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Productivity, nutrient content, nutrient uptake and post-harvest soil nutrient status of pigeonpea as influenced by pigeonpea-based intercropping system on hilly terraces of Nagaland

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ABSTRACT

A field experiment was conducted on "Productivity, nutrient content, nutrient uptake and post-harvest soil nutrient status of pigeonpea as influenced by the pigeonpea-based intercropping system on hilly terraces of Nagaland" during the kharif season of 2021 and 2022 at the experimental research farm, School of Agricultural Sciences (SAS), Medziphema, Nagaland University. There were 16 different treatments such as T_1 - pigeonpea + rice (1:1), T_2 - pigeonpea + rice (1:2), T_3 - pigeonpea + rice (1:3), T_4 - pigeonpea + sesame (1:1), T_5 - pigeonpea + sesame (1:2), T_6 - pigeonpea + sesame (1:3), T_7 - pigeonpea + greengram (1:1) , T_8 - pigeonpea + greengram (1:2) , T_9- pigeonpea + greengram (1:3), T_{10} - pigeonpea + soybean (1:1) , T_{11} - pigeonpea + soybean (1:2) , T_{12}- pigeonpea + soybean (1:3), T_{13} – sole pigeonpea, T_{14} – sole rice, T_{15} – sole sesame, T_{16} – sole greengram and T_{17} – sole soybean. The cultivation practices were the same for all the treatments. Experimental findings revealed that sole pigeonpeaT_{13}recorded the highest seed yield (1382.41 kg ha^{-1}), stover yield (3219.42 kg ha^{-1}), nutrient content in seed and stover of nitrogen (2.91 and 0.614 %), phosphorus (2.24 and 0.309 %) and potassium (0.248 and 1.003 %)and nutrient uptake nitrogen (40.51 and 20.14 kg ha^{-1}), phosphorus (31.14 and 10.13 kg ha^{-1}) and potassium (3.45 and 32.92 kg ha^{-1}).However, among the intercropping system, pigeon pea + soybean (1:1) T_{10} recorded elevated seed yield (1330.37 kg ha^{-1}), stover yield(3121.91kg ha^{-1}) and yield advantage over other treatments. It also recorded higher nutrient content (%) in seed and stover for nitrogen (2.91 and 0.612 %), phosphorus (2.23 and 0.306 %) and potassium (0.246 and 1.00 %) and nutrient uptake in seed and stover of nitrogen (38.87 and 19.51 kg ha^{-1}), phosphorus (29.84 and 9.77 kg ha^{-1}) and potassium (3.29 and 31.89 kg ha^{-1}). Significantly higher levels of available soil nitrogen were noted in pigeonpea + soybean (1:3) T_{12} (271.87 and 288.42 kg ha^{-1}) intercropping system before and after harvest of the crop, potentially attributable to the additional biomass contributed by the intercrops.

Key words: Intercropping system, Pigeonpea, Nutrient content, Nutrient uptake, and Yield.

INTRODUCTION

Pigeonpea is an important legume crop of rainfed agriculture in the semiarid tropics and is considered India's second most important pulse crop after chickpeas. The ability of pigeonpea to adapt and grow well under moisture deficit makes it a pre-eminent crop. Pigeonpea is considered one of the most essential drought-tolerant pulse crops due to the deep root system and germplasm, which have higher osmotic adjustment than other pulses. In recent times, pigeonpea have been gaining popularity due to their restorative nitrogen capacity in the soil and the addition of much organic matter. Pigeonpea also acts as a soil ameliorant and provides several benefits to the soil and its growing environment. Humans and livestock use seeds, pods, and leaves, which are rich in nutrition. The crop generally enhances soil fertility through leaf litter and biological nitrogen fixation (Udhaya *et al.,* 2015). The deep penetration and lateral spread of the root system in the soil profile enable the crop to tolerate drought, nutrient uptake minimisation and moisture uptake from deeper soil layers. When pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index. Intercropping results in higher yield over sole cropping with practical usage of existing resources along with diversified crops with diverse rooting ability, canopy arrangement, height and nutrient requirements, based on the corresponding exploitation of growth resources by the component sole crops (Lithourgidis*et al.,* 2011). Resources can be utilised better when growing more than one crop than when developing a mono-cropping system

