

Application of Different Rates of N:P:K Fertilizer on the Growth and Yield Components of Upland Rice in Rice-Soybean Intercropping System

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Abstract. Nigeria is one of the fastest developing countries in sub-Saharan Africa, and hence, there is an urgent need to invest in agriculture to boost food production to meet the citizen's nutritional needs and for export. Due to the increasing population, urbanisation and industrialisation in Nigeria, especially in the South East, with a small land mass, intercropping is highly recommended. A two-year field experiment was carried out in the 2018 and 2019 cropping seasons to assess the effect of the application of different rates of N:P:K fertiliser on the growth and yield components of upland rice in a rice-soybean intercropping system. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The treatment includes rice and soybeans with five levels of N:P:K 15 :15 :15 (0, 100, 200, 300 and 400 kg) fertiliser rates, as well as rice sole and soybean sole. The result showed that the interaction of upland rice and soybean with N:P:K fertiliser significantly affected the plant height, number of leaves, leaf area index, number of panicles per plant and number of seeds per rice plant. Based on the result of this investigation, it was observed that the cropping system and increased fertiliser rates positively affected upland rice's growth and yield component. It was noted that the N:P:K fertiliser rate (400 kg) gave the highest growth and yield component of upland rice in the rice/soybean intercropping system.

Keywords: Intercropping; Fertilizer; Rice; Soybean; System.

INTRODUCTION

Nigeria is one of the fastest developing countries in sub-Saharan Africa. Hence, there is an urgent need to invest in agriculture to boost food production to meet the citizen's nutritional needs and for export. Due to the increasing population, urbanisation and industrialisation in Nigeria, especially in the South East, with a small land mass, intercropping is highly recommended. Agricultural research initially focused on sole cropping and ignored the potential of intercropping [1], but there has been a gradual recognition of the value of the intercropping system [2]. Intercropping is growing two or more crops on the same land within the same year to promote their interaction and maximise productivity by avoiding dependence on only one crop [3]. The author [4] stated that mixed cropping or intercropping expresses African farmer's desire to minimise risk.

Authors [5, 6] observed that the yield advantage of intercropping has yet to be marked in several situations, possibly due to the use of either super-optimal or sub-optimal plant population proportion for component crops.

Rice is the primary food for nearly half the people on earth. It has become a highly strategic and priority commodity for food security in Africa. Consumption is growing faster than any other major staple on the continent because of high population growth, rapid urbanisation, and changes in eating habits [7].

Rice is an annual crop and the most important staple food crop in tropical countries; commercially, it is the most important cereal after wheat. It is the most critical source of dietary energy in West Africa and the third most important for Africa. Nigeria is the largest producer of rice in the West Africa sub-region. In Nigeria, rice is one of

the few food items whose consumption has no cultural, religious, ethnic or geographical boundary. It is highly priced and widely accepted for festivity. In some rural areas, it is so adored that it is eaten only on Sundays and sometimes on market days [8].

Upland rice (*Oryza sativa*) is a staple food crop for millions in Asia and Africa [9]. It is typically grown in rainfed and upland areas, where the soil is often poor in nutrients and prone to erosion. Intercropping upland rice with legumes can increase rice yields and improve soil fertility through the nitrogen-fixing capabilities of mungbean [9]. Upland rice has been found to have allelopathic effects on other crops, which can be both positive and negative [10]. Some studies have reported that intercropping upland rice with legumes like cowpea and soybean can improve soil fertility and increase the yield of both crops. However, other studies have shown that intercropping with upland rice can also negatively affect the growth and yield of crops such as maize and groundnut [11].

Soybean (*Glycine max*) is another crucial legume crop known for its high protein content and oil production. It is widely grown in the Americas, Asia, and Africa [12]. Soybeans face low soil fertility and pest and disease pressure like mungbeans. Intercropping soybeans with upland rice can improve soybean yields and reduce pest and disease pressure through the allelopathic effect of rice [12].

