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EVVALUATING EFFICIENCY OF VETIVER GRASS (VETIVERIA ZIZANIOIDES L. NASH) IN COMBATING WATER SOIL EROSION HAZARDS UNDER EGYPTIAN ENVIRONMENTAL CONDITIONS

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ABSTRACT

Hazards of soil erosion by rainfall are serious problems in Northwestern coast of Egypt (NWCZ) and lead to reducing the soil quality and increasing the degradation of soil resources. The present study includes field experiments for a one-year during the winter season of 2019/2020 in Wadi El-Raml area in the Northwestern Coast zone, NWCZ. The total treatments are as follow: Control without cultivation (C), barley without mulch cover (B), barley with mulch cover of rice straw of 0.5t.fed^{-1} (BM0.5), barley with mulch cover of rice straw of 1t.fed^{-1} (BM1), vetiver grass without mulch cover (V), vetiver grass with mulch cover of rice straw of 0.5t.fed^{-1} (VM0.5), vetiver grass with mulch cover of rice straw of 1t.fed^{-1} (VM1), Strip cultivation (vetiver grass – barley) (SVB), and Strip cultivation (barley - vetiver grass) (SBV), Six storms are effective during the study period as they caused runoff and consequently soil loss, The decrement percent runoff for different treatments varied from 31 to 72%. The runoff coefficient approaches 5.1, 3.5, 2.7, 2.3, 1.8, 1.5, 1.4, 1.9 and 2.2 % for (C), (B), (BM0.5), (BM1), (V), (VM0.5), (VM1), (SVB) and (SBV) treatments, respectively. The highest decrement is evident with the treatments cultivated by vetiver grass as

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compared to that cultivated by barley crop. The average reduction efficiency for soil loss due to cultivation by barley and vetiver grass on the sloping soil ranged from 43 to 57% and from 65 to 81%, respectively, compared with bare soil treatment. The soil loss ratio approaches 0.57, 0.48, 0.43, 0.35, 0.33, 0.29, 0.36 and 0.39 for (B), (BM0.5), (BM1), (V), (VM0.5), (VM1), (SVB) and (SBV) treatments, respectively. Fresh dry matter of Indian vetiver grass is 6.66t.ha^{-1}. The percentage increment of vetiver grass fresh dry matter was greater than the percentage increment of barley biological yield.

In conclusion, the results suggested that vetiver grass is a promising feed resource for soil protection from water erosion hazards, and as well as, feeding animals under environmental conditions of Northwestern Coast of Egypt.

Keywords: Vetiver grass, land degradation, water erosion, soil loss, runoff, North Western Coast zone of Egypt.

INTRODUCTION

Dry areas cover 41% of the world‘s land surface. Egypt is one of the countries which lie in the arid zones, characterized by dry climate in most of its regions. The Northwestern Coast zone (NWCZ) is one of the most attractive desert regions for sustainable agrarian development due to its abundant qualifications which have not sufficiently used yet. The rainfed agriculture area in the NWCZ of Egypt is about 350.7thousand Faddan. There are 218 wadis with their watersheds and sub-watersheds in The Northwestern Coast zone NWCZ. Hazards of soil erosion by rainfall are serious problems in The Northwestern Coast zone NWCZ and lead to reducing the soil quality and increasing the degradation of soil resources (El-Bastwasy, 2008). Abdel-Kader (2000) showed that the cultivation of cereal crops was abounded on the wadis sides, where water runoff was abounded. Sharkawy (2014) stated that soil slopes of the wadi sides cultivated with cereal crops, which may sometimes up to 10%, suffers from the hazards of water erosion. It is very difficult for humans to control the causes of precipitation, but harmful effects of rainfall can be reduced by the proper management of soil and crops (Tadesse *et al.,* 2017). Wassif *et al*. (2013) showed that runoff yield and soil loss were increased by increasing the slop steepness at some wadis.

Protection of slopes and embankment from erosion has become an important issue in world. Plantation of vetiver system along the slopes is an alternative solution. Vetiver grass (Vetiveria. Zizanioides L. Nash) is a perennial grass of the family Poaceae, which is originated from Southeastern Asia, India and tropical Africa. In mid-eighties vetiver grass was developed by the World Bank for soil and water conservation in India (Akhzari *et al.*, 2013). there are more than 100 countries cultivating and using vetiver Some studies (Lavania, 2003) assed the potential utilize of vetiver grass as commercially herbage for produce the scented oil that can be distilled from its roots. Other studies emphasized its effectiveness in erosion, sediment control, and to be highly tolerant to extreme soil conditions (Balasankar *et al*., 2013). Vetiver grass may also be a promising feed resource because it has various advantages such as high quality, fast growth rate and easy adaptation to the environment and can bear repetitive mowing without occupying farming land (Ahmadi Beni *et al*., 2014). Vetiver systems are more profitable than both engineering structures and other vegetative barriers. Oshunsanya (2013) and Mohamed *et al*. (2013) showed that vetiver grass to be very successful in reducing flood velocity and limiting soil movement. Therefore, this study is aimed at evaluating the plantation of the vetiver grass system as a new plant along the slopes under rainfed agriculture and its effect on soil surface protection against water erosion hazards, relative to the traditional technique. Increase the areas cultivated by the new plant (vetiver plant) as a fodder crop for animal consumption and its ability to bear adverse effects of soil moisture stress during the critical period of the dry season.