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(Sobkowicz, 2006). Besides increased overall productivity and income, intercropping of legumes with cereals helps conserve moisture by reducing runoff, improving the physical properties of soil and building up soil fertility. As short-duration herbs, legumes like green gram/black gram may constitute potential intercrop in upland rice under rainfed conditions. Therefore, we aimed to diversify pigeonpea through intercropping with various crops to enhance and stabilise the productivity of pigeonpea in rainfed uplands.

MATERIALS AND METHODS

The investigation was conducted in the experimental farm of the School of Agricultural Sciences (SAS) Nagaland University Campus, Medziphema, during the *kharif* season 2021 and 2022. The farm is situated at the foothill of Nagaland at 310 meters above the mean sea level with a geographical location of 25° 45/ 43//Northlatitudeand95°53/ 04// East longitude. The average temperature during summer varies from 21-32°C, while during winter; it varies from 8-20°C. The average rainfall varies from 2000-2500 mm starting from April, whereas in November-March, it is dry. The experimental plot's soil was acidic, well-drained and sandy loam in texture. The experiment was carried out with the following treatments, T_1 - pigeonpea + rice (1:1), T_2 - pigeonpea + rice (1:2), T_3 - pigeonpea + rice (1:3), T_4 - pigeonpea + sesame (1:1), T_5 - pigeonpea + sesame (1:2), T_6 - pigeonpea + sesame (1:3), T_7 - pigeonpea + greengram (1:1) , T_8 - pigeonpea + greengram (1:2) , T_9- pigeonpea + greengram (1:3), T_{10} - pigeonpea + soybean (1:1) , T_{11} - pigeonpea + soybean (1:2) , T_{12}- pigeonpea + soybean (1:3), T_{13} – sole pigeonpea, T_{14} – sole rice, T_{15} – sole sesame, T_{16} – sole greengram and T_{17} – sole soybean. The cultivation practices were the same for all the treatments. The recommended dose of fertiliser for the main crop and sole of the intercrop was applied in all the plots.

Seeds were treated with fungicide before sowing. The recommended dose of fertilisers was given (pigeon pea 20:40:30, rice 60:40:30, sesame 30:40:30, green gram and soybean20:60:40) in the form of urea, single super phosphate and muriate of potash, N was applied as three split doses while P and K as basal doses during sowing. In the case of intercropping treatments, fertilisers were applied proportionately to the sole optimum population for the main crop and intercrop separately. Weeding and plant protection measures were undertaken per their need, and the required plant population was maintained. 'PA 291', 'CAU R2', GT 10, Pusa Vishal and JS 9752 varieties of pigeonpea, rice, sesame, greengram and soybean respectively were used. The crops were harvested at their physiological maturity and sun-dried properly before threshing, then the weight for each plot was taken separately, recorded and converted. Nutrient uptake in seed and stover of pigeonpea crop was calculated in kg/ha in relation to dry matter production/ha using the formula.

Nutrient uptake (kg/ha)

$$= \frac{\text{Nutrient content (\%) in seed or stover x Yield (seed or stover in kg/ha)}}{100}$$

RESULTS AND DISCUSSION

I Seed yield of pigeonpea

Yield of pigeonpea

The seed yield of pigeonpea in different intercropping systems was significantly influenced. Pooled data for 2021and2022are presented in Table 2. Sole pigeonpea T_{13} significantly recorded superior crop yield (1382.41kg ha^{-1}) and stover yield (3219.42 kg ha^{-1}) and was substantially at par with pigeonpea+soybean (1:1) T_{10}(1330.37 and 3121.91 kg ha^{-1} for seed and stover yield respectively). Meanwhile, the minimum value was recorded in pigeonpea+rice (1:3) T_3(830.74 and 2169.45kg ha^{-1} for seed and stover yield respectively). Higher yield in sole crop might be due to higher values of yield-attributing characters, such as lower competition for resources, viz. space, moisture, and nutrients in sole cropping, compared to intercropping. Results confirmed the findings of Biradar *et al.* (2020), who also reported that sole pigeonpea produces the highest seed yield. Similar findings were also reported by Kithan *et al.* (2020).

