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Variations in runoff and erosion under various methods of protection

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ABSTRACT In the present study the author examines how it is possible, with simple methods of protection, to decrease the degree of soil erosion. The experiments were performed on seven 350 m^2 vineyard plots under the stake-support cultivation system. On the first plot there was no anti-erosional protection. On the second and third plots furrows were ploughed perpendicular to the slope at every tenth or fifth row, respectively. On the fourth and fifth plots small ridges were raised at the same distances. The ridges were raised at every row on the sixth plot whereas on the seventh plot individual plate-like depressions were applied. Based on data for three years, the degree of erosion was analysed separately for small magnitude and intensity, as well as large magnitude and intensity precipitation events. The results obtained were elaborated using statistical methods.

INTRODUCTION

We have been concerned for two decades with the so-called accelerated erosion and its adverse effects which arise due to viticulture in the Tokaj region. For about 10 years we have been performing experiments to examine the effects of various methods of cultivation on erosion and how it is possible to decrease, with relatively simple means, the degree of erosion. Our measurements were performed in traditional vineyards cultivated with the so-called stake-support system. This method of cultivation is widespread in this area, and it is this method that promotes the greatest degree of erosion.

Our experiments were performed at Tokaj in vineyards planted on loess with 10° and 18° slope angles. In both cases, plots 7-7.5 m wide and 70 m long (in the upslope direction) were delimited. The plots were separated from one another by ridges, so that no external water could get onto the individual plots. Water running off each plot was intercepted by drain pipes and led to a series of measuring tanks. Three tanks were assigned to each plot. Each tank had a cross section area of 40 x 50 cm, and a height of 56 cm. The first two receiving tanks were fitted with splitters. This meant that in the wall of each tank there were five outlet orifices located at identical heights (50 cm). Thus, identical amounts of water flowed out of the tank through the five orifices. The water flowing out of the first orifice was directed to the second tank (similarly equipped with a splitter) located below. One fifth of the water flowing out from this second tank was directed to the third tank. This series of receiving tanks enabled us to determine, for each plot and for any intensity and magnitude of precipitation, the amount of runoff and of eroded material.

Cultivation of the 350 m^2 plots was performed in various ways. On the first parcel, the traditional stake-support system was applied, and there was no protection against erosion. The traditional method of cultivation was also employed in a further four cases. Water-retaining furrows were ploughed perpendicular to the slope at every tenth and fifth row (plots 2 and 3). On plots 4 and 5, ridges were constructed instead of the furrows. On plot 6 the ridges were constructed for every row, whereas cultivation with individual plate-like depressions was applied on plot 7. Since the formation of the plate-like depressions around the vine-stocks required a great deal of manual work, this latter cultivation type is not discussed in the following analysis.

During the 10 year experimental period the annual erosion was highly variable. The three years 1963, 1964 and 1966 have been used as the most suitable to evaluate erosional behaviour.

THE EFFECTS OF THE MAGNITUDE AND INTENSITY OF PRECIPITATION AND OF SLOPE ANGLE ON EROSION

Our investigations over a period of several years suggest that variations in the amount, and particularly intensity, of precipitation can influence erosion to a decisive extent. Therefore, in the evaluation of the experimental results, small magnitude and intensity and high magnitude and intensity events have been treated separately. The boundary between the two categories was established on the basis of experience. Precipitation was considered to be of large magnitude and high intensity at values above 13 mm and 10 mm h^{-1} respectively. With extended rainfall (lasting for several days) when gentle rain was interrupted for a short time by a shower, precipitation was considered to be of high intensity with values of 5-7 mm h^{-1}.

A similar major influence is exerted on erosion by slope angle. Our experiments showed that there was no significant damage on 10° slopes. On the occasion of the most intense precipitation during the 10 year period (22.8 mm, 14.6 mm h^{-1}) the amount of eroded material was less than 0.6 dm^3. On the other hand, soil erosion was significant on the 18° slopes. During the same event 519 dm^3 of material (14.8 $m^3 ha^{-1}$) was eroded from the traditionally cultivated plot (without protection). This represents erosion of a layer 1.5 mm thick from the surface.

