in day t_i .

Germination index (GI) and seedling vitality (V) were calculated by Eqs 4 and 5 (KARAGUZEL et al. 2004; HOSSAIN et al. 2005):

$$GI = \frac{\sum t_i n_i}{N} \tag{4}$$

$$V = \frac{\text{FW} - \text{DW}}{\text{FW}} \times 100 \tag{5}$$

where:

FW - seedling fresh weight,

DW - seedling dry weight.

The experiment was concluded after 30 days and various growth indices such as root and stem length, stem fresh weight, root fresh weight, stem dry weight and root dry weight were measured (Baskin et al. 2004; Phartyal et al. 2005). Dry weight was determined after drying the seedlings in an oven at 80°C for 24 h. Then, seedling weight was measured by digital balance to the nearest mg. At the end of the month, the consumed water of irrigations was estimated (Faucette et al. 2004).

Statistical analysis. Statistical analyses were conducted using SPSS (Version 13.0, 2005). To test whether the differences between the treatments were statistically significant (P < 0.05), one-way ANOVA and Duncan's multiple comparison proce-

dure were performed on germination parameters, biomass production, runoff and soil erosion.

RESULTS AND DISCUSSION

In this study, germination parameters were significantly related to seeding treatments for erosion control (P < 0.0001). MDG was significantly and negatively related to the slope angle of plots (P = 0.043). There was no significant statistical difference in other germination parameters between the slope treatments (P > 0.05). Treatment types had a significant effect on the grass biomass production. There were no significant differences in grass biomass production between the slope treatments except for the total length and total fresh weight of grass (P < 0.05). The irrigation volume of grass in hydroseed mix 2 was significantly different from the other two treatments (P < 0.0001, in both cases) (Table 2).

Germination parameters of grass

Germination parameters of hydroseed mix 2 during the 30 days of study were higher than those of other treatments, particularly in the slope of 20°. MDG and GR in response to the hydroseed mix treatments were significantly faster than in response to the prevalent mix type. Starter fertilizer accelerated the germination of grass. At the end of the study GI varied from 1.78–3.22 in the prevalent mix plots to 6.00–7.60 in the hydroseed mix plots (Table 3). The reason for the low GI of prevalent mix was that the surface of grass seeds had not been covered by a soft layer of organic fertilizer immediately after seeding (COLEMAN, HARRIS 1996; Fox et al. 2010; LIU et al. 2010). GR depended upon the number of live, germinant seeds per unit weight (KARAGUZEL et al. 2004; Hossain et al. 2005). The prevalent seed mix established lower percent grass cover and had a slower GR than the hydroseed mixes. So, based on this result it is not recommended to use this mix for artificial slope stabilization practice. It was confirmed that hydroseed mix 2 provided favourable soil moisture and temperatures for grass seeds and this accelerated the plant establishment.

Biomass production of grass

The grass biomass provided by the prevalent mix during 30 days of July was very low in all replications. The treatment had a significant effect on to-

Table 2. Analysis of variance showing the effect of the different treatments on germination, biomass and irrigation of grass and soil erosion from the plots

C	Treatment type			Slope treatment		T 1
Source of variation	SS	MS	<i>F</i> -value	SS	MS	- <i>F</i> -value
Germination						
Final germination	10,336.9	5,168.4	34.8***	552.7	276.3	1.9
Mean daily germination	12.4	6.2	27.4***	1.5	0.8	4.4*
Germination rate	51,490.8	25,745.4	30.1***	4,080.1	2,040.1	2.4
Germination index	91.7	45.8	38.9***	2.0	1.0	0.9
Biomass production						
Leaf length	38.2	19.1	35.5***	3.2	1.6	2.9
Root length	84.6	42.3	117.0***	4.3	2.1	5.9**
Total length	232.2	116.1	81.8***	12.5	6.3	4.4*
Leaf fresh weight	98.8	49.4	7.3**	52.4	26.2	3.9*
Root fresh weight	35.6	17.8	6.9**	21.9	10.9	4.2*
Total fresh weight	251.1	125.5	7.6**	138.7	69.3	4.2*
Leaf dry weight	3.7	1.8	9.5**	1.2	0.6	3.0
Root dry weight	3.7	1.8	7.0**	1.2	0.6	2.3
Total dry weight	14.8	7.4	10.2**	4.2	2.1	2.9
Vitality	7,455.1	3,727.6	7.3**	442.5	221.2	0.4
Irrigation						
Mean daily irrigation	22,412.7	11,206.4	126.6***	35.2	17.6	0.1
Total irrigation	2.02	1.01	126.5***	31,666	15,833	0.2

