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The Effect of Napier Grass+Cowpea Intercropping and Different Fertilizer Levels on Soil Characteristics and Economics

Manisha Chaudhary[1], Rajeev[1], Ramandeep Singh[1], Kritika[1], Hina Upadhyay[1] 10.18805/ag.D-5894

ABSTRACT

Background: The field experiment was conducted to check the optimization of fertilizer requirement for napier grass and cowpea intercropping system at the farm of Lovely Professional University, Phagwara, Punjab during kharif season (2022).

Methods: Three replications of factorial RBD design with 4 cropping patterns (I_1, I_2, I_3 and I_4) and 3 fertilizer levels (F_1, F_2 and F_3) were set up. Study was conducted on total twelve treatment combinations, I_1 (Sole napier with 100, 75 and 125% RDF), I_2 (Sole Cowpea with 100, 75 and 125% RDF), I_3 (Napier grass+cowpea intercropping in 1:2 ratio with 100, 75 and 125% RDF) and I_4 (Napier grass+cowpea intercropping in 1:3 ratio with 100, 75 and 125% RDF).

Result: The results showed that in the interaction effect of intercropping and fertilizer levels the the highest value of pH and EC was found to be in I_1F_2- Sole Napier+75% RDF (8.04 and 0.42 mhos cm^{-1}, respectively). Higher OC was found in I_4F_3- Napier+cowpea (1:3)+125% RDF (18.23%) as compared to sole napier. However, sole cowpea plots recorded highest OC (18.60 %) in I_2F_3- Sole Cowpea+125% RDF but lowest pH and EC. The lowest N, Pand K in soil were seen in I_1F_2- Napier grass+75% RDF (90.00, 10.93 and 124.4 kg ha^{-1}, respectively) in interaction of intercropping and fertilizer levels among treatment combinations of napier grass. I_2F_3- Sole cowpea+125% RDF recorded (225, 20.68 and 214.93 kg ha^{-1}) N, P and K, respectively, which was highest among all the treatment combinations. Highest net returns and B: C ratio of 3.37 was recorded from intercropping ratio 1:3 and 125% RDF which was followed by 100% RDF (3.13) and 75% RDF (2.77).

Key words: Cowpea, Intercropping, Napier grass, NPK.

INTRODUCTION

Pennisetum purpureum Schumach. (2n=28), commonly known as Napier grass, is a vigorous perennial grass that has been widely used as a tropical feed, yielding more dry matter (DM) than other tropical grasses (Hanna *et al.,* 2004). With excellent agronomic and management methods, Napier is a tall, mostly vegetatively propagated perennial native to Sub-Saharan Africa that may generate biomass of 20-30 tonnes of dry matter ha^{-1} year^{-1}. However, using traditional methods, the productivity of Napier grass begins to decline after a few years, especially if correct care is not applied. Napier grass stem cuttings or root splits are planted 15-20 cm deep in well-prepared soil, using organic or inorganic fertilizers, at 60 cm×60 cm, 90 cm×60 cm, or 90 cm×90 cm spacing, depending on the quantity of rainfall received. The closer the gap, the heavier the rainfall (Orodho, 2006). The introduction of high-yielding Napier fodder types is one of the most promising approaches for increasing forage availability in mixed crop-livestock production systems in high-rainfall locations (Orodho, 2006; Nyambati *et al.,* 2010). In general, Napier grass accessions have distinct growth, days to maturity, plant height, DM yield, morphological fractions*and* climatic adaptability features. These genetic differences are the basis for nutritive value variation, as well as the production, utilization*and* various management practices (Kebede *et al.,* 2016). Cowpea is the ideal intercrop to support the green fodder output as well as the economics of hybrid Napier cultivation during the winter months (Verma *et al.,* 2011). Including a legume in the production of fodder grasses would not only give a nitrogen supply to stimulate grass growth, but it would also improve the feed quality. Legumes help grasses by fixing nitrogen in the air, decaying dead root nodules and mineralizing shed leaves. The major reason for intercropping is yield advantage because environmental resources like water, light and nutrients may be used more efficiently in intercropping than in sole cropping systems (Jinghui *et al.,* 2006). As a result, using grass-legume forage intercropping helps to boost land and livestock feed productivity. According to Iannetta *et al.* (2016), legumes improve soil nitrogen by fixing between 32 and 115 kg ha^{-1} of nitrogen in symbiosis with rhizobium bacteria. This can reduce the need for fertilizer in the crops that are produced afterward, resulting in a nitrogen reduction of between 23 and 31 kg ha^{-1} (Preissel *et al*., 2015). The cereal-legume intercropping method helped in soil

