



Relationship between nutrient and soil loss with respect to land configuration and mulches in ginger (*Zingiber officinale*)

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ABSTRACT

Change in topography and retention of indigenously available biomass as mulch conserves the resources at the site. In high rainfall areas and hilly tract, soil and nutrient loss has paramount importance as these resources directly contribute to the crop yield. Ginger (*Zingiber officinale* Roscoe) is sensitive to soil and nutrient losses. The present study was conducted during 2011–12 and 2012–13 with three land configurations, viz. broad bed and furrow (BBF), ridge and furrow (R&F) and flatbed (FB) in main plots and four mulches, viz. *Imperata cylindrica* (IC), pine needle (PN), paddy straw followed by weed biomass (PS) along with no mulch (NM) in sub-plots and replicated thrice in ginger. The adoption of BBF considerably lowered the soil loss by 74.2% resulting in restoration of nitrogen (N), phosphorus (P) and potassium (K) to the tune of 49.7%, 59.3% and 69.1%, respectively, over FB plots. Similarly, placement of PN significantly reduced the soil loss by 92% and saved a considerable amount of N (49.9%), P (49.4%) and K (58.2%) over NM. In the hilly area, leftover crop residues, abundant weed biomass and ample tree leaf litter fall are not utilized commercially; these materials along with alteration in topography can be potentially utilized for the restoration of soil and nutrient for sustainable ginger production.

Key words: Ginger, Land configuration, Mulching, Runoff, Soil and nutrient loss

Ginger (*Zingiber officinale* Roscoe), is an important rhizomatous crop in the plain and hilly tracts. This can be grown as solitary and can be intercropped under the tree species (Choudhary *et al.* 2015). Recently, the higher demand and assured market price helped increase the cultivation area of ginger (Kushwaha *et al.* 2013). However, there are certain production constraints, i.e. soil and nutrient losses in high rainfall and slope areas especially in the Eastern Himalayan region (EHR) of India (Choudhary and Kumar 2013).

Ginger is a long duration crop which takes about 270–300 days from germination to harvest. During this period, it comes across various constraints like high rainfall, prolonged dry spell, soil and nutrient losses. This leads to a reduction in ginger yield. Among these, soil and nutrient losses are major ones. Rainfall varies largely, high rain events during monsoon and prolonged dry spells before onset and after terminations of monsoon are common phenomena, in such conditions growing crops like ginger is very risky, without adopting appropriate measures for the safe disposal of excess water (Choudhary and Kumar 2013). In India, ~ 146.8 million ha of the land is vulnerable to one or other kind of erosion. The average soil loss in

India is about 16.4 t/ha/year, with a total loss of 5.3 billion t/year (Bhattacharyya *et al.* 2015). In particular, one-third of the eastern Himalaya is prone to soil loss and the majority of loss is by water (Singh *et al.* 2011), mainly because of sloppy and ripple topography, and high rain events. This leads to soil and nutrient losses and ultimately reduction of potential capability of land (Singh *et al.* 2011). Degrading soils carry huge quantity of nutrients along with dissolved materials and other contaminants. Under such situations, site-specific suitable land management practices are urgently required to counter the soil loss and also to improve the water quality (Kothari *et al.* 2004).

In the regions where there are plenty of crop residues, weed biomass and tree leaf litters are available, these can be potentially utilized as mulch to reduce the splash erosion, and to decrease soil and nutrient erosions (Kosmos *et al.* 2000). Placement of mulch materials also protects the soils from evaporation during intense light and consistently supplies the water to plants. Optimum water regimes under the mulch improve crop productivity and also protect the soil loss (Choudhary *et al.* 2013, Thankamani *et al.* 2016).

Many of the researchers elsewhere reported the advantages of mulch on ginger cultivation, but limited attempts were done to evaluate the soil and nutrient losses under the combined approaches of land configuration and mulches. Thus, the present studies were conducted aiming the relationship between runoff and soil loss; soil and nutrient

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loss; and runoff and nutrient loss with land configuration and mulching in ginger.