SS – sum of squares, MS – mean of squares, *** significant at P = 0.001, ** significant at P = 0.01, *significant at P = 0.05, without sign – not significant

Table 3. Effect of the different slope treatments on germination parameters of grass (mean \pm standard error)

Slope (°)	Treatment	FG (%)	MDG	GR	GI
	hydroseed mix 1	67.55 ± 7.70^{b}	2.37 ± 0.23^{b}	141.32 ± 11.56^{b}	6.86 ± 1.05^{b}
20	hydroseed mix 2	86.88 ± 9.42^{a}	3.33 ± 0.35^{a}	201.92 ± 22.45^{a}	7.60 ± 1.75^{a}
	prevalent mix	$30.78 \pm 0.83^{\circ}$	1.06 ± 0.07^{c}	$62.99 \pm 3.64^{\circ}$	$3.22 \pm 0.05^{\circ}$
	hydroseed mix 1	63.08 ± 0.37^{a}	2.10 ± 0.01^{a}	131.15 ± 1.29^{a}	6.48 ± 0.03^{a}
45	hydroseed mix 2	66.45 ± 5.60^{a}	2.22 ± 0.19^{a}	140.79 ± 11.45^{a}	6.67 ± 0.57^{a}
	prevalent mix	23.03 ± 6.33^{b}	0.77 ± 0.21^{b}	47.02 ± 14.88^{b}	2.46 ± 0.56^{b}
	hydroseed mix 1	61.13 ± 4.13^{a}	2.04 ± 0.14^{a}	132.30 ± 8.80^{a}	6.00 ± 0.44^{a}
70	hydroseed mix 2	66.03 ± 6.33^{a}	2.20 ± 0.21^{a}	134.81 ± 14.88^a	6.55 ± 0.56^{a}
	prevalent mix	16.18 ± 4.23^{b}	0.60 ± 0.13^{b}	31.50 ± 9.31^{b}	1.78 ± 0.42^{b}

Means followed by different lower-case letters within columns are significantly different (P < 0.05), FG – final germination, MDG – mean daily germination, GR – germination rate, GI – germination index

tal dry weight of grass, with higher values in hydroseed mix 2 than in the other two treatments. At this time, the average of total lengths for three slope classes was 11.7 and 15.7 cm in the plots of hydroseed mix 1 and 2, and 8.5 cm in the prevalent mix plots, respectively. Vitality ranged from 73.8 to 74.4% in hydroseed mix 2 (Table 4). Root length and biomass in plots treated with hydroseed mix 2 were significantly higher than in the other treatments. Numerous long grass roots growing almost vertically downwards are able to penetrate and mitigate the soil erosion (MICKOVSKI, VAN BEEK 2009).

Water requirement of treatments

A higher volume of total and daily irrigation water was found on the prevalent mix plots. There was also a higher volume of irrigation water found on the higher slope angle plots. The hydroseed mix 1 and 2 treatments were observed to be the most effective in terms of irrigation water volume with 12.8 and 16.5% reduction, respectively, as compared to the prevalent mix treatment (Table 5). A superabsorbent in hydroseed mix controlled the irrigation requirement of grass.