Soybean is an important leguminous crop widely grown in many parts of the world, including Asia, North America, and South America. It is a rich source of protein and oil, making it a valuable crop for human and animal consumption. To increase productivity, soybeans are often intercropped with maize, rice, and other crops. Intercropping soybeans with maize has been found to improve the nitrogen economy of the cropping system, as soybeans fix atmospheric nitrogen, which is then used by Maize [9]. Moreover, intercropping soybeans with other crops has improved soil health, reduced pest and disease incidence, and increased yield.

Therefore, the current study assessed upland rice and soybean growth, yield, and productivity in an intercropping system. It specifically determined the effect of different N:P:K fertiliser rates on the growth and yield of upland rice in a rice-soybean intercropping system.

MATERIALS AND METHODS

Study Area and Location. Three field experiments were conducted at the research farm of Michael Okpara University of Agriculture Umudike in the 2017/2018 and 2018/2019 cropping seasons. Umudike is located around longitude 07° 33'E and latitude 05° 29' N at an elevation of 122 m above sea level in the humid tropical lowland of southeastern Nigeria. Umudike is a typical rainforest vegetation with a relative humidity of 50-95% and a bimodal rainfall pattern with an average temperature of about 20 °C [13]. The soil of the site is classified as an ultisol [14].

Planting Materials. The seeds of Rice (FARO 58) and TGX 47 soybean varieties were used in Experiment 1. Rice (FARO 58) and Soybean (TGX 47) varieties were used in Experiment 2, while Rice (FARO 58), cowpea (SAMPEA 16) groundnut, mungbean and Soybean (IT87K-318-33) were used in Experiment 3. Rice seeds were sourced from the National Cereals Research Institute (NCRI) Amakama Oloroko, Abia State. In contrast, soybean, cowpea, and groundnut seeds were sourced from the Institute of Agricultural Research (IAR), Zaria, except mungbean seeds, which were sourced from the College of Crop and Soil Science, Umudike, Abia State.

Meteorological Information. Weather records such as rainfall, temperature, relative humidity, wind speed, and sunshine were obtained from the National Root Crop Research Institute, Umudike, an Agrometeorological unit located about 350 m from the experimental site.

Experiment: Effect of Application of Different Rates of N:P:K Fertilizer on the Growth and Yield of Upland Rice in Rice/ Soybean Intercropping System

Field preparation and soil sampling. The experimental site was slashed manually on 12th March, and the disc was ploughed and harrowed on 16th March 2018. In 2019, the site was slashed on 5th June, ploughed and harrowed on 7th June. After the ploughing and harrowing, weeds were removed manually to achieve a clean and weed-free experimental site for planting. The field was marked out into plot sites of uniform measurement.

Soil samples were collected randomly at a depth of 0-20 cm from different representation locations of the experimental site with a soil auger and taken to the National Root Crop Research Institute Soil Laboratory, Umudike, to determine

the chemical and physical properties of the soil. Bouyoucos method was used to determine the % of sand, silt, and clay. Soil pH in 1:2.5 soil/water ratio was determined using a pH meter. Organic matter content was obtained by multiplying total carbon by 1.724. Organic carbon content was determined by the Walkley-Black method. Total nitrogen was used to determine by the microkjeldahl method. The bray-1 method was used to determine available phosphorus. Exchangeable cations (Ca, Mg, K and Na) were extracted with one standard neutral ammonium acetate solution and exchangeable K and Na were read using a flame photometer. In contrast, Ca and Mg were read using an atomic absorption spectrophotometer (AAS).

NPK 15:15:15 fertiliser was sourced from the opened market.