EXPERIMENTAL RESULTS

Our experiments indicated that on the 18° slope, the downslope migration of soil particles began at precipitation amounts as low as 3-4 mm. This did not produce significant erosional damage and there was no instance of furrow formation. After movement of a few cm, the material was deposited due to the unevenness of the surface.

The bottoms of the first collecting tanks were thickly covered by eroded loess, in blanketlike form, which obviously originated from the area directly above the recipient drain pipe. With precipitation amounts above 3-4 mm, the formation of small furrows started. With the traditional stake-support system when there was no anti-erosion protection in the vineyard, the average erosion over the three year period associated with small magnitude and intensity precipitation events was 1.72 dm^3 of loess per event. At the same time the average for runoff was 18.26 dm^3 (Table 1). Thus, the

TABLE 1 Amounts of eroded loess and runoff produced by small magnitude and low intensity precipitation events for various plot treatments. (Measurements were performed on an 18° slope on 350 m^2 plots.)

	Treatment: 1	2	3	4	5	6
Loess, mean ($\bar{x}$) dm^3	1.72	1.40	1.15	1.37	0.91	0.13
Loess, standard deviation (σ)	2.12	2.12	1.73	1.87	1.21	0.27
Water, mean ($\bar{x}$) dm^3	18.26	16.44	16.14	16.85	15.77	12.11
Water, standard deviation (σ)	12.80	11.04	10.03	11.00	10.90	7.30
Correlation coefficient (r)	0.87	0.74	0.79	0.80	0.64	0.51
Values recalculated as $m^3 ha^{-1}$:						
Loess, mean	0.05	0.04	0.03	0.04	0.02	0.003
Water, mean	0.52	0.47	0.46	0.48	0.45	0.35

amount of runoff was 10.6 times as great as the amount of eroded loess. Erosion was markedly decreased by the different methods of protection, mainly as a function of their intensity. There was no marked difference as regards erosion between the furrows ploughed at 10 or 5 row intervals and their counterpart ridges constructed at identical distances, although the ridges retained somewhat larger amounts of material. The decrease in erosion on the plot with ridges constructed row by row was quite marked (0.13 dm^3). Compared with the plot cultivated without soil protection, the decrease in the quantity of eroded material was 13-fold on this plot. On the other hand, it is interesting to note that there was no marked difference in the amount of runoff. Even in the case of ridges constructed row by row, the amount of runoff decreased only by one third compared to the plot without protection. These findings demonstrate that the various protective methods reduce the energy of the runoff and cause deposition, but the water still finds its way to the receiving tanks.

A similar picture is obtained if we examine the dispersion of the measurement data round the mean, i.e. the standard deviation. In the case of eroded loess, there was a gradual decrease in the dispersion of the data with the increase in number of furrows or ridges, whereas for runoff the values of standard deviation decreased only slightly. From this it follows that the correlation between the quantity of eroded loess and the associated runoff gradually gets worse as the treatment intensifies. For the unprotected plot, there was a good correlation between eroded loess and runoff amount ($r = 0.87$). In the case of ridges constructed at intervals of five rows or row by row the correlation can only be regarded as intermediate ($r = 0.6$ and $r = 0.51$, respectively).

With high intensity precipitation, the mean value of the quantity of eroded loess over the three year period was 138.8 dm^3 (Table 2).

TABLE 2 Amounts of eroded loess and runoff produced by large magnitude and high intensity precipitation events for various plot treatments. (Measurements were performed on an 18° slope on 350 m^3 plots.)