MATERIALS AND METHODS

The present study includes field experiments for a one-year during winter season of 2019/2020 in Wadi El-Raml, The Northwestern Coast zone NWCZ, to evaluate efficiency of vetiver grass in combating water erosion hazards. Wadi El-Raml is located south-west of Mersa Matrouh. The slope of soil surface is 7% in south- north direction, which determined by abney level instrument through taking the soil surface elevation every 5m from the middle of each site. Location map of the study area is shown in Figure (1). The amount and intensity for each storm of rain during the study period is measured with an automatic rain gauge**.**

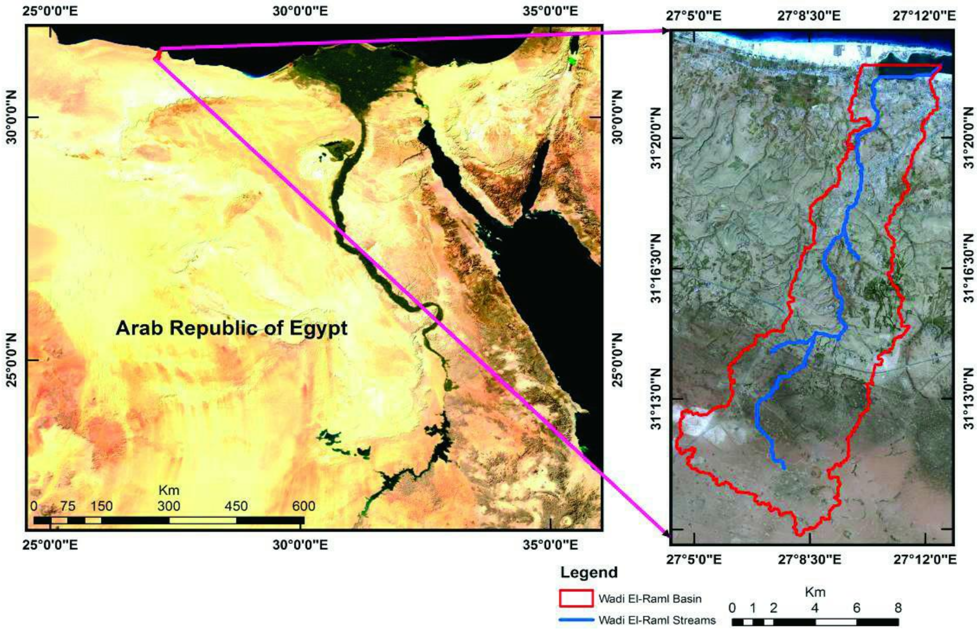

Figure (1): Location map of the study area at Wadi EL-Raml, NWCZ of Egypt.

Surface soil samples (0 - 30cm) were randomly taken. Particle size distribution using the pipette method, soil reaction (pH), electrical conductivity (EC), organic matter (OM), cation exchange capacity (CEC), calcium carbonates ($CaCO_3$), total nitrogen (TN), available phosphors (AV.P) and exchangeable potassium (Ex.K) were determined according to Page *et al.* (1982) and Klute (1986). Soil bulk density and soil moisture were measured by a core sample according to Klute (1986) method.

The field experiment was prepared by removing weeds and plowing them with a chisel plow, and then dividing the field experiment into experimental plots for cultivation vetiver grass and barley crop. A plot of soil with an area of approximately 1600 m^2 was prepared for achieving the field experiment. Chisel plow was attached to the tractor to operate soil tillage before sowing seeds in the experimentally area, Biswas and Mukherjee (2005). The field experiment was divided into experimental plots with dimensions (2m x 24m) and the slope was 7% according to Hudson (1993). Each plot was surrounded by a wall of soil with a height of approximately 25 cm, and each plot was separated from the other by a distance of approximately 30 cm to determine the soil loss resulting from surface runoff.

The experimental treatments were cultivated by barley crop and vetiver grass during the winter seasons of 2019/2020. The vetiver grass and barley crop are cultivated on 30/8/2019 and 15/11/2019, respectively. Barley seeds (Hordieum vulgar L.c.v. Saharawy, H, 100) were cultivated by broadcasting after carry out the tillage operation for the total experimental area at a rate of 50kg.fed^{-1}. However, vetiver offsets (20cm long) is cultivated on a ridge perpendicular on the slope direction. Both barley and vetiver grass treatments is fertilized with rate of 100kg of organic fertilizer (chicken manure). The planting was done on a single row at spacing of 40cm between plants. The space between rows is 50cm. This spacing is within the recommended range for single row spacing of vetiver grass (National Research Council, 1993;

Chomchalow, 2010). To ensure the quicker establishment of the vetiver grass seedlings, they were irrigated from the time they were planted up to the time the rains came in November 2019. The management practices are stripe cropping and cultivation with or without mulch. The ratio between cultivated area by barley crop and vetiver grass at the strip cropping was 1:1. After cultivation, add the rice straw as a mulch with the rate of 1 – 0.5 ton / fed with distribution regularly within the plots.