MATERIALS AND METHODS

A field study was conducted during 2011-12 and 2012-13 for consecutive two years at ICAR-Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, India (27° 95' North latitude and 94° 76' East longitude, with an altitude of 631 m above mean sea level). The climate of the study site is humid sub-tropical, with the daily temperature varying between a minimum of 4°C and a maximum of 35°C. Soil of 20 cm depth of the experimental field was silt loam, acidic in reaction (pH 5.3), moderate in compaction level (bulk density; 1.42 t/m³), contained 13.1 g/kg organic carbon, 96.2 mg/kg available nitrogen (N), 5.1 mg/kg available phosphorus (P) and 104.9 mg/kg exchangeable potassium (K). The average annual rainfall of the study area was 2400 mm.

Ginger cv. Nadia (a variety with 270–300 days maturity, with less fibre content) was used during the study and planted in the split-plot design with three replications. Land configurations, i.e. flatbed (FB), ridge and furrow (R&F, 30 cm height from furrow base), and broad bed and furrow (BBF, 15 cm height and 130 cm broad beds), were assigned to main plots. Mulch materials, i.e. *Imperata cylindrica* (IC, 4 t/ha); pine needles (PN, 4 t/ha); paddy straw (PS, 4t/ha followed by weed biomass, 2 t/ha) and no mulch (NM) were placed in sub plots. The ginger was planted at 45 cm × 20 cm, in BBF 3 rows were adjusted keeping 20 cm from each side. The plot size of the smallest unit was 4.2 m × 4.8 m, where the replications, main plots and sub plots were separated by 1.0 m spacing.

Land was prepared using one pass of moldboard plow followed by one harrowing and at final land preparation 10 t/ha of well-decomposed farmyard manure was applied followed by one pass of the cultivator. The rhizomes were treated with mancozeb at 3 g/l of water for 30 min and shade dried for 4 h and planted at 1.5 t/ha. Urea (46% N) at 75 kg N/ha was applied in two splits [half at 45 days after planting (DAP) and the remaining half at 90 DAP]. Single super phosphate (16% P₂O₅) at 50 kg P₂O₅/ha and muriate of potash (60% K₂O) at 50 kg K₂O/ha were applied in the planting row just prior to planting. The hot and humid climate of the study area favoured severe infestation of weeds, thus crop was subjected to one manual weeding at 60 DAP.

The total amount of eroded soil was estimated from rain events occurred during the cropping period. Rainfall during cropping period (April–January) was categorized into three categories, viz. low (<20 mm/day), medium (20–40 mm/day) and high (>40 mm/day). These were estimated by filtration of a composite sample collected from the tanks after thoroughly mixing the runoff and sediment. Samples of soil and water were collected at 9.00 AM for nutrient and soil loss estimation. The sediment retained after filtration (paper type: Whatman No. 1, pore size 1.2 µm) was dried at 105°C for 24 h and its weight was determined to take into account the weight of the filter paper. The measured sediment

yield (g/l) was converted to t/ha using the sediment yield from the plot area and runoff volume. The dried sediment samples were analyzed within 7 days for measurement of nutrient losses (Jackson 1962).

The various parameters were analyzed using PROC MIXED procedure of the SAS Version 9.3 (SAS Institute Inc., Cary NC USA) and means were compared based on the least significant difference (LSD) at 0.05 probabilities. The ANOVA results (combine over the years) indicated non-significant, hence, the data were presented mean of both the years. The relationship was developed by using Microsoft Excel.