II Response of plant nutrient content and uptake

Nutrient content (%) in pigeonpea:

An inquisition of pooled data depicted on nutrient content in pigeonpea was statistically

Table1: N P K content (%)of pigeonpea under different intercropping systems

Treatments	N-content Seed (%)	N-content Stover (%)	P-content Seed (%)	P-content Stover (%)	K-content Seed (%)	K-content Stover (%)
T_1: P+R (1:1)	2.87	0.605	2.20	0.301	0.237	0.996
T_2: P+R (1:2)	2.80	0.599	2.16	0.295	0.234	0.992
T_3: P+R (1:3)	2.77	0.593	2.12	0.285	0.227	0.988
T_4: P+S (1:1)	2.89	0.609	2.22	0.304	0.246	0.998
T_5: P+S (1:2)	2.81	0.600	2.17	0.297	0.234	0.993
T_6: P+S (1:3)	2.78	0.594	2.13	0.288	0.228	0.989
T_7: P+G (1:1)	2.88	0.606	2.21	0.303	0.241	0.997
T_8: P+G (1:2)	2.84	0.601	2.18	0.298	0.236	0.994
T_9: P+G (1:3)	2.79	0.595	2.14	0.293	0.230	0.990
T_{10}: P+SB (1:1)	2.91	0.612	2.23	0.306	0.246	1.000
T_{11}: P+SB (1:2)	2.85	0.603	2.19	0.299	0.237	0.995
T_{12}: P+SB (1:3)	2.80	0.598	2.15	0.295	0.232	0.991
T_{13}: Sole P	2.91	0.614	2.24	0.309	0.248	1.003
SEm±	0.01	0.001	0.01	0.001	0.000	0.001
CD (P=0.05	0.02	0.002	0.04	0.002	0.001	0.004

P=Pigeonpea, R=Rice, G=Greengram, SB= Soybean GG=Greengram

analysed and presented in Table 1, revealing higher nutrient content in seed and stover of sole pigeonpea $T_{13}$for nitrogen (2.91 and 0.614 %), phosphorus (2.24 and 0.309 %) and potassium (0.248 and1.003 %) in both the years of the experiment and was significantly at par with Pigeonpea + Soybean (1:1) for nitrogen (2.91 and 0.612 %), phosphorus (2.23 and 0.306 %) and potassium, (0.246 and 1.0 %). While Pigeonpea + Rice (1:3) T_3 recorded the least nutrient content in seed and stover for nitrogen (2.77 and 0.593 %), phosphorus (2.12 and 0.285 %) and potassium (0.227 and 0.988 %). Similar findings were reported by Das (2012), who noted that the cropping system significantly affected the N and P content of seed and stover in sole pigeonpea.

Table2: N P K-uptake (kgha^{-1}) of pigeonpea under different intercropping systems

