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Impact of slope and intercropping of Soybean-Maize on soil fertility under different slopes in North-East India

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Abstract
A field experiment was conducted in the experimental research farm of the School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University during the kharif season of 2016 and 2017 to study the impact of slope and intercropping of Soybean-Maize on soil fertility under different slopes in North East India. The experiment was laid out in strip plot design with three replications in which the slope was considered as main plot and intercropping as sub-plot. The data on soil quality indicators revealed that available N and available K showed significant variation due to addition of various treatments, whereas available P and organic carbon did not show any significant variation due to addition of treatments. Available N was found high with a value varied from 574.62 to 605.14 kg ha^{-1}, available P was recorded medium with a range from 10.02 to 13.18 kg ha^{-1} while available K was found low with a value ranged from 73.4 to 99.28 kg ha^{-1}. The organic C in the soil was high with a value varied from 1.38 to 1.48%.

Keywords: Soybean, maize, slope, intercropping, soil fertility

Introduction
Soil is the medium for growing crops and is the main source from where all the essential nutrients are obtained. Hence, protecting the soil is therefore an integral part for improving the productivity of different crops. About 90% of the jhum fields in Nagaland are cultivated upto 60% of slope. However, most of the fertile top soils are washed down during rainy season. According to ICAR reports, the average topsoil erosion during the cropping period is 44 MT/ha/year and it could be as high as over 100 MT/ha/year. It has been estimated that about 88.3 million tonnes of soil are lost actually in the North-eastern states of India along with 10.7, 0.4 and 6.0 thousand tonnes of N, P and K, respectively (Sharma and Prasad, 1995) [12]. However, wide variations in soil and nutrients losses are found depending on the slope gradient, nature of the soil, crop canopy, agricultural activities, etc. Soil and water conservation measures are indispensable for profitable agriculture and other land use development activities in North-east India. The production potential of soils varies with their fertility and inherent limitations and therefore the land needs to be used within its capabilities. The soil conservation measures protect the soil from loss and improve its fertility and productivity. Soybean and Maize are the two most common crops grown in North East India and intercropping of cereal with pulse is one of the most common agronomical soil conservation method practiced by the tribal people. Shifting cultivation variously known as rotational bush, jhumming, slash and burn cultivation is causing resources degradation and soil erosion problems in the hills. Thus, the present study was initiated to evaluate the impact of slope and intercropping of Soybean-Maize on soil fertility under different slopes in North-East India.

Materials and Methods
The field experiment was conducted during *kharif* season of 2016 and 2017 at School of Agricultural Sciences and Rural Development Research Farm, Medziphema Campus, Nagaland University. The research site is located at 25˚45'43" North latitude and 93˚53'04" East longitude with an altitude of 310 meters. The climate of the experimental site is sub-humid tropical with high humidity, moderate temperature and receives medium to high rainfall. Monsoon starts from the first week of June and extends to September and the rains gradually decrease from October. The dry period occurs from November to March. The average rainfall ranges between 2000-2500 mm.

The mean temperature ranges from 21 ºC to 32 ºC during summer and rarely goes below 8 ºC in the winter season. The experiment was laid out in strip plot design with three replications in which the slope (S_1, S_2 and S_3) was considered as main plot and intercropping (T_1, T_2, T_3, T_4, T_5 and T_6) as sub-plot. Soybean and Maize were sown in last week of June in both the years. Agronomic management practices were followed as per standard suggestion. Soil samples from individual plots were collected after the harvest of the crop. The soil samples were collected in a random zig-zag manner from the surface of the plough upto 0-15 cm (generally expressed as plough layer). The collected soil samples were quartered until 250-500 g composite sample was obtained. The air-dry soil samples were then passed through 2 mm sieve for analysis. For certain type of soil analysis (organic carbon) it becomes necessary to grind the soil further. So, the soil samples were passed through finer mesh sieve (size 0.2-0.5 mm). The available N in the soil was determined by using the method of alkaline permanganate as suggested by Subbiah and Asija (1956) [13]. The P extract of the soil was obtained by Bray's method No. 1 (Brays and Kurtz, 1945) [2]. The P content of the extract was estimated colorimetrically (Dickman and Bray, 1940) [3]. The available K was determined by Ammonium Acetate Extraction method (Hanway and Heidel, 1952) [7]. Organic carbon was determined by using Walkley-Black procedure with wet digestion method as outlined by Jackson (1973) [8]. The data were statistically analyzed using standard procedures of ANOVA at 5% level of significance.

