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Influence of terracing and organic manures on the performance of soybean (*Glycine Max* l.) in Nagaland

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ABSTRACT

An experiment was conducted to investigate the influence of terracing and various organic sources on the yield and nutrient uptake of soybean during the kharif season of 2021 and 2022, on the experimental farm of the School of Agricultural Sciences (SAS), Nagaland University. Soybean variety DSB 19 was selected for the experiment. The experiment was performed in a split plot design (SPD) which was replicated thrice and was cultivated under two farming conditions i.e., terraced and non-terraced conditions with nine organic sources in different ratios. A significant increase in the seed and stover yield, as well as nutrient content and uptake, was recorded from the treatment C_1 (Bench terrace), signifying its superior performance over C_2 (non-terrace). Among the different organic sources, the yield attributes confirmed that treatment O_7 (Vermicompost @ 5 t ha^{-1}) recorded the highest seed and stover yield followed by treatment O_3 (FYM @ 10 t ha^{-1}). Further, the N, P, K and S content and uptake showed a significant increase in the treatment O_7. Thus, it can be concluded that terracing in conjunction with Vermicompost @ 5 t ha^{-1} and FYM @10 t ha^{-1} resulted in superior soil health condition, which thereby increased the overall yield and nutrient content of the crop.

Keywords: Vermicompost, FYM, Bench terrace, Seed yield, Nutrient content

INTRODUCTION

Soil, being a vital life support system, provides anchorage for roots, retains nutrients and water, hosts essential microbes for nitrogen fixation and decomposition, regulates water dynamics and nutrient cycling, and supports both human structures and biodiversity. However, with the escalating population, degradation of soil health in many cultivated areas has been manifested through loss of soil organic matter and depletion of native soil fertility, thus emerging as a major factor responsible for stagnation in agricultural production. Hence, attenuating good quality land resources for crop production has highlighted the urgency for continuously enhancing and sustaining the productivity of the land. Therefore, resource conservation by innovative means of management has become the need of the day. Terracing, a conservation measure widely adopted to control soil erosion (Liu *et al.* 2013), is a prominent human signature on global landscapes (Wei *et al.* 2016) as it improves agricultural stability. With its ability to decrease the slope length and gradient by dividing the hillsides into short gradual parts, it serves important functions in the conservation of water, reduction of erosion and flooding, restoration of degenerated habitats and increasing crop yields (Chen *et al.* 2020a). Here, Chen *et al.* (2020b) and Qiang *et al.* (2021) argue that such challenges can be met by building bench terraces. However, building level terraces is a crucial strategy to improve agricultural development in hilly areas as the topsoil of newly built terraces tends to be severely disturbed resulting in low nutrient content and a yield similar to that of conventional farmland. In such cases, organic manure application can be seen improving the soil organic matter, soil properties, soil quality and crop yield of the newly built terraces.

Prolonged application of chemical fertilizers alone leads to the deterioration of soil productivity and fertility (Saket *et al.* 2014). Organic sources of nutrients, according to Aher *et al.* (2018) act as a substitution for the nutrient requirement by the crops; a unique combination of environmentally sound practices with low external inputs while contributing to food availability and quality. Maheshbabu *et al.* (2008)

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also reported that the combined use of farmyard manure and vermicompost led to a significant increase in grain yield compared to their application alone. Soybean (*Glycine max* L.), a well-recognized oil grain legume crop belonging to the Fabaceae family, has been aptly regarded as the 'golden bean' of the 20th century because of its nitrogen-fixing ability through the symbiotic bacteria called Rhizobia within the nodules of their root system. Thus, the application of organic manures in terraced fields for such legume crops has been seen to directly correlate with the crop yield and properties of soil. Keeping these in mind, the present study was conducted to analyse the influence of terracing in conjunction to the application of various organic sources on the growth and yield and nutrient content and uptake of soybean.