Treatments and experimental design. The treatment used were rice (FARO 58)-T₁ and TGX 47 soybean- T₂ with five rates of N.P.K 15:15:15(0, 100, 200, 300 and 400 kg)

Treatments include Sole Rice + 0 kg/ha of N:P:K, Sole Rice + 100 kg/ha of N:P:K, Sole Rice + 200 kg/ha of N:P:K, Sole Rice + 300 kg/ha of N:P:K, Sole Rice + 400 kg/ha of N:P:K, Sole Soybean + 0 kg/ha of N:P:K, Sole Soybean + 100 kg/ha of N:P:K, Sole Soybean + 200 kg/ha of N:P:K, Sole Soybean + 300 kg/ha of N:P:K, Sole Soybean + 400 kg/ha of N:P:K, Rice + soybean + 0 kg/ha of N:P:K, Rice + Soybean + 100 kg/ha of N:P:K, Rice + Soybean + 200 kg/ha of N:P:K, Rice + Soybean + 300 kg of N:P:K, Rice + soybean + 400 kg of N:P:K. Each treatment was replicated three times. Each plot measured 2 x 2 m (4 m²). Each replication had 15 plots with an intra-block spacing of 0.5 m and inter-block spacing of 1 m. Rice seeds were sown at the recommended spacing of 20 x 20 cm, giving a population of 500,000 plants/ha. Sowing was done on (14th March 2018 for the first cropping season and 10th June 2019 for the second cropping season). Rice seeds were sown by direct seeding. Pest was controlled at 2 and 4 weeks after planting using Lambdacyhalothrin 2.5 EC at the rate of 300 ml/ha.

Growth and Yield parameters. Growth parameters were measured 2, 4, 6, 8, and 10 weeks after planting. Four plants were tagged for the collection of growth parameters, while yield parameters were measured ten weeks after planting from 4 plants when the rice plant's panicles and soybean pods started drying up. The plants for

observation and data collection were taken from the inner rows of the treatment plot.

The following data were collected for rice and soybean:

1. Plant height (cm) was measured with a linear tape from the ground level to the tip of the plant.
2. The number of leaves per plant was determined by counting.
3. The leaf area index (LAI) was calculated from the leaf area.
4. The length of the panicle (cm) was measured with a linear tape
5. The number of panicles per plant was determined by counting.
6. The number of seeds per panicle was determined by counting.
7. The number of seeds per pod was obtained by counting.
8. Weight of pods per plant.

Statistical analysis. The morphological and yield data collected were subjected to Analysis of Variance (ANOVA) for a single-factor experiment in Randomized Complete Block Design (RCBD) using Genstat. Treatment means obtained were appropriately compared for statistical significance using Fisher's least significant difference (F-LSD) at the 0.05 probability level.

RESULTS AND DISCUSSION

Soils and Meteorological Data. The soils of the experimental sites were texturally sandy loam in 2018 and 2019 (Table 1). The table below indicates the soil pH was low, with a value of 4.5 in 2018 but high in 2019, with a value of 5.13. Soil organic matter and nitrogen were high in both years, but values in 2018 were higher than in 2019

Available P was high in both years but higher in 2018 than in 2019. Soil calcium and magnesium were above the critical levels. The soil's base saturation was also high in both years.

Table 2 shows the total annual rainfall for 2018 and 2019 as 2028.6 mm and 3075.0 mm, respectively. The rainfall was bimodal and peaked in April and September of 2018 and July and September of 2019, but it was higher in September of 2019 than in other months. April to October experienced high and stable rainy days in 2018

but were higher in 2019. The temperature was relatively high throughout the year 2018 and 2019. The mean monthly max temp was 32.9 °C and 31.7 °C, respectively, in 2018 and 2019. Relatively, humidity was lowest in Feb while it was highest in July.

Table 1 – Physico-chemical properties of the experimental sites in 2018 and 2019 cropping seasons

	2018	2019
Physical properties		
Sand (%)	64,7	81,20
Silt (%)	11,40	9,70
Clay (%)	12,90	11,10
Textural class	Sandy	Sandy

	2018	2019
	loam	loam
Chemical properties		
pH (H ₂ O)	4,50	5,13
Organic matter (%)	2,42	1,71
Organic carbon (%)	1,13	1,07
Total N (%)	0,23	0,17
Available P (mg Kg ⁻¹)	19,80	13,78
Exchangeable K (cmol Kg ⁻¹)	0,17	0,24
Exchangeable Na (cmol Kg ⁻¹)	0,23	0,12
Exchangeable Ca (cmol Kg ⁻¹)	7,40	3,20
Exchangeable Ea (cmol Kg ⁻¹)	0,48	1,49
Exchangeable Mg (cmol Kg ⁻¹)	1,00	1,08
Effective CEC (cmol Kg ⁻¹)	9,14	4,76
Base saturation (%)	94,68	81,53

