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Research Article

EFFECTS OF SPLIT APPLICATION OF FERTILIZERS ON SOIL NUTRIENT TRANSPORT AND WATER QUALITY PARAMETERS UNDER LABORATORY CONDITIONS

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Abstract- The study demonstrate the effects of split application of fertilizers on soil nutrient transport (i.e. Nitrogen (N), Phosphorus (P) and Potassium (K) at different slopes under simulated rainfall conditions and subsequent impact of nutrient transport on runoff water quality parameters were also assessed. The study was conducted on experimental plots under laboratory conditions by using a rainfall simulator to produce the desired range of rainfall intensities of 9.00 cm/h, 13.20 cm/h and 17.00 cm/h at two selected land slopes of 2.00% and 4.00%.The soil nutrients transport due to surface runoff were found higher on one-step application of fertilizer, followed by two step applications and three step application of fertilizer respectively under 9.00 cm/h, 13.20 cm/h and 17.00 cm/h rainfall intensities for selected land slopes. The rainfall intensity was found to have a principal factor affecting nutrient transport as compared to steepness of land for all selected split application of fertilizer. The observed values of electrical conductivity (EC) and pH of runoff water indicated a negative correlation with increase in steps of fertilizer applications. The scenario of three-step split application of fertilizers was found the most efficient method for Nutrient loss management.

Keywords- Rainfall simulator, Nutrient transport, Water quality, Water pollution, Split application of fertilizers

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Introduction

The unscientific and indiscriminate use of the land resources are the one of the major causes of soil erosion and land degradation which resulted in the loss of top fertile soil along with essential plant nutrients through sediment and runoff. The increased rate chemical nutrient losses with sediment outflow and water from the agricultural lands is a serious cause of concern worldwide both from economic and environmental point of view. The soil nutrient transportation from fertilized agricultural lands on one way results in the reduction of fertility level of soils affecting the plant life adversely, on the other hand, the movement of soil nutrients from the field with runoff water and sediment outflow eventually joins different water bodies like reservoirs, river, lakes and ground water. The increase of chemical substances in these water bodies produce harmful toxic effects, which turns unsafe for human as well as for animal consumption and also has negative impact on agricultural and aquaculture eco-systems Most of the agriculture fertilizers shows high solubility in water and prone to be transported with runoff water and also with sediments outflow. It was reported, when field was drained by rainfall on the day of urea application, the 70% of urea was found lost [12]. In the recent past, lots of research have been done on surface runoff and transport of nutrient. [14] analyzed the soil erosion, runoff and nutrient losses under different vegetation and soil conservation measures. The hydrological response and their impact on nutrient loss on small orchids was reported by [8] and suggested that sediment outflow was maximum at beginning of storm. There were several studies conducted for sediment as well as Nutrient movement on large watersheds [1-4] and smaller watersheds [15, 17, 7 and 11]. Such studies were designed to determine the net effects of agricultural practices with time on nutrient loss measured at watershed outlet. The Hydrological process are complex in nature. The uncertainty associated with the occurrence of requisite number of rainfall storms of varying intensity, duration and distribution with varying topographic features at a particular place render these types of studies virtually impossible to conduct under actual field conditions when the resources are limited. Rainfall simulator provides the great flexibility to overcome such issues. [6, 18] studied the Raindrop energy effects on chemical nutrients and sediment transport using rainfall simulator. Several experimental studies were also conducted in past few years using rainfall simulator [10, 20, 6, 16, 5, 13, 9] to understand the complex behaviors of hydrological system, rainfall-runoff relationship, understanding soil erosion and infiltration process. The present study evaluated the nutrient transport for different fertilizer application methods in order to enhance the efficient utilization of soil nutrients and indicated the subsequent impact of nutrient transport on each split application of fertilizer on water quality parameters.

Materialsand Methods

Experimental-Setup

The experimental arrangement mainly involved a rainfall simulator and its regulating unit [Fig-1] which was mainly accountable for the generation of planned uniform rainfall. The rainfall simulator creates rainfall almost analogues to the natural rainfall having raindrop size in the approximate range of 3.00 mm to 4.70 mm. The generated rainfall uniformity coefficient ranges approximately from 87.00% to 92.00%. The falling rain drops terminal velocity has been found varying between 7.5 m/s to 9.5 m/s. The three regulated pressures of 0.20 kg/cm2, 0.40 kg/cm2 and 0.60 kg/cm2 were selected in order to replicate the rainfall intensity of 9.00 cm/h, 13.20 cm/h and 17.00 cm/h respectively.
Three test plots of size (1.00 m × 1.00 m × 0.5.00 m) were used in experimental

study. The experimental test plots were positioned on hydraulic flume, which can have longitudinal slope up to 6.00 %. The test plots were equipped with runoff collection chamber with 2.50 cm diameter multi-slot divisor for uniformity of runoff collection. The wire net of (1.00 mm) was provided in front of these holes to avoid soil scouring. The experimental plots were packed with soil evenly and appropriate compactness was given to the soil. The texture class of soil was sandy loam which was filled on experimental plot.