MATERIALS AND METHODS

The experiments were conducted during the *kharif* seasons of 2021 and 2022 in the experimental farm of the School of Agricultural Sciences (SAS), Medziphema Campus, Nagaland University. Lying in the humid sub-tropical zone, the climate of the study area was characterized by high humidity and moderate temperature with medium to high annual rainfall. The soil was found to be well-drained and sandy loam in texture. The field experiment was arranged in a split plot design (SPD) with eighteen treatments and three replications *i.e.,* Factor I - Farming conditions, which includes C_1 - Bench terrace and C_2 - Non-terrace and Factor II – Organic sources which includes O_1 – Control, O_2 - FYM @ 5 t ha^{-1}, O_3 - FYM @ 10 t ha^{-1}, O_4 - Poultry manure @ 2.5 t ha^{-1}, O_5 - Poultry manure @ 5 t ha^{-1}, O_6 - Vermicompost @ 2.5 t ha^{-1}, O_7 - Vermicompost @ 5 t ha^{-1}, O_8 - Enriched compost @ 2.5 t ha^{-1}, O_9 - Enriched compost @ 5 t ha^{-1}.

The organic manures which include FYM, poultry manure, vermicompost and enriched compost were mixed separately and applied as per the allocation of treatments in plots 15 days before sowing. The recommended dose of NPKS was 20 kg N, 80 kg P_2O_5, 40 K_2O and 40 kg S ha^{-1} for soybean. Prior to sowing, the soybean seed (DSB 19) was treated with fungicide Bavistin @ 2 g L^{-1} of water and *Rhizobium japonicum* @ 20 g kg^{-1} seed which was later dried in the shade for an hour.

Following observations *viz.*, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), nutrient (NPKS) content (%) and uptake (kg ha^{-1}) were recorded. The seed and stover yield were obtained from the harvested soybean pods and plants. The nitrogen content was estimated by the modified Kjeldhal method as described by Black (1965), phosphorus content by the Vanado-molybdate-phosphoric acid method as outlined by Jackson (1973), potassium content by the flame photometer as described by Chapman and Pratt (1961) and sulphur content by the turbidimetric method as outlined by Chesnin and Yien (1951). Macronutrient uptake was calculated by multiplying the nutrient concentration of soybean (seed) with their respective yield. These collected data were further subjected to statistical analysis using Gomez and Gomez (1984). The analysis of variance (ANOVA) and critical difference at a 5 % of significance were calculated.

RESULTS AND DISCUSSION

Seed Yield

The soybean seed yield increased significantly during both years because of terracing (Table 1). This increase might be due to the cumulative effect of soil moisture which ultimately helps improve the nutrient-supplying capacity of soil and use efficiency. In those two years of experimentation, treatment C_1 (Bench terrace) was significantly higher compared to treatment C_2 (Non-terrace), by 13.33 and 18.45%, respectively. Hörbe *et al.* (2021) further demonstrated terraces' efficiency in reducing water deficits and enhancing productivity due to their associated presence with higher water availability, soybean and corn terraces-controlled runoff and higher crop yield. Similar results were reported by Deng *et al.* (2021) and Alam *et al.* (2024). Adding different organic manures resulted in a significant increase in the seed yield. The seed yield was observed to range from 937.46 to 2086.68 kg ha^{-1} in 2021 and 964.60 to 2278.24 kg ha^{-1} in 2022. In both years, treatment O_7 (Vermicompost @ 5 t ha^{-1}) was observed to increase the seed yield significantly over the rest of the treatments. This was followed by treatment O_3 (FYM @ 10 t ha^{-1}), whereby an increase in grain yield of 112.26 and 126.19%, respectively, over control and 16.67

and 21.67 over treatment O_8 (Enriched compost @ 2.5 t ha^{-1}) was observed. The improved crop performance under the application of organic manures might be due to the cumulative effects on soil available nutrients, enhanced organic carbon, higher microbial population, increased enzyme activities and the residual effect (Aher *et al.* 2018). Similar findings were reported by Keerthana *et al.* (2024) and Lestari *et al.* (2024).

Table 1: Effect of terracing and organic manures on the yield of soybean

Treatment	Seed yield (kg ha^{-1})		Stover yield (kg ha^{-1})	
	2021	2022	2021	2022
C_1 : Bench terrace	1875.73	2048.19	2828.83	2966.88
C_2 : Non-terrace	1655.11	1729.10	2673.12	2763.07
SEm±	1.89	5.25	2.92	7.95
CD (P=0.05)	11.50	31.95	17.76	48.39
O_1 : Control	937.46	964.60	1464.23	1472.43
O_2 : FYM @ 5 t ha^{-1}	1809.19	1922.14	2851.90	2956.95
O_3 : FYM @ 10 t ha^{-1}	1989.81	2181.80	3006.86	3218.47
O_4 : PM @ 2.5 t ha^{-1}	1737.78	1888.40	2804.43	2964.17
O_5 : PM @ 5 t ha^{-1}	1912.20	2015.02	2991.47	3085.04
O_6 : VC @ 2.5 t ha^{-1}	1854.76	2003.76	2844.54	2978.10
O_7 : VC @ 5 t ha^{-1}	2086.68	2278.24	3086.47	3255.55
O_8 : EC @ 2.5 t ha^{-1}	1705.50	1793.15	2769.00	2857.66
O_9 : EC @ 5 t ha^{-1}	1855.39	1950.71	2939.85	2996.41
SEm±	3.08	11.95	13.25	19.33
CD (P=0.05)	8.86	34.42	38.16	55.70