Table 4. Effect of the different treatments on grass biomass

Slope (°)	Treatment	LL (cm)	RL (cm)	TL (cm)	LFW (g⋅m ⁻²)	LDW (g·m ⁻²)	RFW (g)	RDW (g⋅m ⁻²)	TFW (g⋅m ⁻²)	TDW (g⋅m ⁻²)	V (%)
20	hydroseed mix 1 hydroseed mix 2 prevalent	7.0^{b} 10.0^{a} 6.0^{b}	6.0 ^b 7.5 ^a 2.7 ^c	13.0 ^b 17.5 ^a 8.7 ^c	66.4 ^b 87.7 ^a 15.5 ^c	16.0 ^b 20.5 ^a 7.1 ^c	42.6 ^b 56.9 ^a 9.9 ^c	19.9 ^a 16.4 ^b 6.9 ^c	109.0 ^b 144.6 ^a 25.5 ^c	35.9ª 36.9ª 13.9 ^b	67.0 ^b 74.4 ^a 45.3 ^c
45	hydroseed mix 1 hydroseed mix 2 prevalent	6.5 ^b 8.5 ^a 6.0 ^b	5.0 ^b 7.2 ^a 2.7 ^c	11.5 ^b 15.7 ^a 8.7 ^c	49.7 ^b 54.2 ^a 8.3 ^c	17.9 ^a 12.2 ^b 4.4 ^c	13.5 ^b 34.2 ^a 6.2 ^c	8.5 ^b 11.7 ^a 4.9 ^c	63.2 ^b 88.4 ^a 14.5 ^c	26.4^{a} 23.8^{a} 9.2^{b}	58.3 ^b 73.0 ^a 36.2 ^c
70	hydroseed mix 1 hydroseed mix 2 prevalent	6.5 ^a 7.5 ^a 5.5 ^a	4.0 ^b 6.2 ^a 2.5 ^c	10.5 ^b 13.7 ^a 8.0 ^c	22.3 ^b 52.7 ^a 4.1 ^c	7.6 ^b 11.3 ^a 2.3 ^c	17.7 ^b 33.6 ^a 2.7 ^c	8.3 ^b 11.3 ^a 1.1 ^c	39.9 ^b 86.3 ^a 6.8 ^c	15.9 ^b 22.6 ^a 3.4 ^c	60.1 ^b 73.8 ^a 50.4 ^c

Means followed by different lower-case letters within columns are significantly different (P < 0.05), LL – leaf length, RL – root length, TL – total length, LFW – leaf fresh weight, LDW – leaf dry weight, RFW – root fresh weight, TFW – total fresh weight, TDW – total dry weight, V – vitality

Table 5. Effect of the different treatments on irrigation rates of grass (mean ± standard error)

Slope (°)	Treatment	MDI (ml)	TI (ml per month)		
20	hydroseed mix 2	348.33 ± 173.54^{b} 343.33 ± 163.33^{b} 405.00 ± 146.34^{a}	10,450.00 10,300.00 12,150.00		
45	hydroseed mix 2	353.33 ± 175.04^{b} 348.33 ± 172.62^{b} 398.33 ± 141.72^{a}	10,600.00 10,450.00 11,950.00		
70	hydroseed mix 2	361.67 ± 192.33 ^b 326.67 ± 134.02 ^c 416.67 ± 184.68 ^a	10,850.00 9,800.00 12,500.00		

Means followed by different lower-case letters within columns are significantly different (P < 0.05), MDI – mean daily irrigation, TI – total irrigation