Table 2 – Agrometeorological data of the experimental sites for 2018 and 2019

Month	Rainfall Amount, mm	Maximum air temperature, °C 2018	Relative humidity, % (0900Hrs)	Rainfall Amount, mm	Maximum air temperature, °C 2019	Relative Humidity (%) (0900Hrs)
January	0.0	34.1	78	38.9	35	65
February	80.1	34.5	81	80.9	34	69
March	9.6	34.4	87	65.7	34	84
April	337.5	32.5	88	137.1	36	79
May	246.6	32.6	87	355.7	32	77
June	326.6	30.9	87	523.4	29	76
July	237	29.6	84	554.1	28	90
August	173.3	30.4	80	206.6	30	89
September	334.7	30.1	85	635.0	27	88
October	238.9	40.8	78	367.3	31	78
November	44.3	30.7	81	107.2	32	70
December	0.0	34.5	87	0.0	32	47
Total	2028.6	395.1	79	3075.0	32	76

Table 3 shows the effect of the cropping system and fertiliser rate on the plant height of rice. The cropping system had no significant difference ($P>0.05$) in the plant height of rice in both cropping seasons except at 8 WAP in 2018. This could be due to the low nutrient uptake and resource competition between the legume crops and rice plants. However, intercrop rice produced significantly the lowest plant height at 2 WAP in both years among the cropping systems. This is consistent with [15], who reported that intercropping significantly reduced the plant height of rice, which could be attributed to competition for resources.

The fertiliser rate showed no significant difference in plant height of rice except at 6 and 10

WAP in 2018, while significant differences were observed at 4, 6 and 8 WAP. Okg NPK (Control) gave significantly the lowest plant height of rice across all the sample ages in 2019. By implication, nitrogen increases and improves considerably the vegetative growth of rice.

Interaction of rice and fertiliser in both sole and intercrop showed consistent significant differences in plant height of rice at 6WAP in the 2018 and 2019 cropping seasons. This is consistent with [16], who reported that fertiliser application in intercropping significantly impacted upland rice's growth and development. Among the intercrop crop interactions, the intercrop 0 kg NPK (control) consistently produced the lowest number of plant heights of rice at 4, 8, and 10 WAP in both years. This is consistent with the findings of

[17], who reported that no fertiliser application can affect the height of upland rice. Intercrop interaction in sole had 400 kg NPK fertiliser as the highest plant height of rice at 4 and 6 WAP in 2018, while in 2019, the trend changed as 400 kg

fertiliser gave the highest plant height at 4, 8 and 10 WAP, respectively. This is also consistent with [16], who reported that the combination of fertiliser and intercropping significantly impacted rice's plant height.

Table 3 – Effect of cropping system and fertiliser rate on plant height of rice at different stages of growth in 2018 and 2019 cropping seasons