At the end of each experimental plot (i.e., down-slope edge) Gerlach trough, Morgan (2005), (i.e. A box of galvanized sheet with dimensions of 50 cm in length, 20 cm in width and 10 cm in height with a movable cover) is placed under the soil surface and connected with an outlet pipe that connected with a plastic jerry to collect the surface runoff and eroded soil particles to determine it after each rainstorm. These containers are taken and left for a while to deposit solid materials in them and separate those from the runoff water. Then, the eroded soil materials are placed in oven to dry it at a temperature of 105°C for 24 hours and are measured. Runoff and associated soil loss for every effective rainstorm were determined volumetrically for the supernatants and gravimetrically for soil loss after dried it on 105ºC.

The treatments tested for rehabilitation techniques of degraded soil by water erosion resulting from rainfall using some plants in sloping soil of Northwestern Coast zone of Egypt are twenty seven plots, Figure (2). Each treatment was replicated 3 times. The total treatments are as follow: Control without cultivation (C), barley without mulch cover (B), barley with mulch cover of rice straw of 0.5t.fed^{-1} (BM0.5)**,**barley with mulch cover of rice straw of 1t/fed (BM1)**,**vetiver grass without mulch cover (V),vetiver grass with mulch cover of rice straw of 0.5t.fed^{-1} (VM0.5)**,**vetiver grass with mulch cover of rice straw of 1t.fed^{-1} (VM1)**,** Strip cultivation (vetiver grass – barley) (SVB),where vetiver grass and barley are cultivated at the top and down-slope, respectively and Strip cultivation (barley - vetiver grass) (SBV), where barley and vetiver grass are cultivated at the top and down-slope, respectively.

Barley and vetiver grass plants are harvested on first May 2020 after end winter season 2019/2020. The biological, straw and grain yields of barley crop were recorded for each plot. Concerning, vetiver grass yield, hand harvesting is performed on shoots of 5 plants from each plot, represented one meter square, after clipped at 10 cm with random above the soil surface. Whole plant except roots is washed gently in water. Then samples are dried at 50°C for 48h using a forced air oven to determine fresh weight (t.ha^{-1}).

RESULTS AND DISCUSSION

Soil Characteristics of the Study Area:

It is clear that the soil of Wadi El-Raml is sandy loam in texture and calcareous, where $CaCO_3$ content vary between 9.95 to 11.47% for different soil layers, **Table (1)**. The average bulk density is 1.4g.cm^{-3}, approximately, for all soil layers. In addition, the data indicate that the soil is non-saline, where its electrical conductivity ranged between 0.85 and 1.14ds.m^{-1} for different soil layers. The CEC values vary from 13.70 to 15.1cmol.kg^{-1} for different soil layers. The soil is poor in organic matter, where its values varied from 0.15 to 0.22% for different soil layers. The values of total nitrogen, available phosphorous and exchangeable potassium are very low, where its values varied from 0.02 to 0.05, 0.7 to 0.81 and from 0.4 to 0.55, respectively. Therefore, the soil of the experimental site at Wadi El-Raml is shallow, sandy loam in texture, calcareous, non-saline, poor in organic matter and low in fertility. Therefore, conserving these soils from water erosion hazards is very important challenge to combat the soil degradation. Among these techniques, the use of cover plants for better soil surface protection stands out, according to Castro *et al.* (2011).

Precipitation Events Characterizes:

The total annual precipitation during the study period for the winter season 2019 / 2020 was 168.5mm, Table (2). The data show that eight rainy days during winter season of 2019 / 2020 are evident at Wadi El-Raml, Northwestern Coast zone of Egypt. The rainy day is defined by Climatological Normals for Arab Republic of Egypt (1979) as when the rainfall is ≥ lmm. However, a rainy storm is defined as when the rainfall is ≥l0mm, according to Hudson (1996). Meanwhile, an effective storm is defined as when causes runoff and consequently soil loss. Six storms are effective during the study period as they caused runoff and consequently soil

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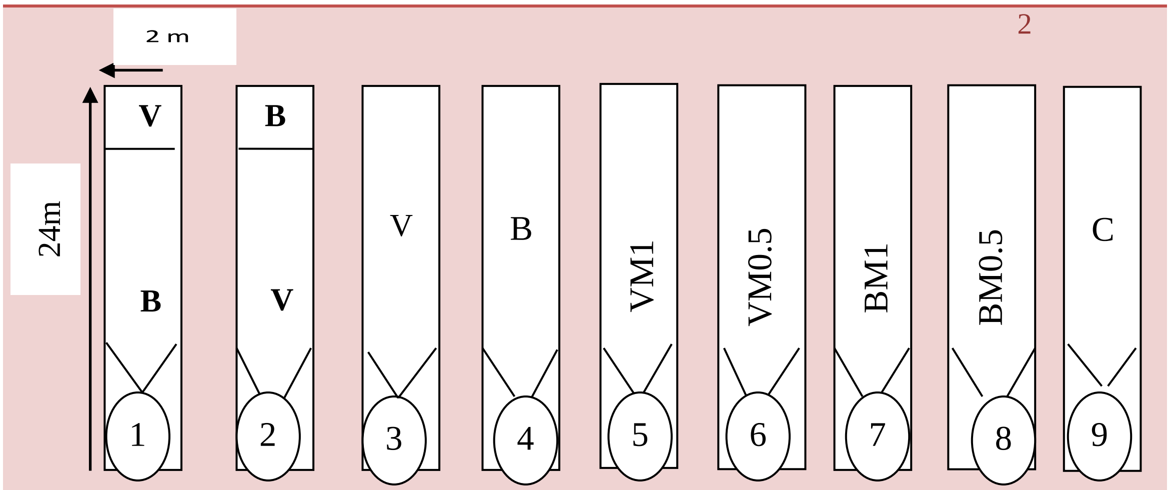
loss, as the depth of rain was greater than 10 mm and the intensity greater than 2.43mm.hr^{-1}. The highest rainfall events occurred on 22 March 2020, when 50mm of rainfall is recorded, followed by 27 March (30mm), 5 January (20.4mm), 13 March (19.4mm), 17 February (18.2mm), and 10 December (15.3mm), respectively. Rainfall intensities of the effective storms varied between 2.43 and 6.10mm.hr-1 during the study periods. The total depth of precipitation for the six storms was 153.3 mm and represented about 80% of the total precipitation that fell in the winter season 2019/2020