	Treatment: 1	2	3	4	5	6
Loess, mean ($\bar{x}$) dm^3	138.8	90.7	58.37	104.05	29.25	2.20
Loess, standard deviation (σ)	213.8	125.3	69.57	183.80	25.06	2.35
Water, mean ($\bar{x}$) dm^3	531.9	318.4	286.3	367.5	149.2	38.6
Water, standard deviation (σ)	817.4	453.9	460.2	621.9	157.7	18.01
Correlation coefficient (r)	0.99	0.91	0.61	0.99	0.95	0.71
Values recalculated as $m^3 ha^{-1}$:						
Loess, mean	3.96	2.59	1.66	2.97	0.85	0.06
Water, mean	15.19	9.09	8.17	10.49	4.26	1.10

The amount of runoff is nearly four times as much. It is interesting to note that this value was 10 times as much with low intensity precipitation. In this case the runoff from small magnitude low intensity rain was unable to induce a more marked degree of erosion. Conversely, with high intensity precipitation the turbulence of the runoff increases its work capacity and this results in greater erosional damage. Again, the amount of eroded material gradually decreased according to the intensity of protection. The decrease was abrupt both for eroded material and runoff for the treatment with ridges constructed row by row. When compared with the data obtained from the vineyard without protection against erosion, only 1.5% of the eroded loess and 7.2% of the runoff was retained in the receiving tanks of the plot with the most intensive protective method. The correlation between eroded loess and runoff is even higher here. In the unprotected vineyard the correlation coefficient was $r = 0.99$. This close correlation persisted,

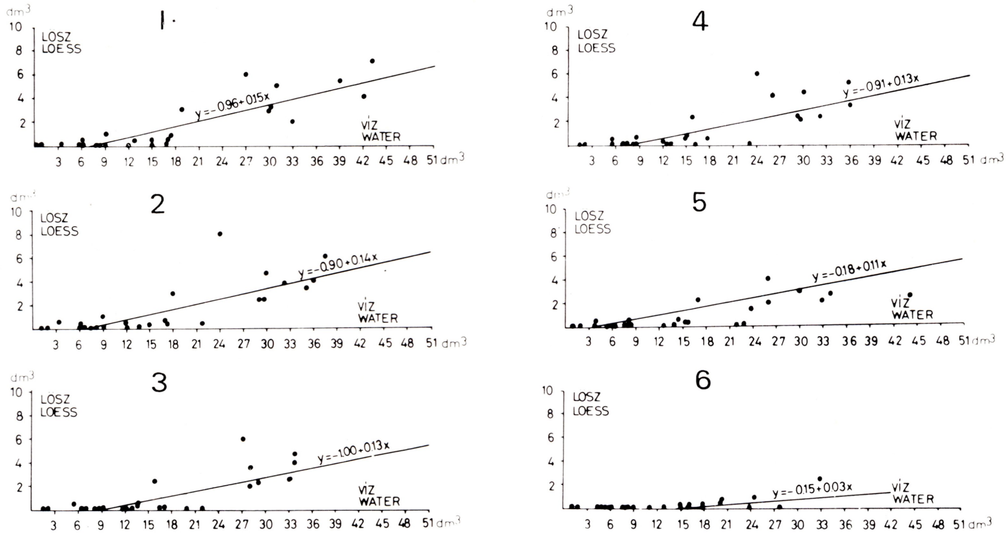

FIG.1 Correlations between the quantity of eroded loess and runoff for precipitation events of small magnitude and low intensity. Numbers refer to plot treatments.

although to a somewhat weaker degree, throughout the various methods of protection (Table 2).

Relationships between the quantity and intensity of precipitation and the amounts of eroded loess and runoff were also examined. Here too, calculations were performed separately for precipitation events of small and large magnitude and low and high intensity. On the unprotected parcels, in the case of small magnitude and low intensity precipitation events, the amount of eroded loess showed a definite correlation with precipitation (r = 0.70). The strength of this correlation changes markedly with the various methods of protection. With the furrows ploughed at 10 or 5 row intervals the value of the correlation coefficient still increases (r = 0.75 and 0.72, respectively). In the case of ridges constructed at five or 10 row intervals the correlation is only intermediate (r = 0.64 and 0.68, respectively), then it continues to reduce in the case of ridges ploughed row by row (r = 0.53).

