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**Research Paper**

# Finger millet (*Eleusine coracana*)–groundnut (*Arachis hypogaea*) strip cropping for enhanced productivity and resource conservation in uplands of Eastern Ghats of Odisha

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## ABSTRACT

A field experiment was carried out during the rainy seasons (July–October) of 2011, 2012 and 2013 at Koraput, Odisha, to access the performance of finger millet [*Eleusine coracana* (L.) Gaertn.] and groundnut (*Arachis hypogaea* L.)-based strip crop combinations in ratios 6:4, 8:4, 10:4 and 12:4. The experiment was laid out in 3 replications on 2% slope in a randomized complete-block design. Among the tested ratios, strip cropping of 6 rows of finger millet with 4 rows of groundnut steadily gave higher finger millet equivalent yield to the tune of 57, 44 and 59% than sole finger millet in 2011, 2012 and 2013 respectively. Sole finger millet cultivation recorded the minimum production efficiency of 12.3 kg/ha/day, whereas finger millet + groundnut strip cropping showed a mean improvement of 17%. The maximum net returns of ₹22,183/ha accrued from planting 6:4 ratio which was nearly double the net returns from sole finger millet cultivation and the ratio also registered the highest benefit: cost ratio (2.87). The superiority of strip ratio 6:4 was also reflected in the monetary advantage index and income-equivalent ratio, registering the maximum values of 6166 and 1.62 respectively. Pooled data of 3 years indicate that runoff conservation potential of finger millet + groundnut strip ratios 6:4, 8:4, 10:4 and 12:4 was 22.4, 11.9, 10.6 and 8.7%, respectively, compared to sole finger millet. On an average, 6:4 ratio gave the lowest values of soil loss (3.02 t/ha) and conserved soil loss by 18.1, 19.6 and 17.4% in 8:4, 10:4 and 12:4 ratios respectively. Sole groundnut arrested the maximum organic carbon loss, i.e. 44.6 t/ha, followed by 6:4 ratio (55.8 t/ha) which also recorded higher values for other nutrients conservation. Water productivity of different strip ratios specified the advantage in 6:4 systems, registering maximum values of 4.28 kg/mm. Maximum value of land-equivalent ratio (1.38) was calculated in 6:4 ratio, indicating 38% area advantage over sole cropping. All the strip cropping systems were advantageous than sole planting systems because the product of relative crowding coefficient (K) of main and intercrops was more than 1. Maximum values of $K_{FM}$ and $K_{GN}$, (7.84 and 1.34) were obtained from 6:4 and 8:4 strip ratios, respectively, directing greater advantage with higher values of product of K (10.15).

***Key words :*** Aggressivity, Runoff, Soil and nutrient losses, Strip cropping

Eastern Ghats region of Odisha connotes a series of mountainous region, comprising hillocks, sloping lands and fertile flat lands. These hills rise abruptly with steep peaks and slope gently to a dissected plateau. Eastern Ghats region encompasses an area of 4.87 million ha in 36 blocks of 6 south-western districts with a population of 2.13 million (Sikka *et al*., 2000). This tribal region is amalgamation of numerous hillocks, broad and narrow river valleys, and flood plains receives an average rainfall of 1,450 mm/annum. Rainfed uplands, situated between hillocks and valleys, constitute a major portion of arable land and contribute immensely to food production of the region. The slopes of such lands vary from 2 to 15% and thus are under heavy water erosion-induced soil and nutrient losses leading to severe land degradation and low crop productivity. Other important reasons of poor crop productivity include occurrence of light-textured soils (red lateritic) with medium to high erodibility, low water-holding capacity, rolling topography, high rainfall, and faulty agricultural practices like cultivated fallows, up and down cultivation, monoculture, unsuitable crop selection combined with occurrence of drought at critical crop-growth stages.