[1]School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India.

Corresponding Author: Rajeev, School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India.
Email: rajeev.26421@lpu.co.in

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conservation, enhanced the properties of the soil and improved nutrient and moisture uptake (Akman *et al.,* 2013). He found that adding legume crops to a system over a sole crop improved the amount of soil organic carbon and the amount of N, P and K that was readily available. So, crop combinations of grains and legumes can be considered a more profitable endeavor to increase the fertility of the soil.Therefore, compared to monocropping systems, legume intercropping with grasses allows lower inputs through reduced fertilizer and pesticide requirements and it contributes to a greater uptake of water and nutrients, increased soil conservation, increased efficiency of land use, improving the capture and use of light, controlling weeds, high productivity and profitability (Coll *et al*., 2012).

MATERIALS AND METHODS

The field experiment was conducted in *kharif* season at Agriculture Research Farm of Lovely Professional University, Phagwara, Punjab (India) in 2022. The farm is located at 5423 m above sea level at a geographical altitude of 31.2690°N at 75.702°E longitude. It has a tropical climate of monsoon with an average rainfall of 600 mm and a climate with severely cold winters and hot summers. The annual average temperature in Punjab ranges from 10°C to 46°C, with temperatures reaching 49°C in the summer and falling to 1°C in the winter. Analyses of the site's soil revealed that it was sandy loam with a pH of 7.72, EC of 0.279 mhos cm^{-1}, an organic carbon content of 0.310% and soil nutrients of N-215, P-21 and K-200 (kg ha^{-1}).

The two crops used as the primary components of the treatments were Napier grass (*Pennisetum purpureum*) and cowpea (*Vigna unguiculata*), both of which intercropped and planted as pure stands as well. The experiment was carried out in Factorial RBD in three replications comprised of twelve treatment combinations in *kharif,* 2022. Three replications of a 4×3 factorial experiment with 4 cropping patterns (I_1, I_2, I_3 and I_4) and 3 fertilizer levels (F_1, F_2 and F_3) were set up. Plots were 7.2 m×5 m in size, with 1 m between each replication. The treatment combinations included were, I_1F_1- Sole Napier+100% RDF; I_1F_2-Sole Napier+75% RDF; I_1F_3- Sole Napier+125% RDF; I_2F_1-Sole Cowpea+100% RDF; I_2F_2- Sole Cowpea+75 % RDF; I_2F_3- Sole Cowpea+125 % RDF; I_3F_1- Napier and Cowpea Intercropping (1:2)+100% RDF; I_3F_2- Napier and Cowpea Intercropping (1:2)+75 % RDF; I_3F_3- Napier and Cowpea Intercropping (1:2)+125 % RDF; I_4F_1- Napier and Cowpea Intercropping (1:3)+100% RDF; I_4F_2- Napier and Cowpea Intercropping (1:3)+75 % RDF; I_4F_3- Napier and Cowpea Intercropping (1:3)+125 % RDF.

Table 1: Soil chemical properties (pH, EC, OC) as affected by different treatments.