Results and Discussion

Organic carbon

The data obtained on organic carbon of the soil under different slope percentage as depicted in Table 1 revealed that, 20% slope (S_3) showed the maximum organic carbon content in the first year of the experiment. However, in the succeeding year the organic carbon content was found to be highest in 9% slope (S_2) with a value of 1.40%. In both the experimental years the organic carbon content was lowest in 0% slope (S_1) with a value of 1.42 and 1.39%, respectively.

The results obtained on organic carbon content under different cropping pattern of maize and soybean revealed varying results in all the cropping system. It was clear from the results presented in Table 1 that sole soybean (T_2) resulted in highest organic carbon content with values of 1.43 and 1.43% during 2016 and 2017, respectively. The control (T_1) closely followed with value of 1.42 and 1.42%, respectively in the two years of experiment. The lowest organic carbon content was recorded in soybean + maize (1:2) (T_6) reporting 1.38 and 1.38% during 2016 and 2017, respectively. However, Habineza *et al*., (2018) [6] reported that intercropping reduced slightly organic carbon compared to sole crop. This could be due to competition among component crops which did not allow high biomass production which could result to high organic carbon production. Differences in organic carbon could also be depended on varietal genetic make ups. Matusso *et al*., (2012) [9] observed higher soil organic carbon in intercropping than in sole crop. Organic C did not show significant difference in both the years.

Table 1: Effect of slope and intercropping on soil organic carbon

Treatments	Organic carbon (%)		
	Pre sowing	2016	2017
Slope			
S_1 (0)	1.44	1.42	1.39
S_2 (9)	1.43	1.43	1.44
S_3 (20)	1.44	1.48	1.40
S.Em±	0.03	0.03	0.03
CD at 5%	NS	NS	NS
Crop			
T_1 - Control	1.42	1.42	1.42
T_2 - Sole Soybean	1.39	1.43	1.43
T_3 - Sole Maize	1.42	1.40	1.39
T_4 - Soybean +Maize (1:1)	1.40	1.39	1.39
T_5 - Soybean +Maize (2:1)	1.41	1.39	1.38
T_6 - Soybean +Maize (1:2)	1.39	1.38	1.38
S.Em±	0.03	0.03	0.03
CD at 5%	NS	NS	NS

Note: NS = Non- significant at 5% level of significance

Available Nitrogen

The data pertaining to the effect of intercropping on available N in soil is presented in Table 2. The available nitrogen of the soil under different slopes percentage varied from 575.01 kg ha^{-1} to 603.62 kg ha^{-1} in the year 2016 and 574.62 kg ha^{-1} to 605.14 kg ha^{-1} in the year 2017. The highest available nitrogen value was recorded in 0% slope (S_1) in both the years followed by 9% slope (S_2) recording 584.07 and 582.10 kg ha^{-1} during 2016 and 2017, respectively. The lowest available nitrogen was recorded in 20% slope (S_3) with a value of 575.01 and 574.62 kg ha^{-1} during 2016 and 2017, respectively. The higher available N value in 0% slope may be due to less erosion whereas the lowest available N value in S_3 i.e., 20% may be due to the steepness of slope which in this case is steeper than S_1 thus resulting in loss of topsoil.

Among the different sub-treatments, the highest available nitrogen i.e., 600.82 and 606.26 kg ha^{-1} were recorded in soybean + maize (1:2) (T_6) and control treatment (T_1) in 2016 and 2017, respectively followed by soybean + maize (2:1) (T_5). Garg (2004) [4] reported that, legumes in good conditions must use a lot of amount of carbohydrate to produce more nodules, hence, nitrogen fixation. The lowest available nitrogen (568.24 and 569.43 kg ha^{-1}) were found in sole maize (T_3) during 2016 and 2017, respectively. The higher available N value in control (T_1) must be due to vegetation cover which reduces the erosivity of runoff. While the lower value in T_3 i.e., Sole maize may be due to the loss of nutrients as maize is an erosion permitting crop.

Available Phosphorus

The data on the effect of intercropping on available P in soil is presented in Table 2. The available P content in soil ranged from 10.69 to 13.18 kg ha^{-1}. The data showed that intercropping of soybean and maize caused a significant increase in available P in all the treatments. Among the slopes, the highest available P was recorded in S_1 (Pre-sowing) and lowest available P was recorded in S_3 (2nd year). The highest available phosphorus i.e., 12.94 and 11.64 kg ha^{-1} were recorded in 9% slope (S_1) in 2016 and 2017, respectively. And the lowest available phosphorus (11.65 and 10.02 kg ha^{-1}) was found in 20% slope (S_3) during 2016 and 2017. The lowest available P in slope 20% (S_3) among the three slopes *viz*., S_1, S_2 and S_3 may be due to the more erosion in S_3 as it was steeper than the other two slopes i.e., S_1 & S_2. Low to medium range concentration of available phosphorus in the soils might be due to its fixation in soil colloid under strongly acidic soil reaction.