1. Strip cultivation (vetiver grass – barley) **(SVB),** where vetiver grass and barley are cultivated at the top and down-slope, respectively.
2. Strip cultivation (barley - vetiver grass) **(SBV),** where barley and vetiver grass are cultivated at the top and down-slope, respectively.
3. Vetiver grass without mulch cover **(V),**
4. Barley without mulch cover **(B),**
5. Vetiver grass with mulch cover of rice straw of 1t/fed **(VM1),**
6. Vetiver grass with mulch cover of rice straw of 0.5t/fed **(VM0.5),**
7. Barley with mulch cover of rice straw of 1t/fed **(BM1),**
8. Barley with mulch cover of rice straw of 0.5t/fed **(BM0.5),**
9. Control without cultivation **(C),**

Figure (2): Experimental layout showing the arrangement of the treatments at the experimental field, Wadi El-Raml, NWCZ of Egypt.

Table (1): Some physical and chemical properties of the studied soil at wadi El-Raml area, NWCZ of Egypt.

(A): Physical Properties.							
Soil depth (cm)	**Bulk density ($g.cm^{-3}$)**	**$CaCO_3$ (%)**	**Particle size distribution (%)**				**Texture class**
			clay	**silt**	**Fine sand**	**Coarse sand**	
0 - 20	1.32	9.95	16.85	11.80	67.90	3.45	Sandy loam
20 - 40	1.37	10.53	17.01	11.23	67.15	4.61	Sandy loam
40 -60	1.49	11.47	17.85	12.05	65.10	5.00	Sandy loam

(B): Chemical Properties.							
Soil depth (cm)	**pH**	**EC ($ds.m^{-1}$)**	**OM (%)**	**CEC ($cmol.kg^{-1}$)**	**Nutrient content**		
					T.N (%)	**AV.P (ppm)**	**AV.K (cmol. kg)**
0 - 20	7.85	1.14	0.22	15.10	0.05	0.70	0.55
20 - 40	7.42	0.85	0.20	14.80	0.03	0.81	0.40
40 -60	7.66	1.12	0.15	13.70	0.02	0.79	0.48

Table (2): Distribution of rainfall during the winter Season (2019 / 2020) at Wadi El-Raml area, NWCZ of Egypt.

Rainstorm Date	Rainfall Amount (mm)	Duration (Hrs.)	Rainfall Intensity ($mm.h^{-1}$)
20 Nov. 2019	8.8	4.4	2.00
10 Dec. 2019	15.3	6.3	2.43
25 Dec. 2019	6.4	5.2	1.23
5 Jan. 2020	20.4	3.4	6.00
17 Feb. 2020	18.2	7.1	2.56
13 Mar. 2020	19.4	3.2	6.10
22 Mar. 2020	50.0	10.2	4.90
27 Mar. 2020	30.0	8.4	3.60
Total	168.5		

Runoff Yield:

The runoff yield was increased by increasing the amount of rainfall as shown in Table (3). Data show that the highest surface water runoff for all the studied treatments is occurred with the rainstorm date of 22 March 2020, where the amount of rainfall is reached to 50mm. The total annual amount runoff yield from control treatment (Bare soil without cultivation) reached 7.83mm.Under all storms, it is clear that runoff values associated with bare soil was higher compared to planting treatment. The lowest total annual amount runoff yield was recorded for vetiver grass with mulch cover of 1t/fed (VM1) treatment, where its value reached to 2.2mm. The annual amount runoff is reduced to 31, 47, 55, 64, 70, 72, 63 and 57% for barley without

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mulch cover (B), barley with mulch cover of rice straw of 0.5t/fed (BM0.5), barley with mulch cover of rice straw of 1t/fed (BM1), vetiver grass without mulch cover (V), vetiver grass with mulch cover of rice straw of 0.5t/fed (VM0.5), vetiver grass with mulch cover of rice straw of 1t/fed (VM1), strip cultivation (vetiver grass – barley) (SVB), and strip cultivation (barley - vetiver grass) (SBV) , respectively, as compared with bare soil. Therefore, the decrement percent runoff for different treatments varied from 31 to 72%. The highest decrement is evident with the treatments cultivated by vetiver grass as compared to that cultivated by barley crop. Similar results were obtained by khan *et al.* (1988), FAO (1993) and Zuzel and Pikwl (1993), they reported that canopy straw mulch reduced runoff erosion and protects soil against degradation.

Table (3): Amount runoff (mm) under both barely and vetiver grass at Wadi-El-Raml, Northwestern Coast zone of Egypt.