Experimental Technique

The three scenarios of split application (i.e. one-step, two-step and three-step) of fertilizers were considered in the study to assess the nutrient transport from experimental field [Table-1].

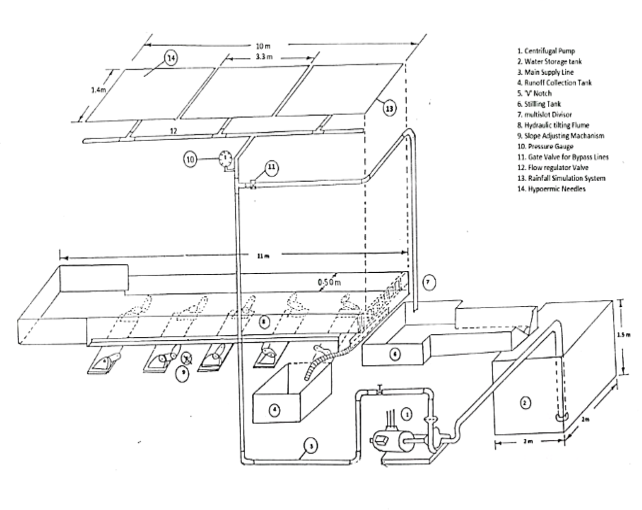

Fig-1 Diagram of Rainfall Simulation system

Table-1 *Experimental methodology for Split application of fertilizers at selected land slopes*

Step application	Fertilizer Treatments doses kg/ha	Rainfall intensity, cm/h	No. of rainfall events	Duration of rainfall for each event, min	Slope,%
One-step application	Basel application @ N:P:K 150:120:40 and Broadcasting@ N:K 150: 40	9.00 13.20 17.00	3 3 3	30 30 30	2 ,4 2, 4 2, 4
Two-step application	Basel application @ N:P:K 150:120:40 Broadcasting @ N:K 150: 40	9.00 13.20 17.00	3 3 3	30 30 30	2 ,4 2, 4 2, 4
Three-step application	Basel application @ N:P:K 100:120:26.6 Broadcasting @ N:K 100: 26.66 Broadcasting @ N :K 100: 26.66	9.00 13.20 17.00	3 3 3	30 30 30	2 ,4 2, 4 2, 4

The fertilizers application to the test field were done under bare field situation, i.e., without any crop. This was intended to not incorporate the effects of the rising crops on nutrient loss. The fertilizer (i.e. Urea, Di-Ammonium Phosphate (DAP) & Muret of Potash (i.e. MOP)) application to the experimental field was done with selected doses as 300.00, 120.00 and 80.00 kg/ha respectively which were near to the recommended doses of many crops such as wheat, potato, sugarcane etc..In one step application, the full recommended dose of fertilizer were applied to the field in a same time. However, two step split application, the recommended dose was applied in two equal splits. Similarly, in three step application, the fertilizer application was done in three equal splits. The Phosphorus was applied to the field as a Basel application with full recommended dose for all selected split application of fertilizers, which is most efficient way to provide phosphorus to field. Simulated rainfall of 9.00 cm/h rainfall intensity for one-minute duration was applied on the fertilized experimental plot without forming the runoff conditions. This simulated rainfall helps the fertilizers to get dissolved & well mixed and to leach down to avoid its easy movement with runoff. The nutrient generally takes 18 h to 24 h to become available to plants. The experiments were conducted considering the fact to know the effect of selected split applications on N, P, and K transport and water quality parameters after 24 h of each fertilizer application. The three rainfall event for each having 30 min duration were scheduled in 24 h interval for each experimental scenario (i.e. One-step, Two-step and Three step). Available Nitrogen (N), Available Phosphorus (P) and Available Potassium (K) were calculated on test plots using random soil sampling taken from throughout the plot, before and after of each experimental procedure. Runoff from each rainfall event was observed in equal interval for 30 min duration and analyzed for nutrient outflow in runoff and their impact on water quality parameters for selected combinations of rainfall intensity and land slopes.

