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# Effectiveness of wheat straw mulch and Polyacrylamide on shallow stability of roadside slopes

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**Abstract**: Soil aggregate instability on unprotected roadside slopes can cause landslide, soil erosion and sedimentation. Different biological and chemical soil stabilizers are used to reinforce the instable slopes. In the present study, straw mulch and Polyacrylamide (PAM) combinations were investigated on a clay soil of road cutslope in campus of Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran. The selected cover treatments were Polyacrylamide (2, 3 and 4 $g\cdot m^{-2}$) with wheat straw mulch (50, 150 and 250 $g\cdot m^{-2}$) which was spread by hand to attain 75% groundcover on a 1:1 slope. After the three months, soil sampling was done to determine the changes in aggregate stability of soil. Results showed that the most efficient treatment with respect to mean weight diameter of soil aggregates in dry and wet sieving (*MWDdry* and *MWDwet*), aggregate stability index (*AS*) and aggregate destruction index (*DI*) was treatment of B (150 $g\cdot m^{-2}$ wheat straw mulch and 3 $g\cdot m^{-2}$ Polyacrylamide tackifier) with 34%, 68% and 47% increment in *MWDdry*, *MWDwet* and *AS*, respectively as well as 37% reduction in *DI* as compared to the bare soil control.

**Keywords**: aggregate stability indices; soil stabilizer; cutslope; sieving; tackifier

Road construction results in soil instability, when soil is exposed to rainfall energy especially the first year after road construction. Rainfall provides the energy to cause detachment of soil particles. Soil properties include particle size distribution or mean weight diameter of aggregates, texture, aggregate stability indices affect soil potential to be washed by runoff. The soil surface can be protected with vegetation cover, straw and wood mulch, geotextile, tackifier materials such as Polyacrylamide (PAM). Straw mulch is the cheapest temporary method of soil loss control. Wheat straw mulch can be easily found in agricultural lands of Iran. Besides PAM is a polymer which can increase and preserve soil aggregate structure by increasing the infiltration and decreasing the runoff and surface crusting.

PAM used in conjunctions with mulch can be more effective in reducing soil instability and loss (Hayes et al. 2005). Bjorneberg et al. (2000) tested PAM in combination of wheat straw for soil instability control. They used the wheat straw at 250 $g\cdot m^{-2}$ and 67 $g\cdot m^{-2}$ with PAM at 0.2 and 0.4 $g\cdot m^{-2}$. Results showed that 250 $g\cdot m^{-2}$ wheat straw cover with PAM (0.2 $g\cdot m^{-2}$) reduce runoff and soil loss by 98% and 99%, compared to bare soil respectively. In another study, Lentz and Bjorneberg (2003) performed wheat straw treatment with PAM on a 1.5% slope silt loam soil. Results showed that with mixing PAM to low (48.5 $g\cdot m^{-2}$) and high (149 $g\cdot m^{-2}$) rates of straw the soil instability decrease by 64% to 100%, respectively. Roa-Espinosa et al. (1999) assessed the effect of straw mulching with PAM and straw mulching without PAM on slope gra-

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dient of 10%. Results confirmed that 2 g·m$^{-2}$ PAM and straw mulch reduce soil loss by 93% compared to control. Dry PAM alone reduced the instability by 83% compared to control. Flanagan and Canady (2006) tested the efficiency of PAM on 4% and 8% slopes with two wheat straw cover levels of 0% and 30% under a rainfall simulator. Results showed that PAM in conjunction with wheat straw reduces runoff about 66% compared to bare soil control.

In the northern forests of Iran, road construction and mining activities are the main sources of soil instability and sedimentation which directly affects water quality and aquatic ecosystem. Several million tons of sediment from construction sites are imported to the streams of Hyrcanian zone each year (Akbarimehr, Naghdi 2012). Simple, available and cheap soil erosion control methods such as straw mulching, wood mulching and seeding are typically recommended for this region. The main objectives of this study were to test the performance of three treatments (wheat straw mulch in conjunction with Polyacrylamide) to limit the soil instability compared to bare soil (control).