Rainstorm Date	**Rainfall amount (mm)**	**Control (Bare soil) (C)**	**Barley (B)**	**Barley with mulch cover of 0.5t/fed (BM0.5)**	**Barley with mulch cover of 1t/fed (BM1)**	**Vetiver grass (V)**	**Vetiver grass with mulch cover of 0.5t/fed (VM0.5)**	**Vetiver grass with mulch cover of 1t/fed (VM1)**	**Strip cultivation (vetiver grass – barley) (SVB)**	**Strip cultivation (barley - vetiver grass) (SBV)**
	Surface water runoff (mm)									
10 Dec. 2019	15.3	0.80	0.55	0.48	0.42	0.35	0.30	0.20	0.30	0.42
5 Jan. 2020	20.4	0.90	0.65	0.50	0.44	0.42	0.37	0.34	0.46	0.52
17 Feb. 2020	18.2	0.75	0.60	0.51	0.42	0.48	0.39	0.33	0.40	0.45
13 Mar. 2020	19.4	0.88	0.62	0.56	0.48	0.45	0.40	0.34	0.52	0.55
22 Mar. 2020	50.0	2.50	1.50	1.20	0.90	0.55	0.45	0.56	0.64	0.78
27 Mar. 2020	30.0	2.00	1.50	0.92	0.85	0.53	0.45	0.43	0.59	0.64
Total	153.3	7.83	5.42	4.17	3.51	2.78	2.36	2.20	2.91	3.36
Runoff Coefficient		0.051	0.035	0.027	0.023	0.018	0.015	0.014	0.019	0.022

According to cover percent with rice straw, the depths of surface runoff are arranged in the following descending order: Bare soil without mulching (C) (7.83mm) > barley without mulch cover (B) (5.42mm) > barley with mulch cover of rice straw of 0.5t.fed^{-1} (BM0.5) (4.17mm) > barley with mulch cover of rice straw of 1t.fed^{-1} (BM1) (3.51mm) > vetiver grass without mulch cover (V) (2.78mm) > vetiver grass with mulch cover of rice straw of 0.5t/fed (VM0.5) (2.36) > vetiver grass with mulch cover of rice straw of 1t/fed (VM1) (2.20mm), respectively, Table (3). The average reduction in surface water runoff due to applied mulching of rice straw at rate of 0.5 and 1t.fed^{-1}, regardless type of plant, is 19 and 28%, respectively, as compared to the treatments cultivated without mulch.

Therefore, mulching treatments with respect to the reduction of surface runoff depth is arranged in the following descending order: mulch cover of rice straw of 1t.fed^{-1}> mulch cover of rice straw of 0.5t.fed^{-1}> without mulching, respectively. Stewart and Moldenhauer (1994) stated that the principle for controlling water erosion include minimizing the impact of raindrops on the soil surface, increasing infiltration rate, and minimizing the distance that surface water can travel. This is achieved with mulching soil surface. Meyer *et al*. (1970) obtained similar results; they mentioned that the application of 0.56metric t.ha^{-1} mulch decreased soil erosion to one third of that from un-mulched treatment. The major effects of mulching in protecting soil erosion are: the interception of rainfall by absorbing the energy of raindrops and thus reducing surface sealing and runoff, the retardation of erosion by decreased surface flow velocity and the physical restraint of soil movement (Coppin and Richards, 1990; Jepsen *et al.*, 1997).

According to type of vegetation cover, the surface runoff are arranged in the following descending order: barley (B) (5.42mm) > barley with mulch cover of rice straw of 0.5t/fed (BM0.5) (4.17mm) > barley with mulch cover of rice straw of 1t/fed (BM1) (3.51mm) > vetiver grass without mulch cover (V) (2.78mm) > vetiver grass with mulch cover of rice straw of 0.5t/fed (VM0.5) (2.36) > vetiver grass with mulch cover of rice straw of 1t/fed (VM1) (2.20mm) respectively, Table (3). The average reduction in surface runoff for vetiver grass without mulch cover (V), vetiver grass with mulch cover of rice straw of 0.5t/fed (VM0.5) and vetiver grass with mulch cover of rice straw of 1t/fed (VM1) is 49, 44 and 38%, respectively, as compared to the treatments cultivated by barley without mulch cover (B), barley with mulch cover of rice straw of 0.5t/fed (BM0.5), barley with mulch cover of rice straw of 1t/fed (BM1). Therefore, type of vegetation cover with respect to the reduction of surface runoff is arranged in the following descending order: vetiver grass plant > barley crop, respectively. Wolde (2015) stated that vetiver systems are known to reduce soil loss to acceptable levels (< 3metric $t.ha^{-1}$) and runoff by as much as 70% depending on slope and soil type. Using mulching cover on the soil surface to protect soil and water losses has been widely applied and recognized as an alternative technology in many developing countries (Bhatt and Khera, 2006; Ramakrishna *et al.*, 2006).

Data in Table (3) reveal that according to type of strip cropping, the depths of surface runoff are arranged in the following descending order: strip cultivation (barley - vetiver grass) (SBV) (3.36mm) > strip cultivation (vetiver grass – barley) (SVB) (2.91mm). The average reduction in surface runoff for strip cultivation treatment (SVB) is 13% as compared to that for strip cultivation treatment (SBV). Therefore, the cultivation of vetiver grass plant on the top-sloping soil is very important to conserve the sloping soil from water erosion hazards. A vetiver grass hedge is a bioengineering method to control soil erosion and conserve runoff, which in recent years has proven to be successful in conserving natural resources in over 120 countries because vetiver has many characteristics that can perform this task much better and more cheaply than others (Truong, 2002).