PM: Poultry manure; VC: Vermicompost; EC: Enriched compost

Stover yield

From the present study (Table 1), it was observed that the stover yield of the soybean crop increased significantly during both years due to terracing. In those two years of experimentation, treatment C_1 (Bench terrace) was recorded with a significantly higher stover yield of 2828.88 and 2966.88 kg ha^{-1} which is 5.83 and 7.38% higher over C_2 (Non-terrace). This might be due to the ability of terracing in increasing the soil moisture content during critical growth stage of soybean which effectively enhances crop endurance to droughts and increases the availability of nutrients, thereby consequently increasing crop yield (Deng *et al.,* 2021). The study further showed that the incorporation of different organic manures significantly increases the stover yield. The stover yield ranged from 1464.23 to 3086.47 kg ha^{-1} in 2021 and 1472.43 to 3255.55 kg ha^{-1} in 2022. In 2021, treatment O_7 (Vermicompost @ 5 t ha^{-1}) was observed to be superiorly significant over the rest of the treatments. This was followed by treatment O_3 (FYM @ 10 t ha^{-1}) whereby an increase in a stover yield of 105.35% over control and 8.59 and 21.67% over treatment O_8 (Enriched compost @ 2.5 t ha^{-1}) was observed. The increase in stover yield with the higher application of organic sources of nutrients was due to higher uptake and metabolism leading to an additional and easy availability of nutrients. Correspondingly, in 2022, treatment O_7 was recorded maximum and was found to be significantly at par with treatment O_3. An increase in a stover yield of 121.10 and 118.58% over control and 13.92 and 12.63% over treatment O_8 was observed. A reduction in the stover yield of 13.92and 10.10% was observed in treatment O_8 and O_2 over O_7. Similar findings were put up by Mohan *et al.* (2023), Verma *et al.* (2023) and Chen *et al.* (2024), whereby they highlighted the effectiveness of terracing in conjunction with the application of organic manures in enhancing agricultural productivity and sustainability as terracing provide favourable physical conditions for proper plant establishment and organic manures brings about an improvement in the soil nutrients and water use at early growth stages to soybean crops thereby contributing to higher seed yield and consequently stover yield.

Table 2: Effect of terracing and organic manures on nutrient content of soybean seed

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	2021	2022	2021	2022	2021	2022	2021	2022
C_1 : Bench terrace	6.14	6.17	0.45	0.47	1.47	1.48	0.25	0.27
C_2 : Non-terrace	6.03	6.08	0.44	0.45	1.44	1.45	0.24	0.25
SEm±	0.005	0.006	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	0.033	0.034	0.009	0.004	0.006	0.005	0.005	0.006
O_1 : Control	5.04	5.07	0.35	0.36	1.27	1.27	0.19	0.19
O_2 : FYM @ 5 t ha^{-1}	6.15	6.19	0.46	0.48	1.47	1.48	0.24	0.26
O_3 : FYM @ 10 t ha^{-1}	6.30	6.36	0.48	0.49	1.50	1.51	0.27	0.29
O_4 : PM @ 2.5 t ha^{-1}	6.13	6.15	0.43	0.44	1.46	1.46	0.23	0.24
O_5 : PM @ 5 t ha^{-1}	6.28	6.32	0.46	0.48	1.48	1.49	0.26	0.26
O_6 : VC @ 2.5 t ha^{-1}	6.16	6.20	0.47	0.48	1.47	1.49	0.26	0.27
O_7 : VC @ 5 t ha^{-1}	6.32	6.38	0.49	0.51	1.52	1.54	0.28	0.31
O_8 : EC @ 2.5 t ha^{-1}	6.11	6.15	0.42	0.44	1.45	1.46	0.24	0.25
O_9 : EC @ 5 t ha^{-1}	6.26	6.32	0.44	0.46	1.48	1.48	0.24	0.26
SEm±	0.016	0.012	0.002	0.004	0.002	0.001	0.002	0.003
CD (P=0.05)	0.046	0.035	0.006	0.012	0.005	0.004	0.006	0.008