## MATERIAL AND METHODS

### Study area description

The study site was located in the campus of Gorgan University of Agricultural Sciences and Natural Resources (36°50'32''N, 54°26'22''E) in the Golestan Province, Iran. The experiments were conducted in April 2018 on road cutslopes with obvious bare and eroded surfaces. The soil texture of cutslope was clay (14% sands, 40% silts, 46% clays). Soil bulk density was 1.2 g·cm$^{-3}$ with a pH of 7.7. Climate records as measured at a Gorgan weather station showed that the mean annual air temperature during the study was 18°C and the mean precipitation was 538 mm. The road was constructed in 2014. The width of travel way was 7.5 meters and the mean of longitudinal slope was 3%. The mean slope gradient in study area was 50%. Totally, 12 sample plots with dimensions of 2 m × 5 m were randomly established on these slopes and then three soil samples were taken from each plot.

### Study treatments

Polyacrylamide (PAM) tackifier is a polymer from acrylamide subunits, is used to increase the soil structure stability. The use of PAM has been recognized as a best management practices (BMP) by the USDA-Natural Resources Conservation Service (NRCS) (Babcock, McLaughlin 2011). The use of acrylic-based polymer mulch is also expanding because of its environmental friendliness and safety. Polyacrylamides are odorless, colorless and non-polluting in surface and underground waters, plant tissues and soil (Manafi et al. 2016; Wang et al. 2019). Treatments were spread by hand to attain 75% groundcover on soil cutslopes (Fig. 1, Table 1 Babcock, McLaughlin 2013).

Fig. 1. General view of the study soil and treatments operation

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Table 1. Treatments used in this study

| Treatments | A | B | C | Control |
|---|---|---|---|---|
| Wheat straw (g·m$^{-2}$) | 50 | 150 | 250 | 0 |
| Polyacrylamide tackifier (g·m$^{-2}$) | 4 | 3 | 2 | 0 |

### Soil sampling and sieving

After the three months from the treatment establishment, soil samples were taken from 0–10 cm depth of cutslope and then mean weight diameter experiments in wet and dry condition was conducted in three replications for each treatment. For each replication 50 g of soil sample with aggregates size of < 4.75 mm was weighed for sieving. Aggregates were transferred on to the series of sieves with 2, 1, 0.5, 0.425, 0.212, 0.090 and 0.045 mm openings. In wet sieving the sieves moved up and down through a vertical distance of 1.5 cm at the rate of 30 oscillations per minute. The remaining soil aggregates on sieve were put into the oven for approximately 24 hours in 105°C (Kemper, Rosenau 1986).

### Measurement of soil stability indices

The Mean Weight Diameter (*MWD*) of soil aggregate was calculated using Equation 1:

$$MWD = \sum_{i=1}^{K} W_i \overline{X}_i \tag{1}$$

where:

$X_i$ – mean diameter of remaining aggregate on sieve,

$W_i$ – ratio of the weight of remained aggregates on each sieve to total weight of sample,

$K$ – number of sieve

After the wet sieving method the aggregate stability index was calculated using Equation 2 (Bissonnais 1996):

$$AS = \frac{WSA - MG}{MS - MG} \times 100 \tag{2}$$

where:

*WSA* – weight of remaining aggregates on sieve 0.25 mm,

*MG* – weight of gravel and MS is the total weight of sample.

The percentage of aggregate destruction is another index for evaluating physical structure of soil which is obtained from the measuring of mean weight diameter of soil aggregate in wet and dry condition. To determine the destruction index (*DI*) the weight of aggregates greater than 0.25 mm is calculated in dry (*MD*) and wet (*MW*) condition (Equation 3, Van Bavel 1950).

$$DI = \frac{MD - MW}{MD} \times 100 \tag{3}$$

### Statistical analysis

The experimental design was systematic randomized sampling method with three replications for each treatment. Soil stability indices were statistically analyzed using ANOVA procedure in SAS software. SNK test (Student Newman Kouls) at probability level of 5% was used to compare the means of variables including *MWDdry*, *MWDwet*, *AS* and *DI* among different treatments of A, B, C and control.