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Finger millet is the most dominant rainy-season crop on these lands. It accounts for about 20% of total cropped area and is utilized as staple food in the region. Finger millet (FM) is one of the most nutritious crops, with high levels of methionine (an essential amino acid); lacking in diets of millions of the poor living on starchy foods (Wanyera, 2007) and high content of important minerals, such as calcium and iron. It is an important crop of rainfed as well as drought-prone regions because of its tremendous ability to withstand stressed environments and grow in marginal and poor soils. Due to eroded soils and poor fertility, FM yields low (1–1.2 t/ha) on marginal lands combined with low profit due to its lower sale price. Hence its sole cultivation can hardly improve economy of tribal people of the region sustainably. Thus, there is need to diversify monocropping practice with some doable technological intervention.

Crop diversification through intercropping has been shown to improve crop productivity and profitability, conservation of resources and provide a kind of biological insurance against risks and aberrant rainfall behaviour in dryland environment (Dutta and Bandyopadhyay, 2006). Strip cropping is a form of intercropping comprises growing of soil-conserving and soil-depleting crops in alternate strips running perpendicular to the slope of the land for the purpose of reducing erosion. Besides increasing overall productivity and income, intercropping of legumes with cereals/millets helps in conserving moisture by reducing runoff, improving physical properties of soil and building-up of soil fertility. Groundnut is the most important oilseed legume crop in India with an area of 5.8 million ha and production of 7.4 million tonnes (DAC, New Delhi, 2014). It contains about 40–45% oil, 20–25% protein, 20.5% carbohydrate, 5% fibre and ash which make a sustainable contribution to human nutrition.

Sole groundnut (GN) cultivation is widely done in the Eastern Ghat region for its multiple benefits of erosion resistance, soil-fertility improvement and nutritive consumption by the tribal populace. Therefore, current study was planned to diversify rainfed uplands through strip cropping of FM with GN for improving the productivity of this region of Odisha. Beneficial effects of FM + GN intercropping in plains of semi-arid dryland areas are reported by the CRIDA (2002) and found intercropping legumes with FM distinctly advantageous over sole cropping. However, intercropping of FM with pigeonpea on sloping lands was established in work of Dass and Sudhishri (2010). The work on the potential of GN with FM for reducing runoff on sloppy lands was lacking for the region. In view of this, the present experiment was conducted to explore the possibility of digression of FM or ragi monocropping with introduction of GN as strip crop for sustainable productivity, profitability and resource conservation of the region.

## MATERIALS AND METHODS

A 3-year field experiment was carried out during the rainy seasons (July–October) of 2011, 2012 and 2013 at the Research Farm of Koraput, Odisha. The climate of the study area is sub-tropical humid with mean annual precipitation of 1,450 mm. More than 80% of precipitation occurs during the monsoon season (June–October). As per the USDA soil classification, soil of the study site comes under Udic Paleustalfs with soil depth of 1.5 m (Lenka *et al.,* 2013). Soil texture is silty-loam, having low organic carbon (OC) (0.49%), medium in available phosphorus (P) (14.5 kg/ha) and available potassium (K) (253 kg/ha).

The experiment consisted of 4 strip crop combinations in ratios 6:4, 8:4, 10:4 and 12:4, with two checks of sole crop (FM and GN) in 3 replications were raised on 2% slope in a randomized complete-block design (RCBD). In all there were 18 experimental plots of 18 m ×10 m. Predominant crop varieties of the region, viz. ‘Bhairbhi’ of FM and local cultivar of GN, ‘TG 38’ were used. Land-preparation of the experiment site was done with help of tractor-drawn cultivator-cum-planker. But sowing was done manually together of both crops altogether making strips of FM + GN sown at spacing of 15 cm × 10 cm + 30 cm × 10 cm (row and plant spacing) in ratios of 6:4, 8:4, 10:4 and 12:4 respectively. The sowing was done in the first week of July in all 3 years of experimentation with recommended seed rates of 10 kg/ha for FM and 110 kg/ha for GN. The fertilizer was added to the seed furrows just before sowing. Crop seeds were manually placed in 3–4 cm deep furrows and covered with soil.