PM: Poultry manure; VC: Vermicompost; EC: Enriched compost

Nutrient content

As per inquisition on the two years data (Table 2), terracing was found to significantly influence the nutrient content of soybean seed due to its ability to increase the moisture by avoiding water loss and effectively enhancing the crop's endurance to droughts which consequently increases the crop yield and simultaneously higher nutrient content (Deng *et al.,* 2021). The N, P, K and S content of soybean seed was recorded as significantly maximum under treatment C_1 (Bench terrace) with values of 6.14 and 6.17, 0.45 and 0.47, 1.47 and 1.48 and, 0.25 and 0.27%, respectively, with treatment C_2 (Non-terrace) recorded as significantly minimum with values of 6.03 and 6.08, 0.44 and 0.45, 1.44 and 1.45, and 0.24 and 0.25%, during both the years of study. The above results corroborate with those of Guzzetti *et al.* (2020) and Chen *et al.* (2021) who stated that conservation practice in the form of bench terrace results in minimal stress which thereby enhances the supply of nutrients and increases the nutrient content in both seed and stover for their effective uptake. Further, the application of organic sources, particularly FYM and vermicompost significantly influenced the nutrient content during the study period. The N, P, K and S content was observed to increase from 21.23 to 25.40, 20.00 to 40.00, 14.17 to 19.69 and 21.05 to 47.37% in 2021 and 21.30 to 25.84, 22.22 to 41.66, 14.96 to 21.26 and 26.32 to 63.16% in 2022 over control. In the year 2021, the N content was recorded maximum from treatment O_7 (Vermicompost @ 5 t ha^{-1}) with a value of 6.32% and was found to be significantly at par with treatments O_3 (FYM @ 10 t ha^{-1}) and O_5 (Poultry manure @5 t ha^{-1}). In the case of P, K and S content, treatment O_7 was found to be significantly highest with recorded values of 0.49, 11.52 and 0.28%, respectively. Meanwhile, the significantly lowest N, P, K and S content was recorded from treatment O_1 (Control) with values of 5.04, 0.35, 1.27 and 0.19%, respectively. However, in the year 2022, treatment O_7 was recorded with the highest N content of 6.38% and was found to be statistically at par with treatment O_3. Corresponding to the initial year, the significantly highest P, K and S content was recorded from treatment O_7 with noted values of 0.51, 1.54 and 0.31%. Gangwar *et al.* (2023) reported a significantly higher concentration of N, P and K by seed with the use of vermicompost due to the ability of the vermicompost to accelerate the availability of nutrients in the soil, through a faster overhaul of organic matter and the availability of growth hormones that accelerate plant growth besides fulvic acid and humic acid contained in organics which bind toxic substances in the soil. Also, proper establishment of roots, higher absorption of mineral nutrients from the soil, transport of more nutrients to seeds, vigorous plant growth and higher yields under proper availability of nutrients results in higher content of sulphur in seed and stover (Narendra *et al.* 2023).

Table 3: Effect of terracing and organic manures on nutrient uptake of soybean seed

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022	2021	2022
C_1 : Bench terrace	116.56	128.07	8.63	9.83	27.75	30.57	4.79	5.61
C_2 : Non-terrace	100.71	106.15	7.32	7.85	24.07	25.33	4.01	4.41
SEm±	0.06	0.37	0.02	0.04	0.04	0.09	0.02	0.03
CD (P=0.05)	0.37	2.25	0.10	0.24	0.24	0.58	0.11	0.16
O_1 : Control	47.29	48.88	3.27	3.46	11.90	12.28	1.76	1.87
O_2 : FYM @ 5 t ha^{-1}	111.33	118.99	8.40	9.20	26.55	28.39	4.34	4.92
O_3 : FYM @ 10 t ha^{-1}	125.56	138.96	9.55	10.66	29.78	33.04	5.36	6.37
O_4 : PM @ 2.5 t ha^{-1}	106.48	116.23	7.48	8.42	25.31	27.67	4.02	4.57
O_5 : PM @ 5 t ha^{-1}	120.09	127.47	8.73	9.60	28.38	30.10	4.94	5.36
O_6 : VC @ 2.5 t ha^{-1}	114.35	124.37	8.68	9.63	27.33	29.78	4.76	5.35
O_7 : VC @ 5 t ha^{-1}	131.99	145.58	10.31	11.76	31.79	35.10	5.87	7.16
O_8 : EC @ 2.5 t ha^{-1}	104.31	110.25	7.17	7.91	24.71	26.18	4.02	4.42
O_9 : EC @ 5 t ha^{-1}	116.29	123.28	8.17	8.91	27.42	28.99	4.52	5.09
SEm±	0.37	0.80	0.05	0.11	0.06	0.18	0.04	0.06
CD (P=0.05)	1.07	2.30	0.13	0.31	0.17	0.52	0.13	0.16