## RESULTS AND DISCUSSION

Results showed that the effect of treatments on *MWDdry* ($P < 0.01$), *MWDwet* ($P < 0.01$) and *AS* ($P < 0.05$) was significant (Table 2). The B treatment resulted in 34% more *MWDdry* than control treatment ($P < 0.05$) but the A and C treatments did not show a significant difference in relation to the control ($P > 0.05$, Fig. 2a). The B treatment was observed to be the most effective in term of *MWDwet* with 68% increment as compared to the bare soil control ($P < 0.05$). This increment for treatments of A and C was estimated to be 42% and 52%, respectively (Fig. 2b).

Kukal and Sarkar (2010) showed that wheat straw and polyvinyl acetate (PVA) were more effective in increasing aggregate stability in sandy loam than in silt loam. Bjorneberg et al. (2000) reported that 70% straw cover with PAM (4 kg·ha$^{-1}$) significantly reduce soil loss by almost 100% compared to bare soil than 70% straw with 2 kg·ha$^{-1}$ PAM. This result is supported by the Omane et al. (2018) and Watson et al. (2000). They reported that the adhesiveness between the molecular structures of the PAM solution is higher and a smaller surface tension leads to decreased evaporation rate. PAMs are manufactured in a broad range of molecular weights,

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Table 2. Analysis of variance for soil structural stability indicators

| Sources of variations | df | Mean squares | | | |
|---|---|---|---|---|---|
| | | *MWDwet* | *MWDdry* | *AS* | *DI* |
| Treatment | 3 | 0.035** | 0.223** | 342.563* | 241.112$^{ns}$ |
| Error | 2 | 0.001 | 0.012 | 12.512 | 9.856 |
| CV (%) | – | 5.124 | 7.635 | 4.524 | 6.131 |

*MWDdry* – mean weight diameter in dry conditions, *MWDwet* – mean weight diameter in wet conditions, *AS* – aggregate stability index, *DI* – destruction index;*, ** significant at probability level of 95% and 99%; respectively, ns – not significant

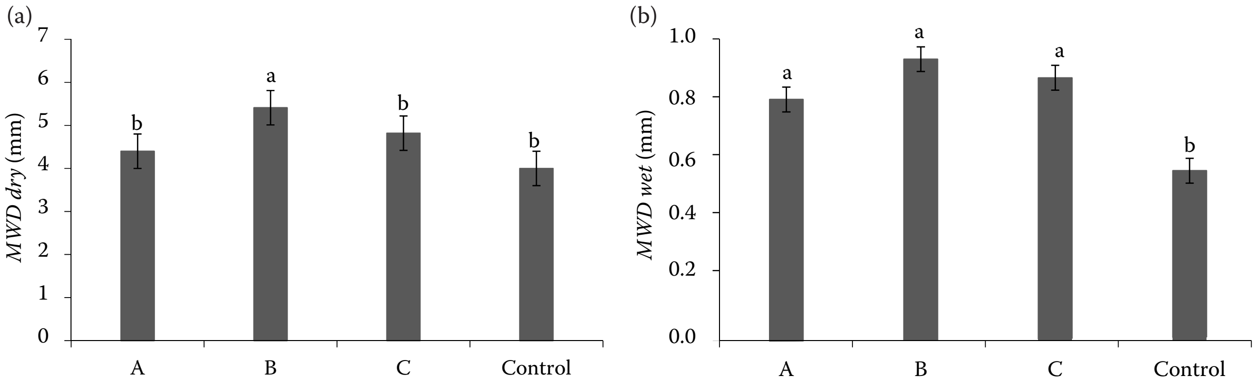


Fig. 2. Effect of treatments on mean weight diameter of aggregates in (a) dry sieving (*MWDdry*), (b) wet sieving (*MWDwet*); different letters shows significant difference at probability level of 5% based on SNK test

charge types, and charge densities. Breakdown of PAM requires several weeks and occurs as a result of mechanical disturbances (Ding et al. 2019).