RESULTS AND DISCUSSION

Soil and nutrient losses

Alteration of soil surface by following land configuration and placement of locally available mulches significantly ($p < 0.05$) influenced the soil and nutrient losses. Among the land configuration, the highest quantity of soil was lost with FB plots (20.1 t/ha), whereas the soil loss under BBF was significantly reduced by 74.2% followed by R&F (41.2%) over FB. The soil also carried N, P and K along with it, but, following appropriate land configuration significantly reduced the loss of soil and total nutrients. The plots under BBF and R&F significantly reduced the losses of N contents by 49.7 and 15.6%, respectively over FB. Similar to N, the reduced losses of P content were 59.3 and 25.1%, respectively and K contents were 69.1 and 24%, respectively than FB plots (Table 1). It was also worth to mention that nutrients (N, P and K) lost from soil and suspension were the highest under FB which accounted by 19.0, 5.4 and 12.9 kg/ha and 2.5, 0.6 and 1.6 kg/ha, respectively. The nutrient loss occurred due to soil and suspension in R&F was less pertinent to BBF, but had significantly lower than the FB plots. The loss of total nutrients was the lowest with BBF mainly due to obstruction of free movement of water, it clearly indicated that land configuration helped in the safe disposal of water during high rain events and retained more moisture during short rain events. This led to lower runoff and finally reduction in sediment load. The earlier reports also reported similar findings (Bhuyan *et al.* 2002, den Biggelaar *et al.* 2004, Lafond *et al.* 2006, Baigoria and Romero 2007, Singh *et al.* 2011). Similarly, appropriate topography alteration reduced the losses of annual total N (33 kg/ha), organic carbon (267 kg/ha) and total P (5 kg/ha) as reported earlier (Rai and Sharma 1998, McDowell and Sharpley 2002).

Placement of mulch had the maximum potential to restore the soil in its original state and very little quantity of soil could lose under it, whereas, the maximum loss was measured with NM plots. Placement of PN recorded 92.0% reduction in soil loss followed by IC and PS (56.6 and 31.6%, respectively) over NM plots. The N loss was 49.9% lower in PN plots followed by IC and PS plots (39.2 and 21.7% respectively). Similar to N, the losses of P and K were 49.4 and 58.2%, respectively lower in PN than the

Table 1 Soil and nutrient loss influenced by land configuration and mulches (pooled data of 2 years)

Treatment	Soil loss (t/ha)	Nutrient loss from deposition (kg/ha)			Nutrient loss from solution (kg/ha)			Total nutrient loss from runoff (kg/ha)		
		N	P	K	N	P	K	N	P	K
<i>Land configuration</i>										
BBF	11.51c	11.00c	3.01c	6.76c	3.34a	0.645a	1.774a	14.34c	3.66c	8.53c
R&F	14.20b	15.21b	4.02b	9.74b	3.37a	0.643a	1.885a	18.58b	4.66b	11.63b
FB	20.05a	18.99a	5.23a	12.85a	2.48b	0.604a	1.571b	21.47a	5.83a	14.42a
SEm±	0.73	0.75	0.11	0.33	0.17	0.02	0.06	0.91	0.13	0.37
LSD (P=0.05)	1.97	2.03	0.30	0.88	0.47	0.05	0.15	2.45	0.34	1.00
<i>Mulch</i>										
IC	13.37bc	13.74a	3.92ab	9.12ab	2.51c	0.500c	1.486c	16.24b	4.42b	10.50b
PN	10.90c	13.84a	3.70b	8.74b	1.24d	0.192d	0.601d	15.08b	3.89b	9.34b
PS	15.91b	15.13a	4.03ab	9.56ab	3.45b	0.712b	1.920b	18.58b	4.74b	11.48b
NM	20.93a	17.56a	4.69a	11.71a	5.05a	1.119a	3.067a	22.61a	5.81a	14.78a
SEm±	1.62	1.48	0.37	1.02	0.28	0.01	0.10	1.43	0.37	1.00
LSD (P=0.05)	4.21	3.84	0.97	2.65	0.74	0.05	0.27	3.71	0.96	2.61

BBF: Broad bed and furrow; R&F: Ridge and furrow; FB: Flatbed; IC: Imperatacylendrica; PN: Pine needle; PS: Paddy straw followed by weed mulch; NM: No mulch. Values with the same letter within each land configuration and mulch group in column are not significantly different at 5% level of significance.