Symbol	Treatments	pH	EC (mhos cm^{-1})	OC (%)
Intercropping				
I_1	Sole Napier	8.02	0.41	17.37
I_2	Sole Cowpea	7.65	0.34	18.44
I_3	Napier+cowpea (1:2)	7.94	0.38	17.82
I_4	Napier+cowpea (1:3)	7.85	0.36	18.13
SE.m±		0.05	0.00	0.06
CD(P<0.05)		0.14	0.01	0.18
Fertilizer levels				
F_1	100% RDF	7.84	0.36	18.00
F_2	75% RDF	7.87	0.37	17.95
F_3	125% RDF	7.84	0.36	18.06
SE.m±		0.04	0.00	0.05
CD(P<0.05)		NS	0.01	0.16
Interaction				
I_1F_1	Sole Napier+100% RDF	8.02	0.41	17.37
I_1F_2	Sole Napier+75% RDF	8.04	0.42	17.23
I_1F_3	Sole Napier+125% RDF	8.00	0.39	17.50
I_2F_1	Sole Cowpea+ 100% RDF	7.66	0.34	18.47
I_2F_2	Sole Cowpea+75% RDF	7.68	0.34	18.27
I_2F_3	Sole Cowpea+125% RDF	7.61	0.33	18.60
I_3F_1	Napier+cowpea (1:2)+100% RDF	7.95	0.38	17.87
I_3F_2	Napier+cowpea (1:2)+75% RDF	7.97	0.39	17.70
I_3F_3	Napier+cowpea (1:2)+125% RDF	7.91	0.37	17.90
I_4F_1	Napier+cowpea (1:3)+100% RDF	7.85	0.36	18.10
I_4F_2	Napier+cowpea (1:3)+75% RDF	7.88	0.36	18.07
I_4F_3	Napier+cowpea (1:3)+125% RDF	7.83	0.35	18.23
SE.m±		0.08	0.01	0.11
CD(P<0.05)		NS	NS	NS

RESULTS AND DISCUSSION

Soil chemical properties (pH, EC, OC) as affected by different treatments after harvest

The data represented in Table 1 revealed that the effect of intercropping in treatment I_4- Napier+cowpea (1:3), showed a significantly lower pH and EC (7.85 and 0.36 mhos cm^{-1}, respectively) as compared to I_1-sole Napier grass (8.02 and 0.41 mhos cm^{-1}, respectively). However, plots of sole cowpea showed significantly lowest pH and EC (7.65 and 0.34 mhos cm^{-1}) among all treatments. The OC% of I_2- sole cowpea (18.44 %) was highest and lowest OC was seen in I_1- sole napier (17.37%). The application of F_3- 125% RDF decreases the pH (7.84) of soil which was having a non-significant effect and highest pH was observed at F_2- 75% RDF (7.87). The EC decreased with every increase in fertilizer dose with higher EC at F_2- 75% RDF (0.37 mhos cm^{-1}). Whereas the OC increased significantly with every increase in fertilizer level having highest value at F3-125% RDF (18.06%). In the interaction effect of intercropping and fertilizer levels the lowest pH and EC was observed in I_4F_3- Napier + cowpea (1:3)+125% RDF (7.83 and 0.33 mhos cm^{-1}, respectively) both of which had a non-significant effect. The highest value of pH and EC was found to be in I_1F_2- Sole Napier+75% RDF (8.04 and 0.42 mhos cm^{-1}, respectively). Higher OC was found in I_4F_3- Napier+cowpea (1:3)+125% RDF (18.23%) as compared to sole napier. However, sole cowpea plots recorded highest OC (18.60 %) in I_2F_3- Sole Cowpea+125% RDF but lowest pH and EC.

This may be because legumes initially added more nitrogen, which caused the soil to become somewhat acidic and reduce the pH. Legumes may also enhance soil structure and water-holding capacity, which can reduce soil salinity and, in turn, soil EC. Additionally, the presence of numerous crops in an intercropping system result in a more effective utilization of soil nutrients, which may decrease soil EC and salt concentration. The results are in line with Rashpinder *et al.* (2018). According to Triveni *et al.* (2022), hybrid plants respond rapidly to inorganic fertilizers, which also improve the soil's physical properties and increase the activity of beneficial microorganisms in soil.