Cultural operations, such as weeding, harvesting and threshing (manually) were done as per farmers’ practice in the region. A fertilizer dose of 40, 8.6 and 16.6 kg N, P and K/ha was applied to FM and FM based strip cropping. Fertilizer dose to sole groundnut consisted of 15, 20 and 20 kg N, P and K/ha. Experiment was conducted under rainfed conditions during all experiment years. The FM and GN were harvested in the third and fourth weeks of October, respectively, every year. Multi-slot divisors were installed for collection of runoff and estimation of soil loss. Runoff from each plot was measured by measuring the depth of water collected in each runoff collection-tank after 24 hours rainfall. Runoff samples were taken after thorough churning with rod in 1 litre capacity glass bottles. For each observation, 2 samples were collected from each tank. These samples were stored in a refrigerator at 40°C for 24–48 hours, in order to allow suspended sediment to settle down. For determining the weight of soil lost, sediment yield from 1 runoff bottle collected from each runoff collection tank was dried in oven at 105°C till constant weight was obtained. Organic carbon (OC), P and K contents in the runoff sediments were determined by using standard methods. A 0.3 m–wide outermost border rows with all the sides of experimental plot, was marked as border area and yield was taken from the innermost complete set of rows with net plot size of 17 × 9 = 126 $m^2$. The crop yield data in sole as well as in strip cropping systems were subjected to statistical analysis only after conversion into the FM-equivalent yield taking into consideration the average market prices of 100 kg grain (FM ₹1,500; GN ₹4,000) during the study period. Then statistical analysis of these data recorded form all the replications, was carried out as per the ANOVA procedures of RCBD (Gomez and Gomez, 1984). Differences between individual means were compared at 5% level of probability.

The mean yield of 3 years of different intercrops in sole stands, i.e. FM 1,350 kg/ha and GN 650 kg/ha were used for computation of competition functions by the following methods suggested by Willey and Rao (1980): Land-equivalent ratios (LER) = La+Lb, La=Yab/Yaa, Lb = Yba/Ybb where, La and Lb are land-equivalent ratio of main and intercrops respectively. LEC = LECa × LECb was calculated where 'a' and 'b' are the two crops. Yaa and Yab are yields of main crop, while Ybb and Yba are the yields of intercrops in sole stands and in intercropping respectively. Area-time equivalent ratio (ATER) = (LaTa+LbTb)/T where La and Lb, are partial LERs of main and intercrops, Ta and Tb are duration of main and intercrops and 'T' is the total duration of the whole intercropping system. Income-equivalent ratio (IER) = income from both main and intercrops in intercropping system/income from sole main crop. Monetary advantage index (MAI) = Net returns from combined produce (₹/ha) × (LER–1)/LER. Aggressivity of main crop (Aab) = {(Yab/Yaa × Zab) – (Yba/Ybb × Zba)} and of intercrop (Aba) = {(Yba/Ybb × Zba) – (Yab/Yaa × Zab)}. Relative crowding coefficient of main crop (Kab) = (Yab × Zba)/(Yaa – Yab) Zab and of intercrop (Kba) = (Yba × Zab)/(Ybb – Yba) Zba, and product of both (K) = Kab × Kba. Competitive ratio of main crop (Cra) = (LERa/LERb) (Zba/Zab) and of intercrop (Crb) = (LERb/LERa) (Zab/Zba) where Zab, proportion of intercrop area allocated to main crop and Zba, proportion of intercrop area allocated to intercrop. Crop profitability was computed as Net returns (₹/ha)/ ÷ Number of days field occupied. Production efficiency was computed dividing net returns to the crop duration and water productivity was calculated as = Yield/ Effective rainfall. Effective rainfall was derived on the basis of seasonal rainfall using FAO CROPWAT software model.