NM. However, IC and PS registered reduction of P loss by 31.5 and 22.6%, respectively and K loss by 40.8 and 28.8%, respectively over NM plots. Apart from these, nutrient lost from the soil and soil solution was the highest with NM plots. The lowest erosion of N in soil and solution were obtained with PN followed by IC and PS. Similar findings were also reported by Choudhary and Kumar (2019) in turmeric. Results obtained from the study confirmed that the bare soil was severely affected by biting action of raindrops, which splashed the soil and eroded the soils in sheet form, along with the substantial quantity of N, P and K (Ramprasad *et al.* 2000, Kothiyari *et al.* 2004). However, the mulched plots significantly reduced the soil erosion and this led to a reduction in nutrient loss. Nevertheless, PN had provided the good cushioning and restricted the direct contact of raindrops with the soil. Under it, the most of the rain was infiltrated and percolated resulting in lowered soil loss (Sharma *et al.* 2001). Placement of mulch materials in the soil surface increased the surface roughness, reduced the velocity by reducing kinetics energy of raindrops and helps the suspended sediments in the runoff to deposit and settled resulted reduce sediment yield (Quin *et al.* 2014). However, with the progress of crop duration, most of the PS got decomposed from the date of application and some of the areas were exposed. These areas were infested with weeds and also sites of action for raindrops resulting in loss of soil as well as nutrients. Therefore, the weeded biomass in PS was placed which might have acted as double mulching and also added the nutrients by decomposition as time progresses and crop got benefitted (den Biggelaar *et al.* 2004).

Relationship between runoff – soil loss

There was a strong positive linear relationship observed between soil loss and runoff (Fig 1). This indicated that the process of soil loss was more dominated with an increase in runoff, with a relatively higher coefficient of determination ($R^2 = 0.93$). It was also recorded that, the crop grown with mulch significantly reduced the runoff loss and resulted in a reduction of soil loss.

Relationship between soil loss – nutrient loss

Components of the nutrients, viz. N, P and K are basic constituents of the soil medium which undergo erosion due to the action of rainfall and runoff. The amount of nutrient loss, therefore, is directly related to the amount of soil loss. Analysis of data indicated a strong positive

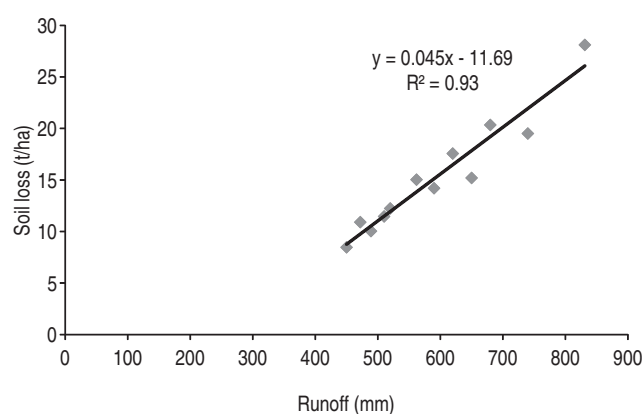


Fig 1 Relationship between runoff and soil loss with respect to land configuration and mulches in ginger.

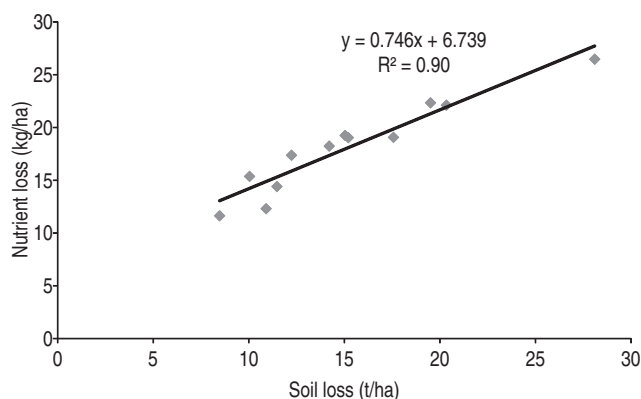


Fig 2 Relationship between soil loss and nutrient loss with respect to land configuration and mulches in ginger.