On the other hand, there is hardly any change in the correlation coefficient for runoff. In every case the correlation between runoff and precipitation is strong (r = 0.78, 0.75, 0.81, 0.75, 0.78, 0.81, 0.78). The calculation of correlation coefficients confirmed our previous statement that the various methods of protection reduce the runoff energy and force it to deposit part of its load. However, the water having deposited part of its load continues to flow, resulting in a weakening correlation between precipitation and eroded loess, even though the correlation with water does not change, and remains strong throughout.

The picture is quite the opposite for high intensity precipitation. In the unprotected vineyard, precipitation did not show any correlation with the quantity of eroded loess (r = 0.06) and runoff (r = 0.08). With the furrows ploughed at five or 10 row intervals, the correlation between precipitation and eroded loess is

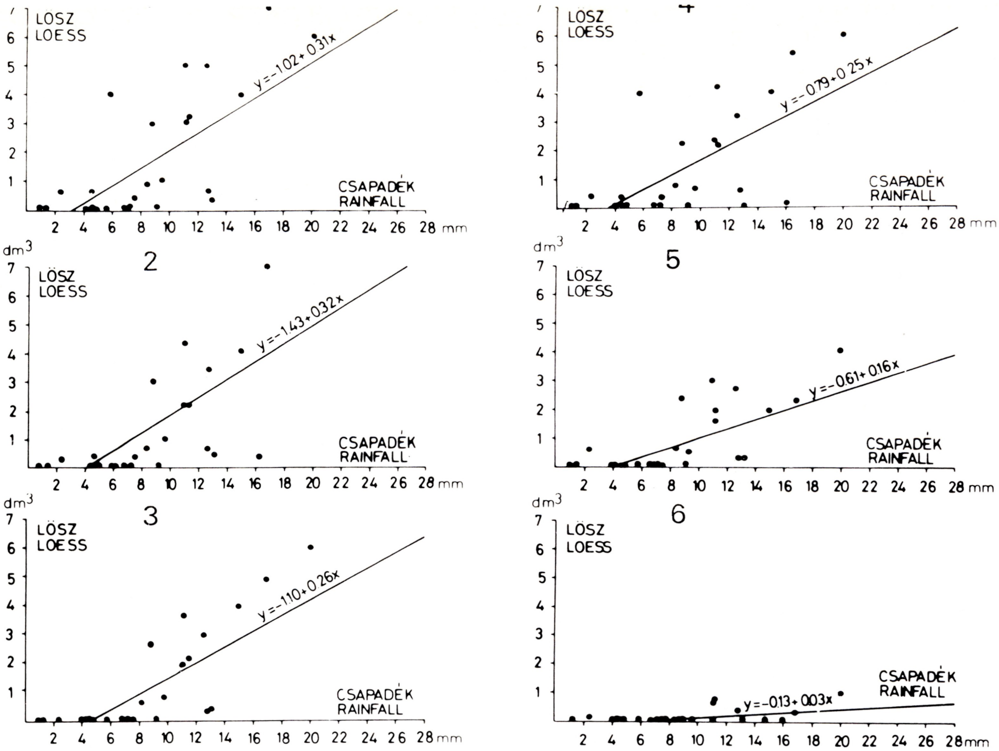

FIG.2 Correlations between the quantity of eroded loess and precipitation for low magnitude and low intensity precipitation events. Numbers refer to plot treatments.