The runoff coefficient, i.e. how much of the rainfall run over the soil surface, approaches 5.1, 3.5, 2.7, 2.3, 1.8, 1.5, 1.4, 1.9 and 2.2 % for approximately for control without cultivation (C), barley without mulch cover (B), barley with mulch cover of rice straw of 0.5t/fed (BM0.5), barley with mulch cover of rice straw of 1t.fed^{-1} (BM1), vetiver grass without mulch cover (V), Vetiver grass with mulch cover of rice straw of 0.5t.fed^{-1} (VM0.5), vetiver grass with mulch cover of rice straw of 1t.fed^{-1} (VM1), strip cultivation (vetiver grass – barley) (SVB), and strip cultivation (barley -

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vetiver grass) (SBV), respectively, Table (3). This finding is agreement with Ali *et al*. (2004); he mentioned that under the conditions of NWCZ the runoff coefficient of 3-5% seem reasonable.

Soil Loss:

The influence of the applied planting treatments with barley and vetiver grass on the amount of soil loss under natural rainfall intensities is given in **Table (4).** The soil loss was increased with increasing the amount of rainfall. The highest soil loss for all the studied treatments is obtained from rain storm No. 5 (22 March 2020), where its amount reached 50.0mm. The annual soil loss is 6.16, 3.51, 2.97, 2.65, 2.19, 2.03, 1.79, 2.23 and 2.43t.ha^{-1}, for bare soil (control treatment), barley without mulch cover (B), barley with mulch cover of rice straw of 0.5t.fed^{-1} (BM0.5), barley with mulch cover of rice straw of 1t.fed^{-1} (BM1), vetiver grass without mulch cover (V), vetiver grass with mulch cover of rice straw of 0.5t.fed^{-1} (VM0.5), vetiver grass with mulch cover of rice straw of 1t.fed^{-1} (VM1), strip cultivation (vetiver grass – barley) (SVB), and strip cultivation (barley - vetiver grass) (SBV) treatments, respectively.

With respect to planting with barley, it is clear that the annual amount of soil loss reduced by 43, 52 and 57 %, for barley without mulch cover (B), barley with mulch cover of rice straw of 0.5t.fed^{-1} (BM0.5), barley with mulch cover of rice straw of 1t.fed^{-1} (BM1) treatments, respectively, as compared to that for bare soil (control) treatment, Table (4). While, for the cultivation with vetiver grass, the decrement percentage in the annual soil loss reached to 65, 67 and 81% for vetiver grass without mulch cover (V), vetiver grass with mulch cover of rice straw of 0.5t.fed^{-1}(VM0.5), vetiver grass with mulch cover of rice straw of 1t.fed^{-1} (VM1), respectively, as compared to that for bare soil (control) treatment. From the preceding data, the average reduction efficiency for soil loss due to cultivation by barley and vetiver grass on the sloping soil ranged from 43 to 57% and from 65 to 81%, respectively, compared with bare soil treatment. Consequently, cultivation of vetiver grass especially on sloping soils will help in avoid water erosion hazards and habitat the degraded soil by action of water erosion. This behavior could be attributed to the fact that plant sheets cover a portion of the soil surface from the energy of rainfall impact, thereby soil detachment decreased. Growing plants also create obstructions to water erosion to water flow over land, slowing down runoff velocity and consequently its carrying capacity and thus reducing soil loss. Similar results were obtained by Gumbs and Lindsay (1982).

Data in Table (4) show that the decrement percentage in the annual soil loss from mulch treatments is 15 and 24% for barley with mulch cover of rice straw of 0.5t.fed^{-1} (BM0.5) and barley with mulch cover of rice straw of 1t.fed^{-1} (BM1) treatments, respectively, as compared to that for barley without mulch cover (B). Also, under cultivation of vetiver grass with mulch of rice straw of rate of 0.5 and 1t.fed^{-1}, the decrement percentage in soil loss reached to 7 and 18%, respectively, as compared to that for soil cultivated by vetiver grass without mulch. In reducing soil erosion, the indirect effects by mulching reduced both soil erodibility and kinetic energy of raindrops. Consequently, planting with soil mulching by cover of rice straw at the rate of 1t.fed^{-1} is better than 0.5t.fed^{-1}, and both of two rates will reduces wash erosion on the average of 11 and 21%, respectively, regardless the type of vegetative cover. Ali *et al.* (2004) reported that the indirect effects by natural vegetation or gravels reduced both soil erodibility and kinetic energy of raindrops. Govers and Poesen (1988) observed the positive effect of 0.250 and 1.12metric t.ha^{-1} soil mulch on reducing soil loss for all particle classes

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Table (4): Soil loss under both barely and vetiver grass at Wadi El-Raml, Northwestern Coast zone of Egypt.