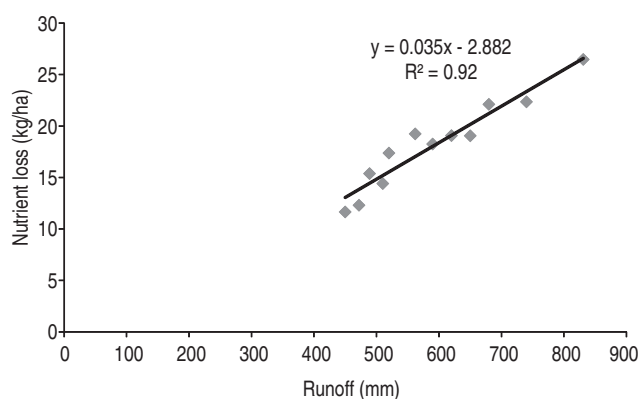


Fig 3 Relationship between runoff and nutrient loss with respect to land configuration and mulches in ginger.

Table 2 Relationship between different nutrients and soil loss (pooled data of 2 years)

Relationship	Equation	Coefficient of determination (R ²)
N loss – soil loss relationship	$y = 0.75x + 6.74$	0.90
P loss – soil loss relationship	$y = 0.21x + 1.49$	0.95
K loss – soil loss relationship	$y = 0.57x + 2.85$	0.90

N, Nitrogen; P, phosphorus; k, potassium; y= dependent variable, x= independent variable

linear relationship ($R^2 = 0.90$), which showed a high degree of correlation between soil erosion and nutrient loss (Fig 2). However, the quantity of nutrient loss was found to be strongly related to runoff.

N loss – soil loss relationship: The maximum loss of N (kg/ha) was observed with FB along with NM followed by R&F with NM. The lowest N loss was obtained with BBF along with PN. The probable reason for this might be due to the smaller quantity of soil was lost from this plot. However, loss of N per unit area of soil loss was the highest for FB with NM, which might be due to the highest soil loss. There was a strong positive linear correlation between N loss and the soil loss (Table 2). This relationship also indicated that the coefficient for losses of N, i.e. slope of the regression line was higher. Zheng *et al.* (2017) also reported that soil nitrogen loss related to surface flow from the slope lands is a global issue and found that there was considerable loss of total N with surface and sub-surface flow.

P loss – soil loss relationships: The relationship between soil loss and P are given in Table 2, this also followed a strong positive linear relationship. The trend was similar to N and the soil loss was higher with FB with NM and the lowest under the combination of BBF along with PN.

K loss – soil loss relationship: The highest K was lost from FB with NM and the lowest with BBF and PN plots. The relationship (Table 2) clearly depicted that there was a positive linear relationship between K and soil loss. The BBF with PN mulches had better crop growth and soil surface was well covered, which provided a better opportunity for infiltration and hence low surface runoff (Ramprasad *et al.* 2000). The amount of soil loss per unit of runoff was found to be superior with FB along with NM.

Relationship between runoff – nutrient loss: The correlation between runoff and nutrient loss showed a strong positive linear relationship ($R^2 = 0.92$; Fig 3). This confirmed that under FB along with NM had the highest runoff, which encouraged the loss of more nutrients. Whereas, BBF along with PN conserved the highest amount of rainfall and lowered the runoff resulting in the lowest nutrient loss.

However, in the regions with plenty of crop residues, environment favours the profuse growth of weeds, and large number of pine trees, the leaf litter of these trees have been least explored for any commercial use. Therefore, these can be judiciously utilized as mulch in order to conserve soil moisture, suppress the weed growth, and better crop growth (Choudhary and Kumar 2013).

Findings of the present study highlighted the importance of land configuration and placement of locally available mulches in order to protect the soil and nutrient losses and also the runoff. Broad bed and furrow were found to be suitable to prevent the most runoff, soil and nutrient losses, followed by ridges and furrow than the flatbeds. The effect of these land alterations on topography further improvised with the placement of mulches and the highest with pine needle mulch followed by double mulching of paddy straw and weed mulch and *Imperata cylindrica* over the no mulch.

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