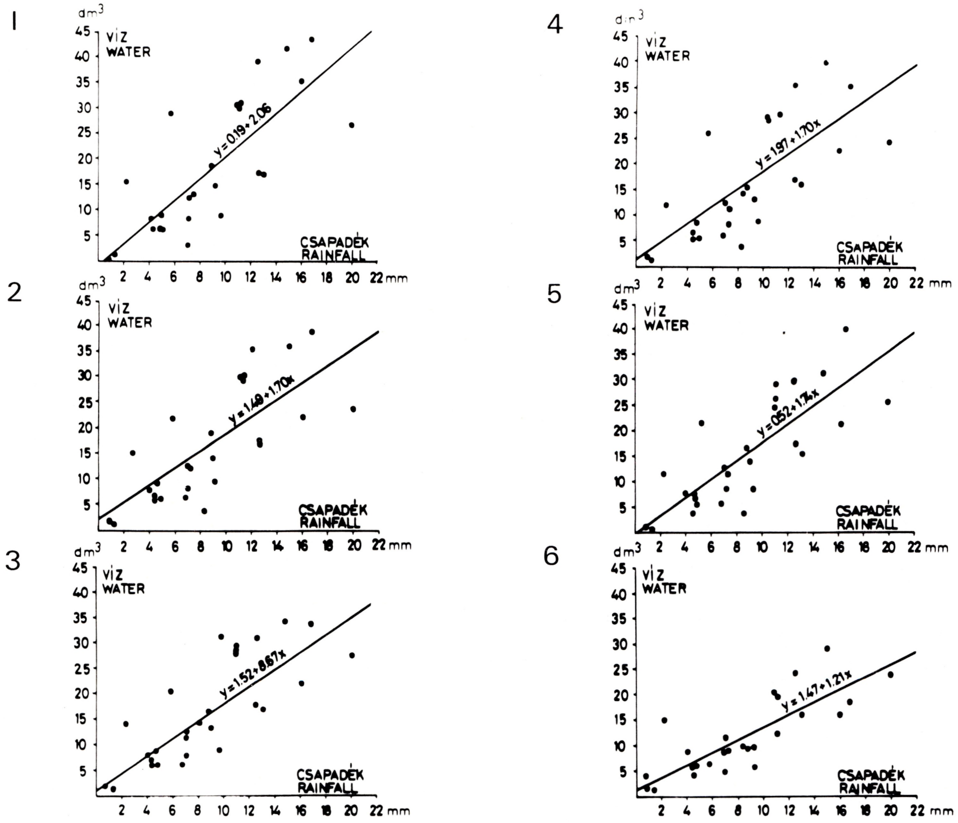

FIG.3 Correlations between the amount of runoff and precipitation for low magnitude and low intensity precipitation events. Numbers refer to plot treatments.