The available Nitrogen was determined by Nitrogen Analyzer which was highly precise and programmed for the most employed procedure. The available phosphorus in extract determined calorimetrically with blue ammonium molybdate method with ascorbic acid as a reducing agent [19]. Available K or exchangeable K was determined in neutral normal ammonium acetate (pH 7) extract of soil solution with standard solution of potassium chloride [19]. The sediment concentration was calculated by oven dry method for runoff samples. The water quality parameters were evaluated by Digital water analyzer.

Results and Discussion

The nutrient losses (i.e. N, P, and K) were observed for three selected approaches of split application of fertilizer at two different land slopes (i.e. 2% and 4%) under varying simulated rainfall intensities (i.e. 9.00 cm/h, 13.20 cm/h and 17.00 cm/h). The observed result revealed that the nutrient losses were increased as the rainfall intensity and land slope increased. However nutrient losses (N, P, and K) were quite significant for higher rainfall intensities as compared to the losses to rainfall intensity 9.0 cm/h.

Effect of rainfall intensity on Nutrient transport

The observation demonstrate the nutrient transport resulted from schedule three successive rainfall events of varying rainfall intensities, when the full does of fertilizer (i.e. one-step application) were applied to the experimental field. The Nitrogen losses were recorded minimum as 44.71 % (i.e. for 9.00 cm/h rainfall intensity at 2.00% land slope) and maximum loss as 71.14 % (i.e. for 17 cm/h rainfall intensity at 4% land.

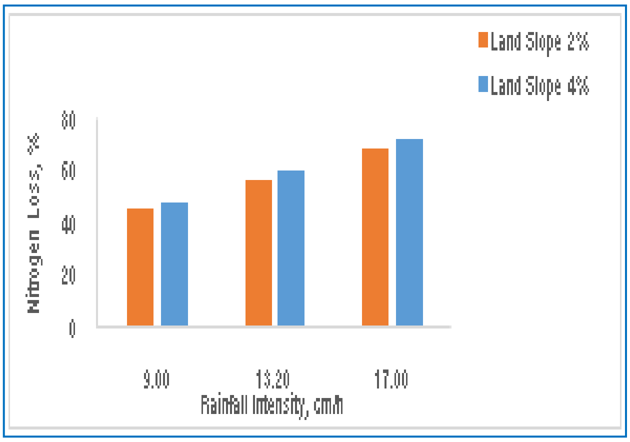

Fig-2 Nitrogen losses at selected land slopes under simulated rainfall intensities

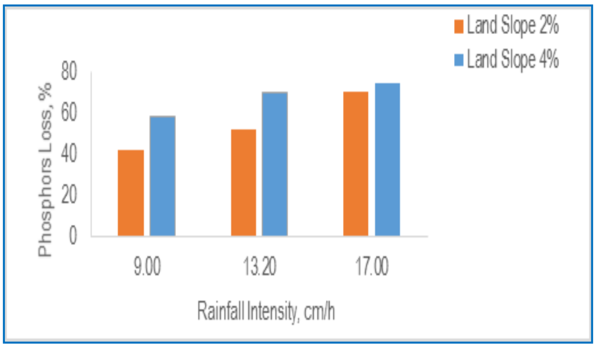

Fig-3 Phosphorus losses at selected land slopes under simulated rainfall intensities

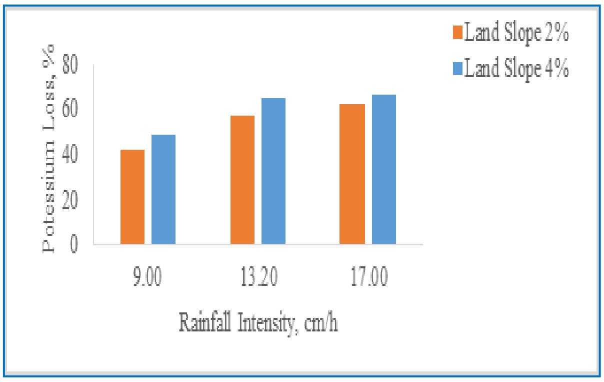

Fig-4 Potassium losses at selected land slopes under simulated rainfall intensities

Similarly, the phosphorus losses were reported minimum as 51% (i.e. for 9.00 cm/h rainfall intensity at 2.00 % land slope) to maximum as 74.71% (i.e. for 17.00 cm/h rainfall intensity at 4.00% land slope). The potassium losses were found in the range of 42% (for 9.00 cm/h rainfall intensity at 2.00 % land slope) to 67% (i.e. for 17.00 cm/h rainfall intensity at 4.00% land slope). The Nutrient loss observations at selected land slopes under varying rainfall intensities are shown in [Fig-2], [Fig-3] and [Fig-4]. It is visualized from the figures that the rainfall intensity had a principal factor effecting Nutrient transport.