Treatments	N-uptake seed (kg ha^{-1})	N-uptake stover (kg ha^{-1})	P-uptake seed (kg ha^{-1})	P-uptake stover (kg ha^{-1})	K-uptake seed (kg ha^{-1})	K-uptake stover (kg ha^{-1})	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1: P+R (1:1)	33.52	17.54	25.72	8.73	2.78	28.88	1169.08	2814.91
T_2: P+R (1:2)	27.89	14.83	21.48	7.32	2.32	24.56	989.44	2454.46
T_3: P+R (1:3)	23.09	12.87	17.68	6.19	1.89	21.42	830.74	2169.45
T_4: P+S (1:1)	36.19	18.36	27.72	9.16	3.07	30.08	1218.89	2903.33
T_5: P+S (1:2)	28.45	15.32	21.93	7.57	2.37	25.34	1011.30	2518.36
T_6: P+S (1:3)	24.92	13.50	19.13	6.54	2.04	22.47	897.59	2272.86
T_7: P+GG (1:1)	34.91	17.97	26.76	8.99	2.92	29.56	1189.81	2850.52
T_8: P+GG (1:2)	30.76	16.43	23.59	8.13	2.55	27.17	1082.22	2635.37
T_9: P+GG (1:3)	23.90	12.96	18.35	6.39	1.97	21.56	857.41	2133.93
T_{10}: P+SB (1:1)	38.87	19.51	29.84	9.77	3.29	31.89	1330.37	3121.91
T_{11}: P+SB (1:2)	28.95	15.32	22.27	7.60	2.41	25.26	1016.67	2536.30
T_{12}: P+SB (1:3)	26.02	13.98	20.01	6.89	2.16	23.18	930.74	2317.35
T_{13}: Sole P	40.51	20.14	31.14	10.13	3.45	32.92	1382.41	3219.42
SEm±	0.53	0.27	0.43	0.14	0.04	0.45	23.85	54.02
CD (P=0.05	1.50	0.76	1.22	0.38	0.13	1.28	67.83	153.59

Nutrient uptake (kg ha^{-1}) in pigeonpea

A critical examination of the pooled data presented in Table 2 revealed that the nutrient uptake in seed and stover was highest in sole pigeonpea $T_{13}$for nitrogen (40.51 and 20.14kg ha^{-1}) and was found at par with pigeonpea + soybean (1:1) T_{10}(38.87 and19.51kg ha^{-1}). Similarly, for phosphorus (31.14 and 10.13kg ha^{-1}) and potassium (3.45 and 32.92kg ha^{-1}) the highest value was noted in sole pigeonpea T_{13}

and was par with pigeonpea + soybean (1:1) T_{10} for phosphorus (29.84 and 9.77 kg ha^{-1}) and potassium (3.29 and 31.89kg ha^{-1}). The lowest nitrogen uptake in seed and stover was recorded from pigeon pea + rice (1:3) T_3 for nitrogen (23.09 and 12.87 kg ha^{-1}), phosphorus (17.68 and 6.19 kg ha^{-1}) and potassium (1.89 and 21.42 kg ha^{-1}). The results were in accordance with Zhao *et al.* (2022) for nitrogen uptake, Chhetri and Sinha (2020) in sole maize for phosphorus and Shivakumar *et al.* (2022) for phosphorus. Higher nutrient uptake may be due to higher dry matter production and concentration of nutrients of pigeonpea sown as sole.

III Response of Soil properties

Available nitrogen (kgha^{-1})

The pooled data presented in Table 3 revealed that the data on available nitrogen in soil under the intercropping system with pigeonpea was significant. Pigeonpea+ soybean (1:3) T_{12}(271.87 and 288.42 kg ha^{-1}) recorded the maximum available nitrogen in soil and was at par with pigeonpea+ greengram (1:3) T_9(267.62 and 285.08 kg ha^{-1}), pigeonpea +sesame (1:3) T_6(263.98 and 282.57 kg ha^{-1}), sole pigeonpeaT_{13}(258.99 and 275.88 kg ha^{-1}) before and after harvest of the crop. The minimum available nitrogen in the soil was recorded in sole rice T_{14} (229.05 and 242.43 kg ha^{-1}). Intercropping resulted in a significant increase in available soil nitrogen content. Singh *et al.* (2008) observed that the highest values of available soil N, P and K were recorded after the harvest of crops in the intercropping system of maize+ soybean.

Available phosphorus (kgha^{-1})

A critical examination of the mean data presented in Table 3 revealed that the available phosphorus of soil failed to show any significant effectduring 2021 and 2022 under inter cropping with pigeonpea.

Available potassium (kgha^{-1})

From the perusal of the result, it was evident from the mean data presented in Table 3 that the available potassium in soil showed no significant effect during 2021 and 2022 under intercropping with pigeonpea.

Soil pH

Pooled data related to the soil pH of pigeonpea with intercrops as influenced by different treatments are summarized in Table 3, from the given mean data of 2021 and 2022, it can be observed that soil pH failed to show any significant difference under an intercropping system with pigeonpea.