Treatment	2018					2019				
	Plant height (cm)									
	Weeks after planting (WAP)									
Cropping system (C)	2	4	6	8	10	2	4	6	8	10
Sole rice	4.39	9.84	15.27	16.73	22.25	5.15	10.28	15.41	23.54	39.5
Intercrop rice	4.35	9.20	16.09	18.63	22.74	5.29	10.73	16.58	22.14	39.1
LSD _(0.05)	ns	ns	ns	1.407	ns	ns	ns	ns	ns	ns
NPK-15:15:15 Fertilizer rate (F) (kg ha ⁻¹)										
0 (Control)	4.61	9.09	14.16	16.20	19.83	5.02	9.70	14.03	19.45	35.4
100	4.44	9.54	13.77	18.25	20.88	5.07	9.88	15.20	21.00	37.7
200	4.43	9.03	16.14	18.03	22.60	5.05	10.45	14.87	21.08	37.6
300	4.58	10.15	16.29	18.22	25.94	5.30	10.80	18.81	23.34	38.3
400	3.80	9.79	18.03	17.70	23.63	5.68	11.68	17.07	26.82	47.5
LSD _(0.05)	ns	ns	2.371	ns	3.077	ns	1.587	2.225	5.500	ns
Interaction (C × F)										
Sole rice × 0 kg ha ⁻¹	4.39	9.96	14.17	16.30	19.83	4.53	9.58	13.50	19.60	35.8
Sole rice × 100 kg ha ⁻¹	4.62	10.22	13.77	18.17	22.57	4.93	9.47	13.50	21.73	38.6
Sole rice × 200 kg ha ⁻¹	4.27	9.22	16.14	15.38	23.67	5.07	10.93	15.20	22.50	34.1
Sole rice × 300 kg ha ⁻¹	4.82	9.48	16.29	15.77	23.74	5.27	10.23	18.57	25.20	40.1
Sole rice × 400 kg ha ⁻¹	3.87	10.32	18.03	18.03	21.47	5.93	11.17	16.30	28.65	49.1
Intercrop rice × 0 kg ha ⁻¹	4.83	8.23	14.13	16.10	19.03	5.50	9.83	14.57	19.29	35.0
Intercrop rice × 100 kg ha ⁻¹	4.27	8.87	13.52	18.33	19.20	5.20	10.30	16.90	20.27	36.8
Intercrop rice × 200 kg ha ⁻¹	4.60	8.83	16.75	20.67	21.53	4.97	9.97	14.54	19.66	41.0
Intercrop rice × 300 kg ha ⁻¹	4.33	10.82	18.02	20.67	28.13	5.33	11.37	19.05	21.47	36.6
Intercrop rice × 400 kg ha ⁻¹	3.73	9.27	18.02	17.37	25.80	5.43	12.20	17.83	25.00	45.9
LSD _(0.05)	ns	ns	3.353	3.147	4.351	1.169	2.244	3.147	ns	Ns

Table 4 shows the effect of the cropping system and fertiliser on several leaves/plants of rice at different stages of growth in 2018 and 2019. The cropping system had no significant effect ($P>0.05$) on the number of leaves/plants of rice in both cropping seasons across the sampled dates except at 8 WAP in 2019 (Table 4). This is consistent with [18], who reported no significant difference in the number of leaves per plant between sole cropping and intercropping systems. However, intercrop rice consistently gave the lowest number of leaves/plant of rice at 2 WAP in both cropping seasons.

Among the fertiliser rates, 4, 6, and 10, WAP produced significant differences in the number of rice leaves in 2018, while significant differences were observed across the sample ages expected

at 2 WAP in 2019, respectively. Among the fertiliser rates, 0 kg (control) gave the lowest number of leaves of rice significantly across the sample dates in 2018, except at 4 WAP, while consistency was observed in the trend in 2019, except at 2 WAP. This is consistent with previous studies by [19], who reported that 0 kg N:P:K (control) significantly produced the lowest number of leaves of rice/plant in sole crop and intercrop.

The interaction of rice and fertiliser in sole and intercrop showed a significant difference across all the sampled ages, except for 2 WAP in both cropping seasons. This is consistent with [20], who reported a positive effect of intercropping on the crops. Among the interactions of rice and fertiliser in sole 0 kg N:P:K (control), fertiliser consistently gave the lowest number of rice

leaves at 4, 6, and 10 WAP in 2018 and 2019, respectively. Among the intercrop crop interactions of rice and fertiliser, 100 kg fertiliser gave the lowest number of rice leaves at 6 WAP in both

years. In comparison, 400 kg fertiliser gave the highest number of rice leaves at 6 WAP in 2018 and 2019, respectively. This could be attributed to the availability of nutrients to the rice plant.