## RESULTS AND DISCUSSION

### *Yield*

Maximum grain yield of FM and pod yield of GN was found in their sole strands along the years (Table 1). The strip cropping of GN in varying ratios (6:4 to 12:4) significantly influenced both component crops' yield. A glance on the component yield of FM in 2011 indicates yield loss of 4.5, 16, 11.3 and 6% due to inclusion of GN strips (1.2m width) in 6:4, 8:4, 10:4 and 12:4 ratios, respectively. In 2012, the percentage loss increased by 11.3, 20.2, 16.4 and 8.3 in same ratios. However in 2013, the grain yield of FM was found to be non-significant. The per cent of FM yield compensated by GN in different years (on minimum support price ₹ 4,000/q) was 62, 50, 43 and 44% in 2011; 55, 46, 39 and 34% in 2012; and 60, 56, 45 and 41% in 2013 for 6:4, 8:4, 10:4 and 12:4 ratios respectively. Form above facts, it is evident that with each successive addition of 2 rows of FM the pod yield of GN decreased by 50–69%. Significant decrease in pod yield in GN strip cropping in ratios 6:4, 8:4, 10:4 and 12:4 was 54, 61, 67 and 71% in 2012; and 53, 57, 65 and 69% in 2013 respectively. Drop in yield of GN when intercropped with FM could be expounded by the decreasing proportionate area under GN and subsequent decrease in yield attributes. It may also be attributed to more solar radiation interception by FM plants in strip cropping in comparison to sole planting.

A better representation of component yields in strip combinations is equivalent yield of dominating crop, i.e. FM-equivalent yield (FMEY). Among the different ratios of strip cropping, 4 rows of GN with 6 rows of FM consistently gave the higher FMEY along the years (2011–13). Strip ratio 6:4 gave 57, 44 and 59% higher yield than sole FM in 2011, 2012 and 2013, respectively. The pooled analysis of FMEY indicates an increase of 13.9, 14.4 and 16.1% in 6:4 ratio over strip ratios 8:4, 10:4 and 12:4 respectively. However, it was interesting to note that productivity of FM-based intercropping systems in terms of total as well as equivalent yield was higher than sole planting patterns. Our results confirm the findings of Dass and Sudhishri (2010).

The efficiency of different treatments is elucidated with yield function known as Production efficiency ($P_E$). Sole FM cultivation recorded the minimum $P_E$ of 12.36 kg/ha/day; whereas strip cropping of FM+GN showed improvement with average hike of 17%. Among different treatments strip ratio 6:4 registered an impressive increase of 17.6, 18.6 and 19.2% in strip ratios 8:4, 10:4 and 12:4 respectively. In a similar study with sorghum, pod yield of GN was significantly influenced in the intercropping system with cereal fodders (Ghosh, 2004).

**Table 1.** Effect of different strip cropping systems of finger millet, groundnut yield and economic returns

| Treatment | Yield of individual crop (t/ha) 2011 FM | 2011 GN | 2012 FM | 2012 GN | 2013 FM | 2013 GN | FMEY (t/ha) 2011 | FMEY 2012 | FMEY 2013 | COC (× $10^3$₹/ha) | NR (× $10^3$₹/ha) | Benefit: Cost ratio | Crop profitability (₹/ha/day) | Production efficiency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finger millet (FM) | 1.47 | – | 1.60 | – | 1.38 | – | 1.47 | 1.60 | 1.38 | 10.80 | 11.45 | 2.06 | 95 | 12.36 |
| Groundnut (GN) | – | 0.68 | – | 0.73 | – | 0.68 | 1.83 | 1.93 | 1.81 | 11.68 | 16.20 | 2.39 | 135 | 15.49 |
| FM + GN (6:4) | 1.40 | 0.34 | 1.42 | 0.33 | 1.37 | 0.31 | 2.31 | 2.30 | 2.21 | 11.85 | 22.18 | 2.87 | 185 | 18.94 |
| FM + GN (8:4) | 1.23 | 0.27 | 1.27 | 0.28 | 1.36 | 0.29 | 1.96 | 2.02 | 2.00 | 12.18 | 17.78 | 2.46 | 148 | 16.65 |
| FM + GN (10:4) | 1.30 | 0.24 | 1.33 | 0.24 | 1.30 | 0.23 | 1.94 | 1.97 | 1.92 | 12.93 | 16.31 | 2.26 | 136 | 16.20 |
| FM + GN (12:4) | 1.37 | 0.21 | 1.46 | 0.20 | 1.37 | 0.21 | 1.93 | 2.00 | 1.93 | 13.19 | 16.34 | 2.24 | 136 | 16.30 |
| SEm± | 0.05 | 0.02 | 0.03 | 0.02 | 0.07 | 0.01 | 0.06 | 0.05 | 0.06 | – | 0.32 | 0.03 | – | – |
| CD (P=0.05) | 0.15 | 0.05 | 0.11 | 0.05 | NS | 0.03 | 0.18 | 0.15 | 0.19 | – | 0.96 | 0.09 | – | – |