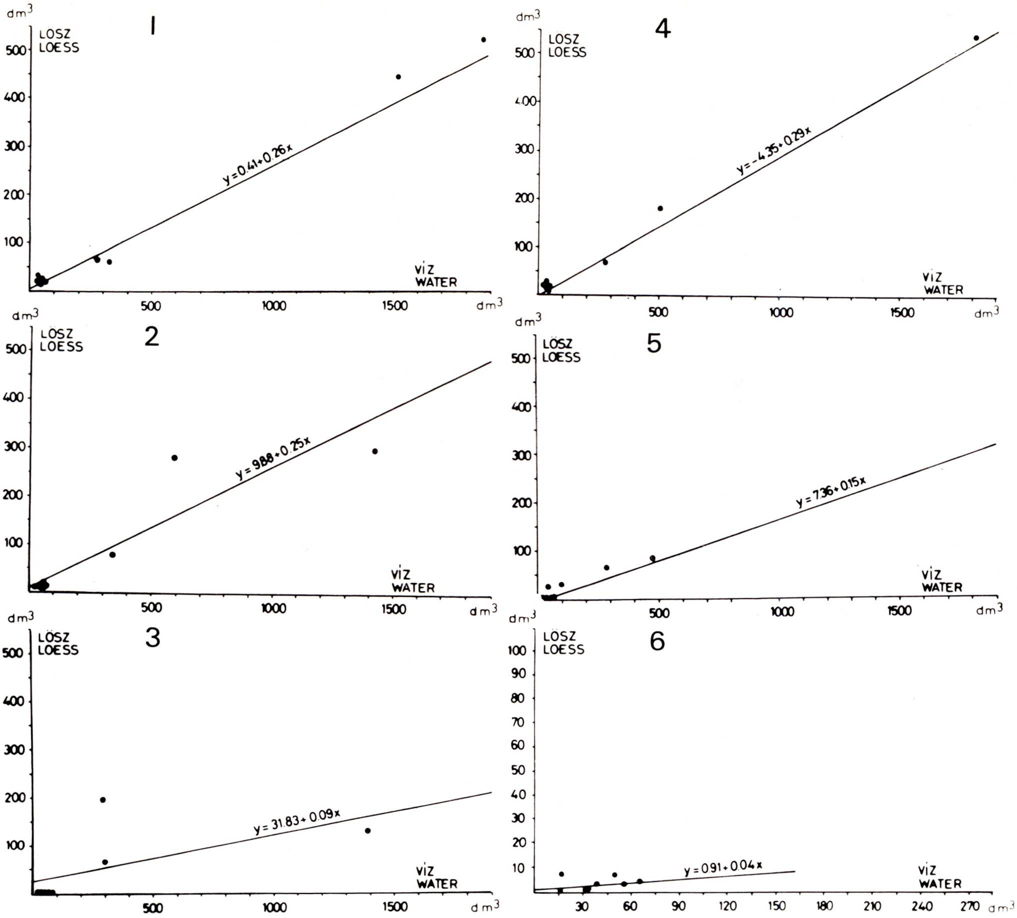

FIG.4 Correlations between amount of eroded loess and runoff for large magnitude and high intensity precipitation events. Numbers refer to plot treatments.

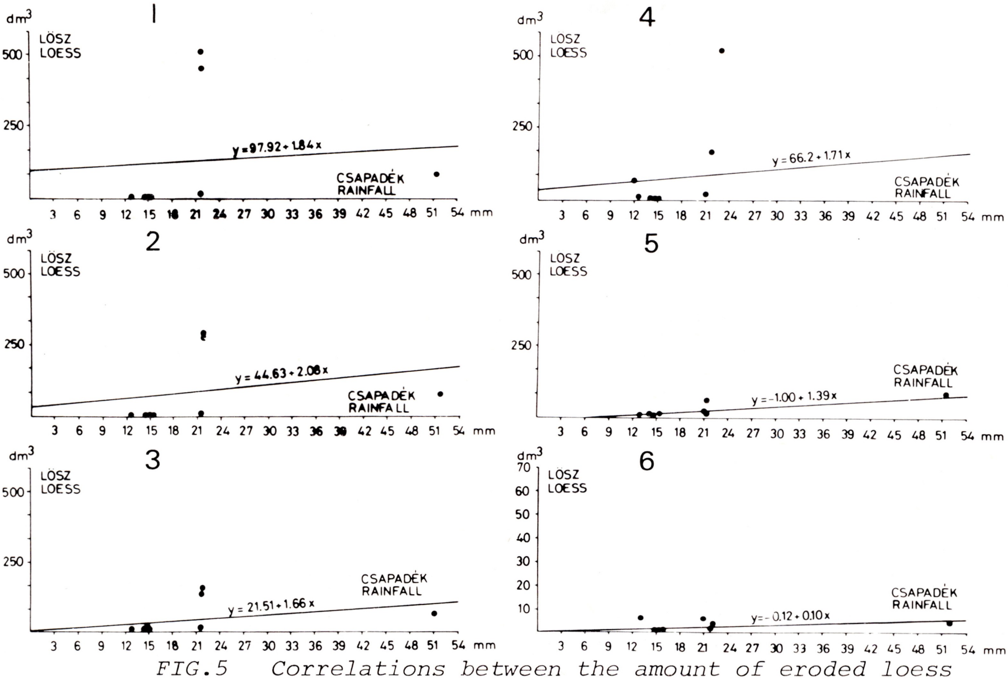

FIG.5 Correlations between the amount of eroded loess and precipitation for large magnitude and high intensity precipitation events. Numbers refer to plot treatments.