Comparative evaluation of split application of fertilizers on Nutrient transport

The comparative evaluation of different split applications of fertilizers revealed that the Nitrogen and Potassium losses were significant reduced on three step split application of fertilizer, followed by two step split application and lastly on one step application of fertilizers. The comparison for the losses of phosphorus due to split applications were insignificant because it was applied with full selected does to the field for all the split application scenarios. The percentage of nutrient losses (i.e. N and K) for different split applications of fertilizers at selected land slopes under varying rainfall intensities are shown in [Fig-5],[[Fig-6],[Fig-7] and [Fig-8]

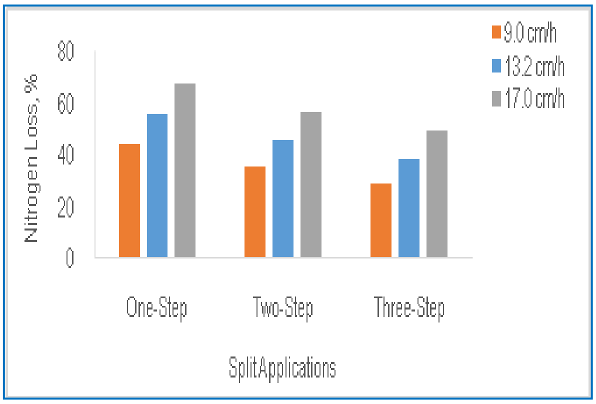

Fig-5 Nitrogen losses at 2% land slope for selected split applications of fertilizers

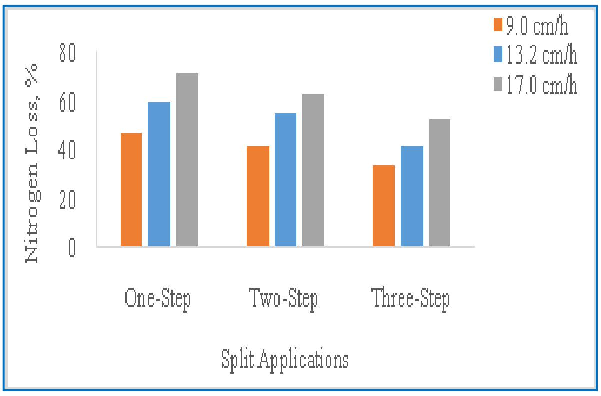

Fig-6 Nitrogen losses at 4% land slope for selected split applications of fertilizers

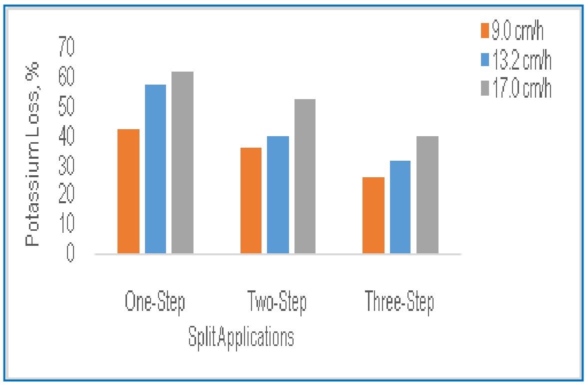

Fig-7 Potassium losses at 2% land slope for selected split applications of fertilizers

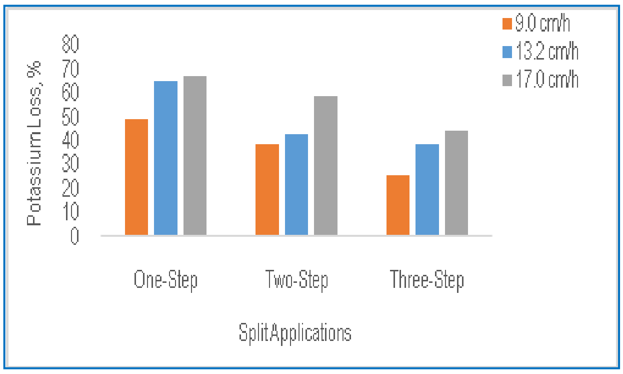

Fig-8 Potassium losses at 4% land slope for selected split applications of fertilizers