FMEY, Finger millet equivalent yield; COC, cost of cultivation, NR; net returns

### *Economics*

Pecuniary analysis of different treatments directs (Table 1) that with marginal increase in cost of cultivation from 1,050 to 2,690/ha substantial higher net returns were obtained. Strip cropping of FM+GN in different tested ratios enhanced net profits. Maximum net returns accrued from 6:4 ratio were nearly double the net returns from sole FM cultivation. The higher benefits are attributed to higher yield, high market price of component crop as well as low cost of cultivation of the treatment. Same ratio also gave significantly higher benefit: cost ratio.

The superiority of strip ratio 6:4 is also reflected in the MAI and IER, registering the maximum values (Table 3). The MAI followed the trend of LER, which indicates relative advantage from the produce in fiscal terms without any loss in comparison to sole FM cultivation. The IER shows the capability of the system giving 62% additional income (that of sole FM) in strip ratio 6:4 without any increase in area. Ghosh (2004) reported similar monetary benefits of GN intercropping with sorghum. Crop profitability describes net returns/ha/day obtained from different strip cropping systems. On mean data basis, the maximum values were recorded for strip ratio 6:4, which was 42% higher than farmers' practice (sole FM cultivation). All the strip ratios were numerically higher than sole GN cultivation, indicating strip cropping advantage statistically as well as economically.

### *Runoff, soil and nutrient losses*

On an average, 16 runoff events (17, 19 and 15) were obtained from a cumulative crop season rainfall of 912, 482 and 1,197mm in 2011, 2012 and 2013, respectively (Fig. 1). Strip cropping of GN with FM decreased runoff in all the strip cropping ratios. Being an erosion-resisting crop, GN reduced the runoff in 6:4 strip ratio to the tune of 25, 12.2 and 30% compared to sole FM in 2011, 2012 and 2013 respectively (Table 2). Average data of 3 years revealed that runoff conservation potential of FM+GN strip ratios 6:4, 8:4, 10:4 and 12:4 was 22.4, 11.9, 10.6 and 8.7%, respectively, compared to sole FM. The likely manifestation is that, due to spreading canopy of GN,