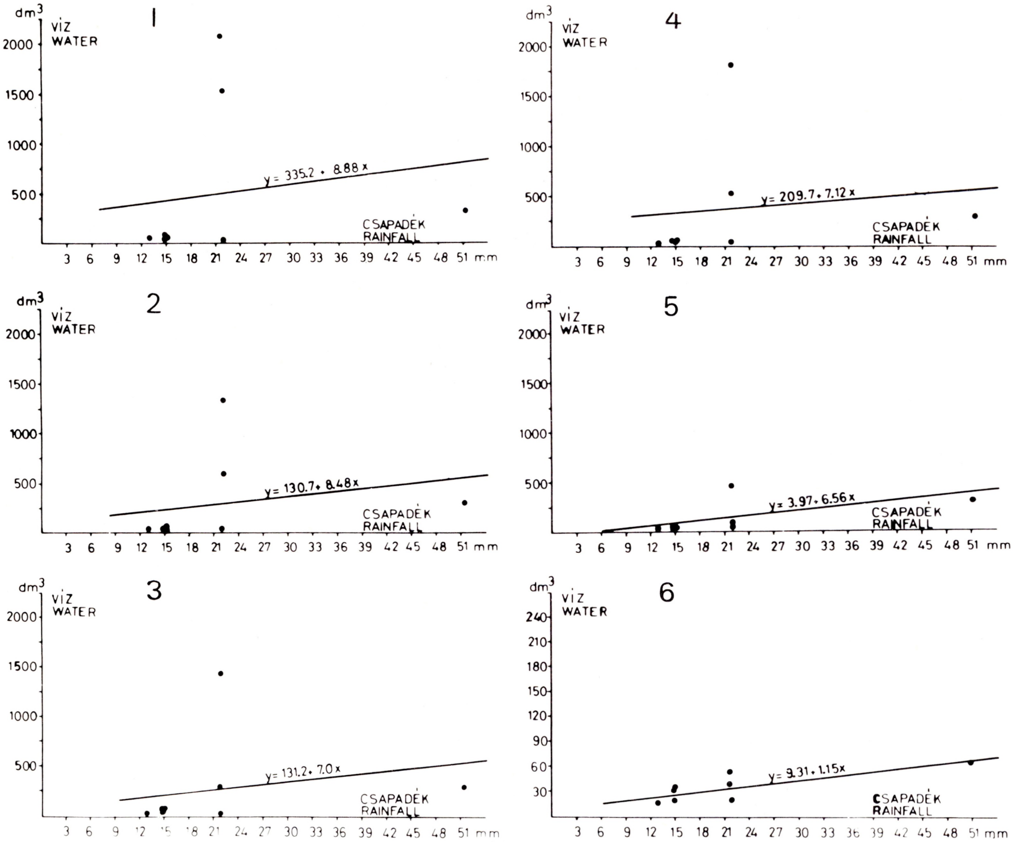

FIG.6 Correlations between the quantity of runoff and precipitation for large magnitude and high intensity precipitation events. Numbers refer to plot treatments.

positive but weak (for eroded loess r = 0.10, 0.25, for water r = 0.18, 0.15). There is an abrupt change for the ridges constructed at varying distances. With ridges constructed at five row intervals the correlation with precipitation can be regarded as intermediate for both loess and water (r = 0.67 and 0.47, respectively). With ridges constructed row by row, the correlation is stronger for runoff (r = 0.81), although it is somewhat weaker for eroded loess (r = 0.66).

In summary it can be stated that there is hardly any correlation between the precipitation amount of large magnitude and high intensity events and eroded loess and runoff in unprotected vineyards. Correlations gradually improve with the various methods of protection and are quite high with ridges constructed row by row.

In the preceding analysis the strength of the correlation between the various factors was described. However, the data obtained from the experiments also allow us to determine the equation of the regression lines. The regression line gives the most probable value of y pertaining to a give value of x. For example, according to Fig.2(1) the most probable value of eroded loess pertaining to a given quantity of precipitation is given by the expression

$y = -1.02 + 0.31x$. In the figures presented here (Figs 1-6) the correlations between the individual elements and the trend of the regression line are shown.

REFERENCE

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