Soil fertility as influenced by different treatments after harvest

The data in Table 2 revealed that after harvest, the N, P, K available in soil differs significantly in intercropping system. Highest N among the treatments was found to be in I_4- Napier

Table 2: Soil available N, P and K as influenced by various treatments.

Symbol	Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Intercropping				
I_1	Sole napier	94.22	12.31	197.84
I_2	Sole cowpea	200.67	20.31	134.87
I_3	Napier+cowpea (1:2)	112.33	18.68	174.96
I_4	Napier+cowpea (1:3)	130.05	16.31	151.20
SE.m±		1.14	0.16	1.27
CD(P<0.05)		3.36	0.46	3.75
Fertilizer levels				
F_1	100% RDF	145.83	16.15	159.18
F_2	75% RDF	133.83	17.06	164.23
F_3	125% RDF	147.00	15.91	155.78
SE.m±		0.98	0.135	1.10
CD(P<0.05)		2.91	0.40	3.24
Interaction				
I_1F_1	Sole napier+100% RDF	93.00	12.44	138.33
I_1F_2	Sole napier+75% RDF	90.00	10.93	124.4
I_1F_3	Sole napier+125% RDF	99.67	13.56	141.87
I_2F_1	Sole cowpea+100% RDF	201.00	20.31	193.8
I_2F_2	Sole cowpea+75% RDF	176.00	19.94	184.8
I_2F_3	Sole cowpea+125% RDF	225.00	20.68	214.93
I_3F_1	Napier+cowpea (1:2)+100% RDF	116.33	16.5	149.33
I_3F_2	Napier+cowpea (1:2)+75% RDF	104.33	15.19	145.6
I_3F_3	Napier+cowpea (1:2)+125% RDF	116.33	17.25	158.67
I_4F_1	Napier+cowpea (1:3)+100% RDF	125.00	18.99	175.47
I_4F_2	Napier+cowpea (1:3)+75% RDF	122.81	17.57	168.33
I_4F_3	Napier+cowpea (1:3)+125% RDF	142.33	19.49	181.07
SE.m±		1.97	0.27	2.20
CD (P<0.05)		5.81	NS	6.49

Table 3: Green fodder yield, cost of cultivation, gross returns, net returns and benefit cost ratio.

Treatment	Yield		Gross returns	Total cost of	Net returns	B:C
	GFY 1st cut (t ha^{-1})	GFY 2nd cut (mixture) (t ha^{-1})	(` ha^{-1})	cultivation (` ha^{-1})	(` ha^{-1})	ratio
I_1F_1	29.41	45.60	112515	41878.50	70636.50	1.68
I_1F_2	24.90	42.03	100395	40777.53	59617.47	1.46
I_1F_3	34.21	49.56	125655	42978.96	82676.04	1.92
I_2F_1	28.17	20.23	90345	43905.44	46439.56	1.05
I_2F_2	27.83	19.35	87525	43188.08	44336.92	1.02
I_2F_3	32.50	24.05	93075	44622.80	48452.20	1.08
I_3F_1	41.57	56.93	147750	45628.50	102121.50	2.23
I_3F_2	36.33	52.65	133470	44527.53	88942.47	1.99
I_3F_3	47.00	59.18	159270	46728.96	112541.00	2.40
I_4F_1	56.23	69.65	188820	45628.5	143191.50	3.13
I_4F_2	49.63	62.33	167940	44527.53	123412.50	2.77
I_4F_3	60.67	75.69	204540	46728.96	157811.00	3.37

Green fodder price- ` 1500 t^{-1}.