Rainstorm Date	Rainfall amount (mm)	Control (Bare soil) (C)	Barley (B)	Barley with mulch cover of 0.5t/fed (BM05)	Barley with mulch cover of 1t/fed (BM1)	Vetiver grass (V)	Vetiver grass with mulch cover of 0.5t/fed (VM05)	Vetiver grass with mulch cover of 1t/fed (VM1)	Strip cultivation (vetiver grass – barley) (SVB)	Strip cultivation (barley - vetiver grass) (SBV)
		Soil loss (t.ha^{-1})								
10 Dec. 2019	15.3	0.53	0.32	0.30	0.27	0.21	0.16	0.14	0.23	0.24
5 Jan. 2020	20.4	0.75	0.48	0.38	0.36	0.30	0.28	0.24	0.29	0.31
17 Feb. 2020	18.2	0.66	0.44	0.35	0.32	0.27	0.24	0.19	0.29	0.31
13 Mar. 2020	19.4	0.70	0.40	0.36	0.33	0.27	0.25	0.20	0.28	0.31
22 Mar. 2020	50.0	1.98	0.98	0.91	0.77	0.64	0.61	0.58	0.61	0.71
27 Mar. 2020	30.0	1.54	0.88	0.66	0.60	0.51	0.48	0.43	0.53	0.55
Total	153.3	6.16	3.51	2.97	2.65	2.19	2.03	1.79	2.23	2.43
Soil loss ratio			0.57	0.48	0.43	0.35	0.33	0.29	0.36	0.39

The rates of soil loss resulted from strip cultivation (vetiver grass – barley) (SVB) and strip cultivation (barley - vetiver grass) (SBV) treatments is 2.43 and 2.23t.ha^{-1}, respectively. As shown in **Table (4)**, the decrement percentage of soil loss is 64 and 61% for strip cultivation (vetiver grass – barley) (SVB), and strip cultivation (barley - vetiver grass) (SBV) treatments, respectively, compare to bare soil treatment. Therefore, cultivation of vetiver with barley in strip cropping system on sloping soil led to decrease average annual soil loss by 63% approximately. In this respect, **Sharkawy (2014)** concluded that the use of conservation techniques and rainwater harvesting practices led to reduce the amount of runoff and soil loss with retain or conserve the utmost amount of rainwater in the soil, which is reflected on the productivity of wheat crop.

The soil loss ratio, i.e., amount of soil loss from conservation treatment divided by its value from bare soil (control treatment), approaches 0.57, 0.48, 0.43, 0.35, 0.33, 0.29, 0.36 and 0.39 for barley without mulch cover (B), barley with mulch cover of rice straw of 0.5t/fed (BM0.5), barley with mulch cover of rice straw of $1t.fed^{-1}$ (BM1), vetiver grass without mulch cover (V), vetiver grass with mulch cover of rice straw of $0.5t.fed^{-1}$ (VM0.5), vetiver grass with mulch cover of rice straw of $1t.fed^{-1}$ (VM1), strip cultivation (vetiver grass – barley) (SVB), and strip cultivation (barley-vetiver grass) (SBV), respectively, Table (4). Truong (2002) reported that surface runoff and soil loss from fields treated with vetiver grass were significantly lower and crop yield was much improved. Rao *et al.* (1992) stated that relative to control plots, average reductions of 69% in runoff and 76% in soil loss were recorded from vetiver plots. Despite that, the Vetiver grass and the barley plant can be used as a barrier against surface run-off and soil loss. However, it is recommended to use the vetiver grass and the using strip cultivation and mulching treatment 1t.fed^{-1} is the most suitable for soil preservation and water and reduce rate of soil degradation. According to Chong and Chu (2007) and Mickovski and Van Beek (2009), the use of vetiver grass is recommended for the control of soil erosion due to the following reasons: it forms a living and dense plant barrier that retains sediment and reduces the potential energy of surface runoff; it is highly adaptable to different soil and weather conditions; and it has a penetrating root system able to withstand fissures in soil structures. Among the physical qualities of soil, soil resistance to penetration (RP) is the one that roots actually encounter.

Yield:

Values of grains and straw yields, as well as the biological yield, of barley are given in Table (5). It is clear that straw, grain and biological yields significantly increased due to mulch cover rate increasing. Maximum biological yield is achieved with the application of one tone of rice straw as a mulch cover per feddan as mulch; its value is 8.57t.ha^{-1}. The average biological yield of barley at winter season 2019/2020 was 5.95, 6.66 and 8.57t ha^{-1} for barley (B) barley with mulch cover of 0.5t.fed^{-1} (BM0.5) barley with mulch cover of 1t.fed^{-1} (BM1), respectively. Mulch cover with barley plant at rate of 0.5 and 1t.fed^{-1} increase biological yield of barley by12% and 44%, respectively, as compared to that for the barley plants cultivated without addition of mulch cover. Therefore, the applications of mulch cover from rice straw on the soil surface at all rates of application significantly increase the barley grain, straw and consequently, biological yield. It is interesting to note that, rice straw (1t.fed^{-1}) which has been shown to conserve moisture as a result of higher soil moisture storage, organic content and reduce evaporative loss under drought conditions of NWCZ, where intermittent long dry spells are mostly common were associated with higher biological yield of barley crops. This will undoubtedly influence crop growth and ultimate yield. Wassif *et al*. (2014) stated that using conservation agriculture systems for 2-year, especially zero tillage with 50% soil covering by rice straw and 10m^3 of Farm Yard manure (FYM) for cultivation wheat or barely under rainfed agriculture contributed to increase the biological yield as result of its impact on enhancing soil quality, conserve soil water and increasing soil fertility.