Table 3: Available nutrients (kgha^{-1}), soil pH and soil organic carbon of pigeonpea under different intercropping systems

Treatments	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		pH		OC (%)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T_1: P+R (1:1)	249.14	259.99	23.42	23.40	158.14	157.90	4.94	4.76	1.44	1.39
T_2: P+R (1:2)	242.35	250.79	23.51	23.88	159.94	160.38	4.98	4.88	1.50	1.46
T_3: P+R (1:3)	255.14	262.13	24.52	25.02	167.55	172.93	5.01	4.92	1.53	1.49
T_4: P+S (1:1)	244.86	254.97	23.33	23.29	154.56	154.56	4.90	4.75	1.38	1.37
T_5: P+S (1:2)	250.95	260.86	23.50	23.50	158.82	164.86	4.96	4.83	1.47	1.44
T_6: P+S (1:3)	263.98	282.57	24.47	24.64	164.86	172.03	4.99	4.90	1.53	1.50
T_7: P+GG (1:1)	247.44	257.90	23.22	23.20	152.32	155.90	4.93	4.75	1.41	1.38
T_8: P+GG (1:2)	249.75	261.94	23.48	23.61	158.48	163.52	4.96	4.87	1.46	1.45
T_9: P+GG (1:3)	267.62	285.08	24.13	24.38	161.73	169.09	5.03	4.91	1.58	1.55
T_{10}: P+SB (1:1)	244.57	254.14	23.16	23.08	148.29	151.42	4.84	4.68	1.37	1.32
T_{11}: P+SB (1:2)	249.29	260.85	23.44	23.46	150.98	159.94	4.95	4.81	1.45	1.40
T_{12}: P+SB (1:3)	271.87	288.42	23.71	23.81	160.83	168.45	4.99	4.89	1.63	1.62
T_{13}: Sole P	258.99	275.88	22.82	22.95	148.29	148.49	5.08	4.99	1.55	1.52
T_{14}: Sole R	229.05	242.43	21.01	22.85	143.36	145.15	5.11	5.16	1.49	1.50
T_{15}: Sole S	243.88	248.70	22.97	23.09	146.05	146.05	5.09	5.02	1.52	1.50
T_{16}: Sole GG	244.14	252.88	22.92	23.14	148.74	158.48	5.04	4.94	1.55	1.52
T_{17}: Sole SB	244.44	253.88	23.07	23.17	150.08	158.81	5.06	4.97	1.57	1.54
SEm±	5.68	9.13	0.63	0.51	17.24	13.93	0.05	0.13	0.05	0.04
CD(P=0.05)	16.36	26.30	NS	NS	NS	NS	NS	NS	NS	0.11

Soil organic carbon (%)

The pooled data pertaining to soil organic carbon are presented in Table 3. Data in the table indicate that the intercropping system with pigeonpea treatments had no significant impact on the soil organic carbon in the first year of the experiment in 2021 but was influenced significantly in 2022. The highest soil organic carbon was found pigeonpea + soybean T_{12}(1.62 %) and was considerably at par with found pigeonpea + greengram T_9 (1.55 %), sole soybean T_{17} (1.54 %), sole greengram T_{16} (1.52 %) and sole pigeonpea T_{13}(1.52 %). Chidowe *et al.* (2017) reported similar observations in their experiment.

CONCLUSION

Based on the experiment results, the following conclusion can be made: sole pigeonpeaT_{13}recorded superior seed yield over the rest of the treatments. Among the intercropping systems, pigeon pea + soybean (1:1) T_{10}intercropping recorded the highest seed yield and yield advantage over other treatments. The sole pigeonpea crop also recorded higher nutrient content and nutrient uptake, possibly due to higher seed yield of the main and intercrop. Soil organic carbon and available soil nitrogen were significantly higher in the pigeonpea+ soybean (1:3) T_{12}intercropping system, which may be associated with biomass added by the intercrops and the ability of the legumes to fix atmospheric nitrogen.

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