+cowpea (1:3) (130.05 kg ha^{-1}) followed by I_3- Napier+ cowpea (1:2) (112.33 kg ha^{-1}) and I_1- Sole Napier (94.22 kg ha^{-1}). However, sole cowpea obtained the highest nitrogen (200.67 kg ha^{-1}) in soil among the treatments. The lowest P and K were recorded in I_4- Napier+cowpea (1:3) (16.31 and 151.20 kg ha^{-1}, respectively). It was seen that different fertilizer levels on N, P and K of soil had a significant effect. N increases with every dose of nitrogenous fertilizer, whereas P and K decrease with extra addition of fertilizers. The highest N (147 kg ha^{-1}) and lowest P and K (15.91 and 155.78 kg ha^{-1}) were recorded in F3-125% RDF. The interaction effect of intercropping and fertilizer levels showed that available N and K differ significantly, but P showed a non-significant effect. The lowest N, P*and* K in soil were seen in I_1F_2- Napier grass+75% RDF (90.00, 10.93 and 124.4 kg ha^{-1}, respectively) in interaction of intercropping and fertilizer levels among treatment combinations of napier grass. I_2F_3- Sole cowpea+125% RDF recorded (225, 20.68 and 214.93 kg ha^{-1}) N, P and K, respectively, which was highest among all the treatment combinations.

By enhancing the microbial activity and soil health, intercropping can promote the mineralization of organic matter and the availability of nutrients, particularly nitrogen. With higher quantities of N application, there was more NPK readily available in the soil (Damane *et al.,* 2017). The diversity of soil microorganisms may grow because of intercropping, which may enhance nutrient cycling and increase nutrient availability in the soil. Through the release of organic acids, legumes could fix atmospheric nitrogen and improve soil P availability. According to Shekara*et al.* (2009), soil organic carbon content as well as available N and P have increased. The cereal-legume intercropping method increased soil properties, improved soil nutrient and moisture uptake*and* helped conserve soil. These findings were consistent with that of Kumar (2016).

Economics as affected by different treatments

The data presented in Table 3 showed that the maximum cost of cultivation was observed in plots intercropping with 125% RDF (` 46728.96) followed by 100% RDF (` 46728.96) and the lowest in sole napier plots with 75% RDF (` 40777.53). The highest cost of cultivation in intercropped treatments and more RDF must be due to additional cost of intercrops and additional fertilizer doses.The data showed the highest gross returns in intercropping with 1:3 ratio and 125% RDF (` 204540) followed by 100% RDF (` 188820). The least returns were obtained from sole cowpea with 75% RDF (` 87525). The higher gross return in intercropping might be due to more fodder yield on the system.Higher net returns were found in intercropping with 1:3 ratio and 125% RDF (` 157811) followed by 100% RDF (` 143191.5). The lowest returns were obtained from sole cowpea with 75% RDF (` 44336.92) followed by 100% RDF (` 46439.56). Maximum B: C ratio of 3.37 was recorded from intercropping ratio 1:3 and 125% RDF which was followed by 100% RDF (3.13) and 75% RDF (2.77). The higher green fodder yield in these treatments increased the B: C ratio. The lowest B: C ratio of 1.02 was recorded from sole cowpea plots and 75% RDF.

According to Rashpinder *et al.* (2018), all mixtures of Napier Bajra hybrid+cowpea and Napier Bajra+maize/Bajra (25 and 50% of recommended seed rate) had greater Benefit Cost Ratios. Similar results were found by Anita and Lakshmi (2017).

CONCLUSION

This study demonstrated that intercropping and higher quantities of nutrients enhanced the soil fertility, increased the nutrient availability in soil and helps in conservation of soil. The soil properties were improved by adopting cereal-legume intercropping. Legumes may also enhance soil structure and water-holding capacity, which can reduce soil salinity. Additionally, the presence of numerous crops in an intercropping system result in a more effective utilization of soil nutrients.Net return, Gross return and B: C ratio was also improved in intercropping with cowpea.

Conflict of interest

There is no conflict of interest in the manuscript and the manuscript had not been submitted to other journal.

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