Among the different sub-treatments, the available phosphorus in the soil after various cropping pattern ranged from 10.69 to 11.78 kg ha^{-1} and 10.23 to 11.29 kg ha^{-1} in 2016 and 2017, respectively (Table 2). In both the years of the experiment the highest available phosphorus was found in soybean + maize (1:2) (T_6) followed by soybean + maize (2:1) (T_5) and the lowest was observed in sole maize (T_3). The lower available P value in T_3 i.e., sole maize may be due to the loss of nutrients as Maize is a voracious feeder and also an erosion permitting crop. This agrees with the results found by Phiri *et al*., (2013) [11] who reported that, some legumes have the capacity to enhance the availability and efficient utilization of residual phosphorus which is otherwise not available to cereals. Bandyopadhyay *et al*., (2007) [1], found that, legumes help in solubilizing insoluble phosphorus in soil, enhancing the soil physical area, improving soil microbial activity and restoring organic matter. Ghosh *et al*., (2009) concluded that soybean in advanced stages, with a developed root system, can increase the availability of native and fixed P for intercrops. The critical analysis of the data clearly revealed that there was no significant variation in both the years. This agrees with Matusso (2014) [10], who reported that, the available phosphorus values did not show any significant differences among treatments.

Table 2: Effect of slope and intercropping on soil available N, P and K

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	Pre sowing	2016	2017	Pre sowing	2016	2017	Pre sowing	2016	2017
Slope									
S_1 (0)	595.98	603.62	605.14	13.18	11.71	10.65	83.48	84.67	84.00
S_2 (9)	597.04	584.07	582.10	13.11	12.94	11.64	88.08	81.07	73.40
S_3 (20)	605.09	575.01	574.62	12.10	11.65	10.02	103.19	99.28	92.57
S.Em±	2.42	2.71	5.23	0.55	0.48	0.38	2.47	1.86	2.38
CD at 5%	9.68	10.65	20.55	NS	NS	NS	9.69	7.29	9.36
Crop									
T_1 - Control	599.69	600.41	606.26	11.76	11.35	10.23	100.95	86.93	78.70
T_2 - Sole Soybean	599.55	582.18	595.46	10.97	11.33	11.07	100.10	89.8	86.25
T_3 - Sole Maize	599.22	568.24	569.43	11.55	10.69	10.68	87.65	83.28	75.14
T_4 - Soybean +Maize (1:1)	598.36	573.94	581.80	11.49	11.48	11.14	86.02	81.12	76.63
T_5 - Soybean +Maize (2:1)	598.86	599.81	590.54	11.87	11.74	11.21	83.97	85.72	78.88
T_6 - Soybean +Maize (1:2)	600.54	600.82	580.21	11.79	11.78	11.29	90.81	83.20	76.33
S.Em±	0..57	7.39	7.26	0.30	0.49	0.33	2.71	1.82	3.11
CD at 5%	1.78	23.28	22.87	NS	NS	NS	8.53	5.75	9.79

Note: NS = Non- significant at 5% level of significance

Available Potassium

The data on the available potassium are presented in Table 2. Perusal of the data under different slope percentage revealed that the highest available potassium was noted in 20% slope (S_3) with a value of 99.28 and 92.57 kg ha^{-1} in both the experimental years. The lowest was recorded in 9% slope (S_1) with a value of 81.07 and 73.4 kg ha^{-1}. Under the different cropping patterns, the maximum available K was found in sole soybean (T_2) with a value of 89.80 and 86.25 kg ha^{-1} in 2016 and 2017, respectively. However, the minimum available K of 81.12 kg ha^{-1} was observed in soybean + maize (1:1) (T_4) in 2016 and 75.14 kg ha^{-1} in sole maize (T_3) in 2017. The less available potassium in soybean and maize intercropping in 2016 is in conformity with the findings of Zhi- Gang *et al*., (2014) [14] who reported that only maize/soybean intercropping decreased soil exchangeable K by 17.30% as compared to the corresponding mono-crops. The medium concentration of available potassium found in the soils during the research years may be due to the result of constant dynamics of potassium exchange in the soils.

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