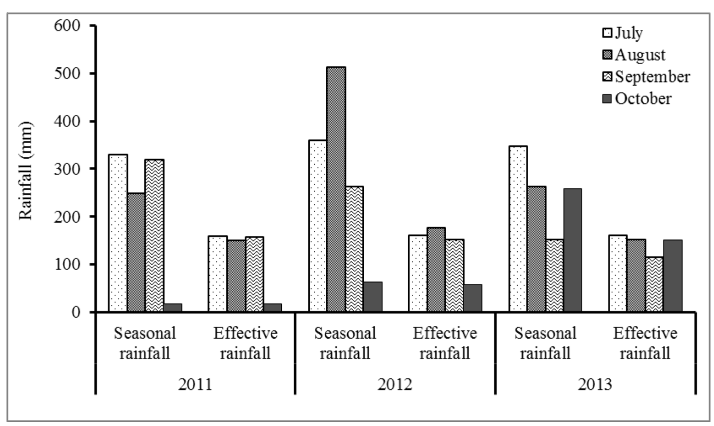


**Fig. 1.** Rainfall-distribution pattern during crop season.

**Table 2.** Effect of different strip cropping systems on resource conservation and water productivity

| Treatment | Runoff (%) | | | | Soil loss (t/ha) | | | | Nutrient loss (kg/ha) | | | Water productivity (kg/ha-mm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | Mean | 2011 | 2012 | 2013 | Mean | Organic carbon | P | K | 2011 | 2012 | 2013 | Mean |
| Finger millet (FM) | 10.71 | 13.00 | 9.26 | 10.96 | 9.83 | 11.03 | 6.20 | 9.02 | 83.8 | 0.200 | 3.01 | 3.04 | 2.93 | 2.40 | 2.79 |
| Groundnut (GN) | 6.59 | 7.93 | 5.20 | 6.57 | 2.13 | 3.20 | 1.23 | 2.19 | 44.4 | 0.143 | 1.56 | 3.80 | 3.54 | 3.15 | 3.49 |
| FM + GN (6:4) | 9.40 | 9.70 | 6.46 | 8.50 | 3.27 | 4.30 | 1.49 | 3.01 | 54.7 | 0.176 | 2.13 | 4.78 | 4.22 | 3.84 | 4.28 |
| FM + GN (8:4) | 10.53 | 10.57 | 7.93 | 9.70 | 3.97 | 5.47 | 1.80 | 3.75 | 67.6 | 0.186 | 2.67 | 4.07 | 3.71 | 3.48 | 3.75 |
| FM + GN (10:4) | 10.63 | 11.20 | 7.66 | 9.83 | 4.20 | 5.20 | 1.70 | 3.70 | 72.5 | 0.183 | 2.63 | 4.03 | 3.61 | 3.32 | 3.66 |
| FM + GN (12:4) | 10.10 | 11.93 | 8.10 | 10.03 | 3.80 | 5.57 | 1.69 | 3.68 | 71.9 | 0.186 | 2.62 | 4.01 | 3.68 | 3.34 | 3.68 |
| SEm± | 0.29 | 0.49 | 0.40 | 0.21 | 0.23 | 0.34 | 0.08 | 0.04 | 6.8 | 0.02 | 0.10 | 0.12 | 0.13 | 0.12 | 0.04 |
| CD (P=0.05) | 0.93 | 1.55 | 1.28 | 0.67 | 0.73 | 1.08 | 0.26 | 0.30 | 20.7 | NS | 0.33 | 0.38 | 0.38 | 0.35 | 0.12 |

which mars the beating action of raindrops. Across the slope sowing of alternate cereal and legume strips attributes better crop establishment and retention of sediment laden runoff by micro-depression created due to contour sowing and enhanced crop cover. Earthing-up in GN is an important cultural practice for root proliferation, pegging and for proper pod development. This practice also contributes to soil and moisture conservation and hence generated the least runoff in strip cropping treatments.

Soil and nutrient losses are governed by the runoff and soil fertility (nutrient availability). Maximum soil losses of 11.03, 9.83 and 6.20 t/ha were recorded in sole FM cultivation during the 2011, 2012 and 2013 respectively. The reason ascribed is that FM has poor canopy and on sloping uplands its poor plant stand leaves interspace area bare; which on rainfall causes high sediment loss. Like runoff, soil loss also showed a decreasing trend with assessable sediment loss in all strip cropping treatments. On an average, 6:4 ratio showed the lowermost soil loss values (3.02 t/ha) and conserved soil loss by 18.1, 19.6 and 17.4% in 8:4, 10:4 and 12:4 ratios. Most appropriate combination of FM with GN (6:4 ratio) leads to arrest of sediment. However, in the other strip cropping ratios, the balance was not maintained which is evident from different competitive functions (Table 3). The relationship between rainfall–runoff and runoff–soil loss was linearly correlated for all the treatments (Fig. 2). The regression equations for prediction of runoff and soil loss from rainfall were based on the highest $R^2$ and lowest RSS values (Table 4). The $R^2$ values spun around mean value of 0.84 and 0.68 for rainfall–runoff and runoff–soil loss respectively. These equations can be used for the estimation of runoff and soil loss under diverse strip cropping measures for different rainfall events for sloping lands of Eastern Ghats and contiguous areas of India. However, some points were scattered and laid far from the regression line. These results proved that the variability in the runoff might not be exclusively related to the amount of rainfall.