Table (5) show that the fresh matter of Indian vetiver grass (conventional cultivation without adding rice straw as mulch cover) is 2.8t.fed^{-1} under Egyptian environmental conditions. Figure (7) indicate that the mulch cover with Indian vetiver grass plant at rate of 0.5 and 1t.fed^{-1} increase fresh matter yield of Indian vetiver grass by 14 % and 61%, respectively, as compared to that for the barley Indian vetiver grass plant cultivated without addition of mulch cover. Hammam *et al.* (2019) stated that the 38,000 plants per fed treatment should be used as it translates to higher yield and more protection for the soil. EL Shereef and Shehata (2020) illustrated that Vetiver grass is planted at Middle Sinai research station (El-Maghara) and produced 2.14t.fed^{-1}.

Table (5): Yield of both barely and vetiver grass at Wadi El-Raml, Northwestern Coast zone of Egypt, as affected by treatments.

TREATMENTS	GRAIN	STRAW	BIOLOGICAL YIELD	FRESH MATTER
	t.ha^{-1}			
Barley (B)	0.36	5.59	5.95	….
Barley with mulch cover of 0.5t.fed^{-1} (BM0.5)	0.60	6.07	6.66	….
Barley with mulch cover of 1t.fed^{-1} (BM1)	0.84	7.72	8.57	….
Vetiver grass (V)	……	……	….	6.66
Vetiver grass with mulch cover of 0.5t.fed^{-1} (VM0.5)	……	……	…..	7.62
Vetiver grass with mulch cover of 1t.fed^{-1} (VM1)	…….	….	…..	10.71

From another point, data in Table (5) illustrated that the percentage increment of vetiver grass fresh matter was greater than the percentage increment of barley biological yield. Therefore, adding rice straw as mulch cover at different rates, especially 1t.fed^{-1}, with cultivation at different sites along the NWCZ of Egypt is needed to confirm these results and encourage the farmers to cultivate their soils to fill the food gap and achieve food security.

In conclusion, the results suggested that vetiver grass is a promising resource for soil protection from water erosion hazards, and as well as, feeding animals under environmental conditions of Northwestern Coast of Egypt.

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تقييم كفاءة نبات نجيل الهند فى مجابهة مخاطر انجراف التربة بالماء تحت الظروف البيئية المصرية

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المستخلص

تضمنت الدراسة الحالية تجارب حقلية لمدة عام واحد خلال فصل الشتاء ٢٠٢٠/٢٠١٩ في منطقة وادي الرمل بمنطقة الساحل الشمالي الغربي. كانت المعاملات كما يلي: التحكم بدون زراعة (C) ، الشعير بدون تغطية سطح التربة (B) ، الشعير بتغطية سطح التربة من قش الأرز بمقدار ٠,٥ طن / فدان (BM0.5) ، الشعير بتغطية سطح التربة من قش الأرز بمعدل ١ طن / فدان (BM1) ، نجيل الهند بدون تغطية سطح التربة (V) ، نجيل الهند بتغطية سطح التربة من قش الأرز ٠,٥ طن / فدان (VM0.5) ، عشب نجيل الهند بتغطية سطح التربة من قش الأرز ١ طن / فدان (VM1) ، الزراعة الشرائطية (نجيل الهند–الشعير) (SVB) ، والزراعة الشرائطية (الشعير– نجيل الهند) (SBV). اظهرت الدراسة وجود ست عواصف فعالة خلال فترة الدراسة حيث تسببت في الجريان السطحي وبالتالي فاقد التربة. تراوح معامل الجريان السطحي للمعاملات المختلفة من ٣١ إلى ٧٢٪. بلغ معامل الجريان ٥,١ ، ٣,٥ ، ٢,٧ ، ٢,٣ ، ١,٨ ، ١,٥ ، ١,٤ ، ١,٩ و ٢,٢٪ لمعاملة (C)، (B)، (BM0.5)، (BM1)، (V)، (VM0.5)، (VM1)، (SVB) و (SBV) على التوالي. يتضح مما سبق أن أعلى انخفاض في المعاملات المزروعة تم بواسطة معاملة نبات نجيل الهند مقارنة بتلك المزروعة بمحصول الشعير.

تراوح متوسط كفاءة الحد من فاقد التربة نتيجة زراعة الشعير ونجيل الهند على التربة المنحدرة من ٤٣ إلى ٥٧٪ ومن ٦٥ إلى ٨١٪على التوالي، مقارنة بمعالجة التربة البؤر الغير منزرعة. تراوحت نسبة فاقد التربة حوالى ٠,٥٧ و ٠,٤٨ و ٠,٤٣ و ٠,٣٥ و ٠,٣٣ و ٠,٢٩ و ٠,٣٦ و ٠,٣٩ بالنسبة لمعاملة (B)، (BM0.5)، (BM1)، (V)، (VM0.5)، (VM1)، (SVB) و (SBV) على التوالي. بلغت المادة الطازجة من عشب نجيل الهند ٦,٦ طن/ هكتار، حيث جاءت نسبة الزيادة

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في المادة الجافة الطازجة لعشب نجيل الهند أكبر من النسبة المئوية للزيادة في المحصول البيولوجي للشعير.

نستنتج من النتائج إلى أن نجيل الهند هو مورد واعد لحماية التربة من مخاطر الانجراف بالماء، وكذلك تغذية الحيوانات في ظل الظروف البيئية في الساحل الشمالي الغربي لمصر.

الكلمات المفتاحية: الشعير– نجيل الهند– فاقد التربة– الساحل الشمالى.