The observed data suggested that the Nitrogen losses were reduced as 35% on three-step split applications of fertilizer while comparing the Nitrogen losses from one-step application of fertilizer at 2.00% land slope. Similarly, at 4.00% land slope, the Nitrogen losses were reduced as 28% for three split application of fertilizers in comparison to one-step application. The potassium losses were also found reduced as 38% for three-step split application in comparison to one-step application at 2.00% land slope. However in case of 4.00% land slope, Potassium losses were approximately 40% reduced for three-step split application of fertilizer with respect to losses observed from one-step application. It is visualized from the graph that the rainfall intensity had a predominant effect on Soil Nutrient transports as compared to land slopes for all selected split application of fertilizers. The overall results analysis clearly indicated that increase in step application of fertilizer had reduced the transport of important soil nutrients. In this study, the three step application of fertilizer was found to be most efficient way to apply fertilizer, followed by two step fertilizer application and lastly one-step fertilizer application under different slopes under varying rainfall intensity using a rainfall simulator.

Nutrient transportation effect on Water Quality Parameters for different split applications

The runoff water quality were observed for contamination effect due to the nutrient transport on different split applications of fertilizers. The observed data showed that the concentration of sediment in runoff water was increased as the land slope and rainfall intensity increased [Table-2] and [Table-3]. However there were no significant changes observed on sediment concentration while comparing the selected split application of fertilizers. It was also found that the average P^H of runoff water gradually increased as the rainfall intensity increased, gradually leading the runoff water in saline state. However, P^H value shown a decreasing trend with increase in Split application of fertilizer which signifies the less contamination of water due to Soil Nutrient transport. The EC values also indicated an increasing trend for land slope with respect to rainfall intensity. The increase in P^H & EC values may be due to high nutrient losses and sediment concentration on Runoff. The EC values showed a decreasing trend for three-step split application of fertilizer, followed by two-step split application and one-step application of fertilizes [Table-2].

Table-2 *Observed runoff water quality parameters for Different split applications of Fertilizers at 2% land slope*

Split application	Simulated rainfall intensity, (cm/h)	Sediment concentration, (ppm)	PH	Electrical conductivity, (mmhos/cm)
One step	9.00	679	8.51	0.51
	13.00	925	8.57	0.51
	17.00	1237	8.80	0.52
Two step	9.00	650	8.32	0.43
	13.00	978	8.41	0.45
	17.00	1270	8.43	0.46
Three step	9.00	710	8.19	0.44
	13.00	990	8.23	0.44
	17.00	1265	8.18	0.44

The similar trend of water quality parameters were also observed for 4% land slope, however the quantitative values for runoff and sediment concentration were found more as compared to 2% land slope [Table-3].

Table-3 *Observed runoff water quality parameters for Different split applications of Fertilizers at 4% land slope*

Split application	Simulated rainfall intensity, (cm/h)	Sediment concentration, (ppm)	P^H	Electrical conductivity, (mmhos/cm)
One step	9.00	810	8.57	0.55
	13.20	1011	8.62	0.55
	17.00	1470	8.83	0.56
Two step	9.00	816	8.37	0.45
	13.20	1024	8.41	0.46
	17.00	1411	8.47	0.47
Three step	9.00	806	8.21	0.44
	13.20	1019	8.26	0.44
	17.00	1431	8.37	0.45

Conclusion

The study reports the effect of selected split applications of fertilizer on major soil nutrient transport (Nitrogen, Phosphorus and Potassium) and their effects on runoff water quality parameters. The rate of nutrients losses (N, P, K) were found to be increased with rainfall intensity and land slopes for all selected split application of fertilizer. The rainfall intensity was found to have a dominant factor affecting soil nutrient transport as compared to land slope for all selected split application of fertilizers. The available nitrogen and available potassium losses were higher in one step application of fertilizer. The three step application of fertilizers were found most efficient to control the nutrient losses in comparison to two-step & one-step fertilizer application for all the selected combination of land slopes and rainfall intensities. The values of electrical conductivity (EC) and PH shown a positive correlation with respect to rainfall intensity and slope, however both EC and PH showed negative correlation with the increase in step applications of fertilizer. Future research can be planned with split application of fertilizer considering different combinations on various crops to observe the transport pattern and their subsequent impact on runoff water quality.

Conflict of Interest: None declared

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