CONCLUSIONS

This study explored the effectiveness of three soil stabilization treatments. A new proposed treatment was the use of hydroseed mix 2 as a mulchbased treatment. Hydroseed mix 2 was clearly much more efficient than hydroseed mix 1 and prevalent seeding in terms of grass germination, vegetation biomass and irrigation level. Cellulose fibre mulch, organic tackifier and superabsorbent in hydroseed mix 2 provided a hydrogel layer during the study time that was the reason for 16.5% reduction in irrigation requirement. The hydrogel layer can reserve water in its structure and consume water during the day. In addition, starter fertilizer and biohumus in hydroseed mix 2 contain fortified amino acids, gibberellic acid and microelements which can accelerate seed germination and produce more grass biomass. We found that the average germination index and biomass in all of the slope classes increased to 6.94 and 27.77 g·m⁻², respectively, when hydroseed mix 2 was used. From the management point of view, our results support the use of hydroseed mix 2 as an efficient bioengineering alternative to stabilize hillslopes after forest road construction.

References

Adekalu K.O., Olorunfemi I.A., Osunbitan J.A. (2007): Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. Bioresource Technology, 98: 912–917.

Akbarzadeh A., Taghizadeh Mehrjardi R., Refahi H.G., Rouhipour H., Gorji M. (2009): Using soil binders to control runoff and soil loss in steep slopes under simulated rainfall. International Agrophysics, 23: 99–109.

Albaladejo Montoro J., Alvarez Rogel J., Querejeta J., Díaz E., Castillo V. (2000): Three hydro-seeding revegetation techniques for soil erosion control on anthropic steep slopes. Land Degradation & Development, 11: 315–325.

Baskin J.M., Davis B.H., Baskin C.C., Gleason S.M., Cordell S. (2004): Physical dormancy in seeds of *Dodonaea viscosa* (Sapindales, Sapindaceae) from Hawaii. Seed Science Research, 14: 81–90.

Babcock D.L., McLaughlin R.A. (2011): Runoff water quality and vegetative establishment for groundcovers on steep slopes. Journal of Soil and Water Conservation, 66: 132–141. Babcock D.L., McLaughlin R.A. (2013): Erosion control effectiveness of straw, hydromulch and polyacrylamide in a rainfall simulator. Journal of Soil and Water Conservation, 68: 221–227.

Bochet E., García-Fayos P. (2004): Factors controlling vegetation establishment and water erosion on motorway slopes in Valencia, Spain. Restoration Ecology, 12: 166–174.

- Coleman R., Harris L. (1996): Case for planting native grasses and wildflowers. Public Works, 127: 54–83.
- Dodson E.K., Peterson D.W. (2009): Seeding and fertilization effects on plant cover and community recovery following wildfire in the Eastern Cascade Mountains, USA. Forest Ecology and Management, 258: 1586–1593.
- Enriquez A., Carrasco M.J., Varela J.M. (2004): Monitoring the effectiveness of plant restoration of the slopes of the highways. Civil Engineering, 134: 27–35.
- Faucette L.B., Risse L.M., Nearing M.A., Gaskin J.W., West L.T. (2004): Runoff, erosion, and nutrient losses from compost and mulch blankets under simulated rainfall. Journal of Soil and Water Conservation, 59: 154–160.
- Fox J.L., Bhattarai S.P., Gyasi-Agyei Y. (2010): Evaluation of different seed mixtures for grass establishment to mitigate soil erosion on steep slopes of railway batters. Journal of Irrigation and Drainage Engineering, 137: 624–631.
- Grace J.M. (2002): Effectiveness of vegetation in erosion control from forest road sideslopes. Transactions of the ASAE, 45: 681–685.
- Groen A.H., Woods S.W. (2008): Effectiveness of aerial seeding and straw mulch for reducing post-wildfire erosion, north-western Montana, USA. International Journal of Wildland Fire, 17: 559–571.
- Gyasi-Agyei Y. (2004): Optimum use of erosion control blankets and waste ballast (rock) mulch to aid grass establishment on steep slopes. Journal of Hydrologic Engineering, 9: 150–159.
- Holt G., Buser M., Harmel D., Potter K., Pelletier M. (2005): Comparison of cotton-based hydro-mulches and conventional wood and paper hydro-mulches – study 1. Journal of Cotton Science, 9: 121–127.
- Hossain M.A., Arefin M.K., Khan B.M., Rahman M.A. (2005): Effects of seed treatments on germination and seedling growth attributes of Horitaki (*Terminalia chebula* Retz.) in the nursery. Research Journal of Agriculture and Biological Sciences, 1: 135–141.
- Karaguzel O., Cakmakci S., Ortacesme V., Aydinoglu B. (2004): Influence of seed coat treatments on germination and early seedling growth of *Lupinus varius* L. Pakistan Journal of Botany, 36: 65–74.
- Li L., Zhang X.M., Runge M., Li X.M., He X.Y. (2006): Responses of germination and radicle growth of two *Populus* species to water potential and salinity. Forestry Studies in China, 8: 10–15.
- Li X.H., Zhang Z.Y., Yang J., Zhang G.H., Wang B. (2011): Effects of Bahia grass cover and mulch on runoff and sediment yield of sloping red soil in southern China. Pedosphere, 21: 238–243.