Table 4 – Effect of cropping system and fertiliser rates on the number of leaves/plants of rice at different stages of growth in the 2018 and 2019 cropping seasons

Treatment	2018					2019				
	Number of leaves/plant									
	Weeks after planting (WAP)									
Cropping system (C)	2	4	6	8	10	2	4	6	8	10
Sole rice	3.820	10.51	26.4	35.6	37.19	4.27	10.71	23.46	40.6	40.4
Intercrop rice	3.747	8.90	25.1	36.9	37.75	4.13	10.55	23.09	30.8	41.2
LSD _(0.05)	ns	ns	ns	ns	ns	ns	ns	ns	6.53	ns
NPK-15:15:15 Fertilizer rate (F) (kg ha ⁻¹)										
0 (Control)	3.717	8.52	20.2	31.0	29.98	4.33	8.50	18.71	29.3	32.6
100	3.719	8.47	23.3	33.0	30.65	4.17	9.97	20.32	32.7	46.6
200	3.817	10.00	26.2	39.5	44.84	4.00	11.23	23.05	33.7	40.2
300	3.767	11.40	28.9	38.7	40.40	4.17	11.42	25.59	39.7	39.8
400	3.900	10.13	30.0	39.1	41.48	4.33	12.02	28.70	43.0	44.8
LSD _(0.05)	ns	2.734	6.68	ns	6.041	ns	2.780	4.775	10.32	11.34
Interaction (C × F)										
Sole rice × 0 kg ha ⁻¹	3.833	8.53	20.8	35.0	29.82	4.00	8.33	16.77	27.6	23.6
Sole rice × 100 kg ha ⁻¹	3.500	9.33	28.2	33.1	32.90	4.67	9.33	23.38	35.5	45.5
Sole rice × 200 kg ha ⁻¹	3.933	11.67	27.3	34.9	44.63	4.00	11.80	24.50	43.1	47.0
Sole rice × 300 kg ha ⁻¹	3.933	12.00	27.7	34.6	36.71	4.33	12.40	25.62	44.9	34.1
Sole rice × 400 kg ha ⁻¹	3.900	11.00	28.0	40.7	41.88	4.33	11.67	27.04	51.7	51.9
Intercrop rice × 0 kg ha ⁻¹	3.600	8.50	19.7	27.0	30.13	4.67	8.67	20.65	31.0	41.6
Intercrop rice × 100 kg ha ⁻¹	3.933	7.60	18.5	32.9	28.39	3.67	10.60	17.27	29.9	47.7
Intercrop rice × 200 kg ha ⁻¹	3.700	8.33	25.2	44.2	45.05	4.00	10.67	21.60	24.2	33.5
Intercrop rice × 300 kg ha ⁻¹	3.600	10.80	30.2	42.9	44.10	4.00	10.43	25.57	34.6	45.5
Intercrop rice × 400 kg ha ⁻¹	3.900	9.27	32.1	37.6	41.07	4.33	12.37	30.37	34.2	37.6
LSD _(0.05)	ns	3.866	9.45	12.56	8.544	ns	3.932	6.753	14.60	16.04

As shown in Table 5, the cropping system significantly affected the leaf area index of rice across all the sampled ages in both years, except at 2 and 4 WAP in 2018. However, the intercrop rice gave the highest leaf area index at 8 and 10 WAP in the 2018 and 2019 cropping seasons. This is due to the availability of N from the legumes to the upland rice.

The fertiliser rates showed significant differences ($p < 0.05$) in the leaf area index of rice across all the sampled dates in 2018 and 2019 except at 4 WAP in 2018, respectively. This is consistent with previous studies by [21], who reported that the application difference in fertiliser rate thus significantly influenced the leaf area index of rice. Among the fertiliser rates, 0 kg (control) of N:P:K gave the lowest leaf area index across the sampled ages in both years except at 4

and 6 WAP in 2018, respectively. This is consistent with the studies by [22], who reported that inadequate fertilisation resulted in nutrient deficiency, leading to stunted growth and a decreased leaf area index, while 400 kg N:P:K gave the highest leaf area index at 2, 4, and 6 WAP in 2018 as well produced the highest leaf area index consistently across all the sample age in 2019. This implies that a higher fertiliser application would significantly increase the leaf area index of upland rice compared to a lower fertiliser application rate.