PM: Poultry manure; VC: Vermicompost; EC: Enriched compost

Nutrient uptake

Based on the two-year experimental data (Table 3), the nutrient uptake of soybean seed was seen to be significantly influenced by terracing. In 2021, the N, P, K and S uptake by soybean seed was recorded as significantly highest under treatment C_1 (Bench terrace) with values of 116.56, 8.63, 27.75 and 4.79 kg ha^{-1}, respectively, while the significantly lowest was recorded under treatment C_2 (Non-terrace) with values of 100.71, 7.32, 24.07% and 4.01 kg ha^{-1}, respectively. The N, P, K and S uptake in terraced plots were 15.73, 17.90, 15.29 and 19.45% higher over non terraced plots. This might be attributed to better availability and distribution of plant nutrients required for proper growth of soybean because of relatively better soil moisture regimes and slower organic matter decomposition under conservation practices, thus directly influencing the uptake of higher nutrients in conservation practices over non-conservation practices. These results agreed with the findings of Deng *et al.* (2021) and Khumbar *et al.* (2021). The study also showed that the application of organic sources results in an appreciable increase in nutrient uptake, noting significant variations within the treatments during both the years of study. In 2021, applications of various organic manures in different treatments (O_2 to O_9) caused an increase of 120.57 to 179.11, 119.27 to 215.29, 107.65 to 167.14 and 128.41 and 233.52% of N, P, K and S uptake by soybean seed over control, respectively (Table 3). Further, treatment O_7 (Vermicompost @ 5 t ha^{-1}) significantly increased the N, P, K and S uptake in soybean seed, thus noting to be superiorly higher with recorded values of 131.99, 10.31, 31.79 and 5.87 kg ha^{-1} over the rest of the treatments. Meanwhile, treatment O_1 (Control) was found to be significantly lowest in uptake of N, P, K and S with recorded values of 47.29, 3.27, 11.90 and 1.76 kg ha^{-1}. In 2022, the N, P, K and S uptake of soybean seed was observed to increase from 125.55 to 197.83, 128.61 to 239.88, 113.19 to 185.83 and 136.36 to 282.89% over control. Similar to the initial year, treatment O_7 was observed as significantly highest for the N, P, K and S uptake of soybean seed, with recorded values of 145.58, 11.76, 35.10 and 7.16 kg ha^{-1}. This was followed by treatment O_3. Meanwhile, treatment O_1 was seen as significantly lowest for all the nutrient uptake with recorded values of 48.88, 3.46, 12.28 and 1.87 kg ha^{-1}, respectively. The extent of crop removal of N, P, K and S was the highest in treatments receiving vermicompost and FYM than other treatments due to the higher availability of available nutrients in adequate quantity throughout the crop growth period (Aher *et al.* 2019). Singh and Lakhan (2022) also recorded higher uptake of nutrients with application of vermicompost.

CONCLUSION

Based on the results of the above investigation, terracing was seen to influence the

overall yield attributes of the soybean crops more than non-terraced plots. In addition, the application of organic manures, especially vermicompost and FYM was observed to influence and increase the growth performance equally and, thereby the crop yield. Higher nutrient content and uptake were also obtained in treatments with vermicompost and FYM. Thus, with sustainable agricultural practices being the need of the hour, it can be concluded that integration of conservation practices in the form of terracing (bench terrace) along with the application of Vermicompost @ 5 t ha^{-1} and FYM @ 10 t ha^{-1} resulted in improved soil fertility, which thereby enhanced the overall growth, yield and an increase in the nutrient content and uptake of the soybean crop.

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