- Liu G., Tian F.X., Warrington D.N., Zheng S.Q., Zhang Q. (2010): Efficacy of grass for mitigating runoff and erosion from an artificial loessial earthen road. Transactions of the ASABE, 53: 119–125.
- Marques M.J., Bienes R., Jiménez L., Pérez-Rodríguez R. (2007): Effect of vegetal cover on runoff and soil erosion under light intensity events. Rainfall simulation over USLE plots. Science of the Total Environment, 378: 161–165.
- Mickovski S.B., van Beek L.P.H. (2009): Root morphology and effects on soil reinforcement and slope stability of young vetiver (*Vetiveria zizanioides*) plants grown in semi-arid climate. Plant and Soil, 324: 43–56.
- Mohammadi J., Shataeea S., Namiranianb M., Næssetc E. (2017): Modeling biophysical properties of broad-leaved stands in the Hyrcanian forests of Iran using fused airborne laser scanner data and ultraCam-D images. International Journal of Applied Earth Observation and Geoinformation, 61: 32–45.
- Muzzi E., Roffi F., Sirotti M., Bagnaresi U. (1997): Revegetation techniques on clay soil slopes in northern Italy. Land Degradation & Development, 8: 127–137.
- Pan C., Shangguan Z. (2006): Runoff hydraulic characteristics and sediment generation in sloped grassplots under simulated rainfall conditions. Journal of Hydrology, 331: 178–185.
- Phartyal S.S., Baskin J.M., Baskin C.C., Thapliyal R.C. (2005): Physical dormancy in seeds of *Dodonaea viscosa* (Sapindaceae) from India. Seed Science Research, 15: 59–61.
- Rivera D., Mejías V., Jáuregui B.M., Costa-Tenorio M., López-Archilla A.I., Peco B. (2014): Spreading topsoil encourages ecological restoration on embankments: Soil fertility, microbial activity and vegetation cover. PLoS ONE, 9: e101413.
- Robichaud P.R., Beyers J.L., Neary D.G. (2000): Evaluating the Effectiveness of Postfire Rehabilitation Treatments. General Technical Report RMRS-GTR-63. Fort Collins, USDA Forest Service, Rocky Mountain Research Station: 85.
- Sheldon J.C., Bradshaw A.D. (1977): The development of a hydraulic seeding technique for unstable sand slopes.I. Effects of fertilizers, mulches and stabilizers. Journal of Applied Ecology, 14: 905–918.
- Sosa L., Llanes A., Reinoso H., Reginato M., Luna V. (2005): Osmotic and specific ion effects on the germination of *Prosopis strombulifera*. Annals of Botany, 96: 261–267.
- Wagenbrenner J.W., MacDonald L.H., Rough D. (2006): Effectiveness of three post-fire rehabilitation treatments in the Colorado Front Range. Hydrological Processes, 20: 2989–3006.

Received for publication January 13, 2018 Accepted after corrections March 8, 2018