Among the nutrient losses, GN arrested maximum organic carbon loss, i.e. 44.6 t/ha followed by 6:4 ratio (55.8 t/ha) which also recorded the highest values for other nutrients (P, K) conservation. However, P loss remained non-significant with the reason ascribed that P remains in water-insoluble form. But K loss was significantly lowered by 22% in 6:4 strip ratio in comparison to sole FM; other strip cropping ratios remained statistically at par. These findings confirm those of Truman and Williams (2001). Srinivasarao *et al*. (2012) in their experiment, found an increase in GN pod yield by 13 kg/ha/year for every 1 Mg increase in profile SOC stock and emphasized on crop rotation and inclusion of residue in rainfed areas. Productivity of water (Wp) is the economic value of production

**Table 3.** Competitive functions in different strip cropping systems (mean data of 3 years)

| Treatment | LER | LEC | ATER | MAI | IER | $A_{FM}$ | $A_{GN}$ | $CR_{FM}$ | $CR_{GN}$ | $K_{FM}$ | $K_{GN}$ | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FM + GN (6:4) | 1.38 | 0.43 | 1.27 | 6166 | 1.62 | 0.378 | –0.378 | 1.33 | 0.75 | 7.84 | 1.30 | 10.15 |
| FM + GN (8:4) | 1.22 | 0.33 | 1.12 | 3214 | 1.61 | 0.027 | –0.027 | 1.02 | 0.98 | 2.27 | 1.34 | 3.04 |
| FM + GN (10:4) | 1.20 | 0.29 | 1.10 | 2768 | 1.49 | 0.023 | –0.023 | 1.02 | 0.98 | 2.56 | 1.28 | 3.29 |
| FM + GN (12:4) | 1.23 | 0.28 | 1.11 | 3011 | 1.40 | 0.029 | –0.029 | 1.02 | 0.98 | 4.11 | 1.29 | 5.30 |

LER, Land-equivalent ratio; LEC, land-equivalent coefficient; ATER, area time equivalent ratio; MAI, monetary advantage index; IER, income equivalent ratio; A- aggressivity; CR, competitive ratio; K, relative crowding coefficient; FM, finger millet; GN, groundnut

**Table 4.** Rainfall–runoff and runoff–soil loss relationship in different treatments

| Treatment | Rainfall–Runoff | | Runoff–Soil loss | |
|---|---|---|---|---|
| Finger millet (FM) | y = 0.2863x – 6.52 | $R^2$ = 0.88 | y = 0.0815x + 0.112 | $R^2$ = 0.75 |
| Groundnut (GN) | y = 0.1738x – 3.71 | $R^2$ = 0.84 | y = 0.0312x + 0.035 | $R^2$ = 0.67 |
| FM + GN (6:4) | y = 0.2596x – 6.04 | $R^2$ = 0.88 | y = 0.0313x + 0.055 | $R^2$ = 0.60 |
| FM + GN (8:4) | y = 0.2863x – 6.52 | $R^2$ = 0.88 | y = 0.045x + 0.015 | $R^2$ = 0.74 |
| FM + GN (10:4) | y = 0.204x – 3.60 | $R^2$ = 0.77 | y = 0.0619x - 0.047 | $R^2$ = 0.72 |
| FM + GN (12:4) | y = 0.3395x – 7.99 | $R^2$ = 0.80 | y = 0.0526x - 0.014 | $R^2$ = 0.62 |