The B treatment resulted in 47% more AS than control treatment ($P < 0.05$) but the A and C treatments show 28% and 36% increment, respectively (Fig. 3a). The B treatment was observed to be the most effective in term of *DI* with 37% reduction as compared to the bare soil control ($P < 0.05$). This reduction for treatments of A and C was estimated to be 20% and 30%, respectively (Fig. 3b). Flanagan and Canady (2006) tested the effectiveness of PAM on 4% and 8% slopes with two wheat straw cover levels of 0% and 30% under a rainfall simulator. Results showed that PAM in conjunction with wheat straw increase *MWD* of aggregates and consequently reduced runoff up to 66% compared to bare soil control. Moradi et al. (2017) showed that application of amendments have a significant effect on structural stability indicators. According to the results of this research, application of both PAM and wheat straw improved structural stability and treatment B (150 g·m$^{-2}$ wheat straw mulch

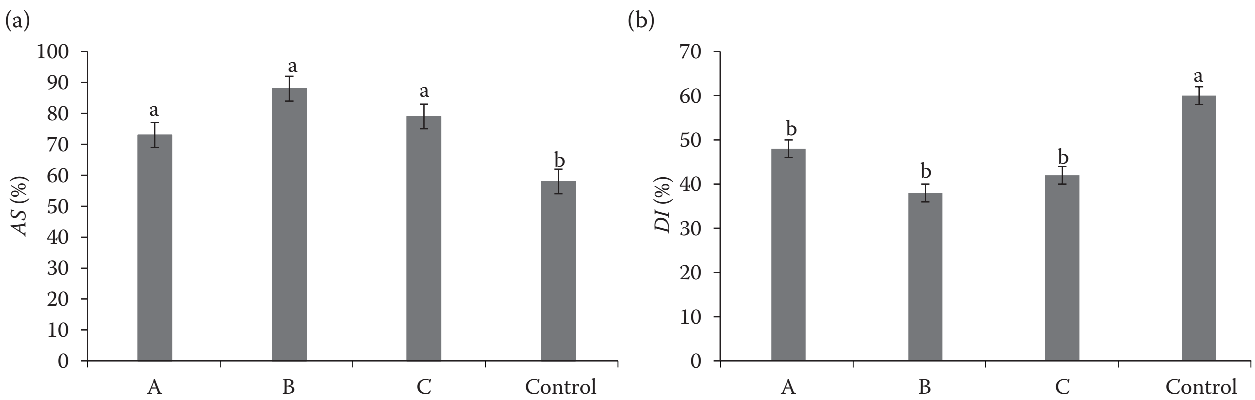


Fig. 3. Effect of treatments on aggregate (a) stability index (*AS*), (b) destruction index (*DI*); different letters shows significant difference at probability level of 5% based on SNK test

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and 3 g·m$^{-2}$ Polyacrylamide tackifier) was better than other treatments in decreasing the percentage of destruction aggregate.

## COCLUSIONS

The main objective of the study was to test the soil stabilization performance of selected treatments compared to the bare soil control in terms of aggregate stability of soil. Results confirmed the efficiency of straw mulch in conjunction with Polyacrylamide to increase soil stability. In current study, the most efficient treatment with respect to *MWD*, *AS* and *DI* was treatment of 150 g·m$^{-2}$ wheat straw mulch and 3 g·m$^{-2}$ Polyacrylamide tackifier. Wheat straw can be used in erosion control as mulch. Straw mulch is inexpensive and easier to spread by hand or machine. Straw provides a high degree of cover to reduce the impact of raindrops and prevent soil particle detachment. Besides, Polyacrylamide increased and preserved surface aggregate structure, with reduced surface crusting, increased infiltration and decreased runoff volume.

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