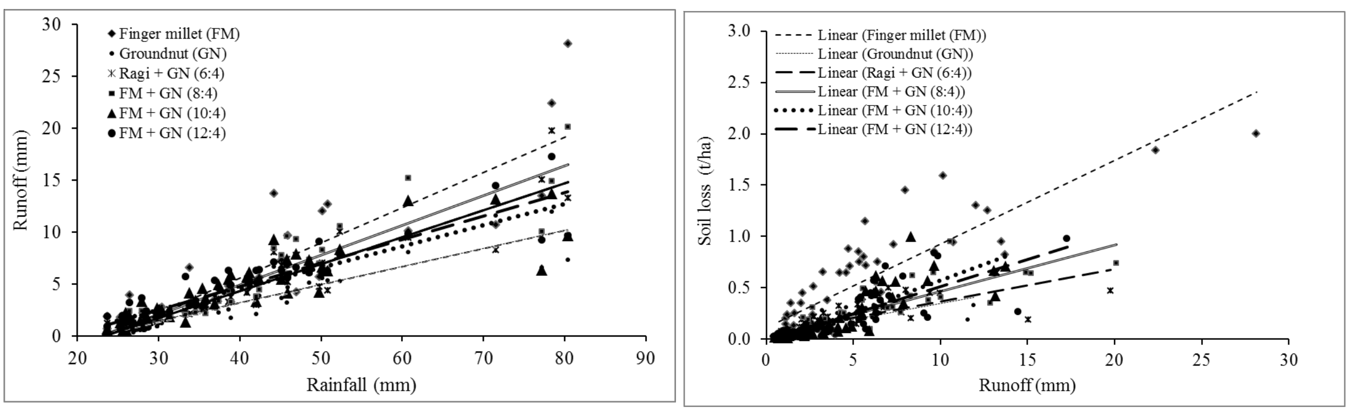


**Fig. 2.** Rainfall–runoff and runoff–soil loss relationship in different treatments.

measured against available water. In rainfed areas, Wp is of paramount importance as the conservation of rainfall in terms of runoff reduction affects the yield of the crop. A glance on the Wp of different strip ratios specifies the superiority of 6:4 system, registering maximum values of 4.78, 4.22 and 3.84 in 2011, 2012 and 2013 respectively. Soil-moisture conservation by legume crop in different soil depths might have contributed in enhanced water productivity. Mean data analysis of 6:4 ratio showed 14.1, 16.9 and 16.3% higher effect than 8:4, 10:4 and 12:4 ratios respectively.

### *Competition functions*

The LER of various strip cropping ratios was more than 1 in all the treatments (Table 3), indicating advantage over sole cropping. Maximum value of 1.38 was calculated in 6:4 ratio, indicating 38% area advantage over sole FM cultivation. Same strip ratio also recorded the maximum values for LEC and ATER to the tune of 0.43 and 1.27 respectively. Higher LEC values with FM+GN intercropping hints that inter-specific competition in 6:4 strip cropping systems was relatively less than the other ratios. It also indicates that FM+GN in this ratio have utilized available land, space properly and both with respect to time most efficiently. Higher values of LER and ATER in FM+GN strip cropping reflect the development of complimentarily with least competition in 6:4 ratio. It also establishes that growth requirement of both the component crops in FM+ GN differs in time, resulting in higher yield/ day of the system due to temporal complementary effect.

The aggressivity (A) values for all the strip cropping ratios were negative which indicate that FM have shown dominance over GN; however, dominance was the lowest in 10:4 strip ratio. Similar values of competition functions were also reported by Kumar and Singh (2006) with cereal/oilseed and legume intercropping. All the strip cropping systems were advantageous than sole planting systems because the product of relative crowding coefficient (K) of main and intercrops was more than 1 due to their complimentary relationship. The maximum values of $K_{FM}$ and $K_{GN,}$ 7.84 and 1.34 obtained from 6:4 and 8:4 strip ratios, respectively, directing greater advantage. This was further evident from their respective higher values of product of K (10.15). Our findings confirm those of Tuti *et al.* (2012). Higher values of competitive ratio (CR) of FM of its intercropping with GN indicated that it was more competitive to GN because it had relatively rapid initial growth leading to competition for resources with FM. Groundnut was comparatively less competitive because of their initial slow growth which is further evident from the fact that main crop had higher values of competitive ratio in association with these crops.

Our results fulfill the need of diversification of FM monocropping in Eastern Ghat region of Odisha through strip cropping; involving combination of 2 widely adopted crops of this tribal region. When these crops are grown in strips; they fetch drastic diminution in runoff, soil and nutrient loss along with benefits of increased nutrient conservation. Then best treatment of 6:4 ratio can be replicated on slope varying up to 2–4%, i.e. undulating upland region and farmers can get good returns. The finding has implication for improving the soil and crop productivity of the marginal land owners of uplands of Eastern Ghats region.

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