Interaction of rice and fertiliser in both sole and intercrop showed a consistent trend and significant difference in both cropping seasons across the sample dates except at 4 WAP in 2018. Among the interaction of rice and fertiliser in sole rice, 100 kg fertiliser consistently gave the

lowest leaf index of rice at 4 and 6 WAP in both years, whereas 400 kg consistently showed the highest leaf area index of rice at 2, 4, 6, and 8 WAP in both cropping season. Intercrop crop in-

teraction of rice and fertiliser 0 kg N:P:K (control) significantly gave rice's lowest leaf area index across all the sampled ages in both years except at 10 WAP in 2018, respectively.

Table 5 – Effect of cropping system and fertiliser rate on leaf area index of rice at different stages of growth in 2018 and 2019 cropping seasons

Treatment	2018					2019				
	Leaf area index									
	Weeks after planting (WAP)									
Cropping system (C)	2	4	6	8	10	2	4	6	8	10
Sole rice	0.030	0.137	0.829	1.771	2.065	2.553	0.029	0.139	0.806	1.916
Intercrop rice	0.031	0.131	2.051	2.238	2.505	0.027	0.139	0.871	1.680	2.687
LSD _(0.05)	ns	ns	0.203	0.333	0.364	0.002	0.037	0.187	0.271	0.356
NPK-15:15:15 Fertilizer rate (F) (kg ha ⁻¹)										
0 (Control)	0.026	0.079	0.637	1.248	1.561	0.023	0.106	0.502	1.206	1.552
100	0.029	0.073	0.617	1.337	1.767	0.028	0.109	0.628	1.382	2.365
200	0.031	0.095	0.968	2.270	2.944	0.029	0.126	0.877	1.729	2.795
300	0.034	0.167	1.188	2.703	2.342	0.031	0.168	1.046	2.258	2.976
400	0.034	0.268	1.290	2.463	2.811	0.031	0.187	1.142	2.415	3.412
LSD _(0.05)	0.005	ns	0.321	0.527	0.575	0.003	0.059	0.296	0.428	0.562
Interaction (C × F)										
Sole rice × 0 kg ha ⁻¹	0.025	0.079	0.698	1.368	1.287	0.0230	0.1051	0.458	1.112	1.099
Sole rice × 100 kg ha ⁻¹	0.028	0.073	0.503	1.217	1.749	0.0286	0.0868	0.549	1.371	2.365
Sole rice × 200 kg ha ⁻¹	0.031	0.095	0.833	1.674	2.769	0.0325	0.1287	0.944	2.000	3.517
Sole rice × 300 kg ha ⁻¹	0.032	0.167	0.949	2.039	2.136	0.0308	0.1717	0.986	2.416	2.650
Sole rice × 400 kg ha ⁻¹	0.033	0.268	1.165	2.557	2.385	0.0325	0.2027	1.095	2.682	3.153
Intercrop rice × 0 kg ha ⁻¹	0.027	0.089	0.576	1.129	1.835	0.0228	0.1064	0.547	1.300	2.004
Intercrop rice × 100 kg ha ⁻¹	0.032	0.131	0.731	1.457	1.784	0.0275	0.1309	0.707	1.393	2.385
Intercrop rice × 200 kg ha ⁻¹	0.031	0.123	1.103	2.865	3.119	0.0258	0.1232	0.810	1.459	2.073
Intercrop rice × 300 kg ha ⁻¹	0.036	0.183	1.427	3.368	2.548	0.0303	0.1649	1.105	2.100	3.302
Intercrop rice × 400 kg ha ⁻¹	0.036	0.128	1.415	2.370	3.236	0.0294	0.1715	1.188	2.148	3.670
LSD _(0.05)	0.007	ns	0.453	0.745	0.813	0.005	0.0838	0.4178	0.605	0.796

Table 6 shows the effect of the cropping system and fertiliser rate on soybean plant height at different stages of growth. The cropping system showed no significant difference across all the sampled ages in 2018 and 2019, respectively. However, sole soybean consistently gave the highest plant height across all the sample ages in both cropping seasons, except at 10 WAP in 2019.

The fertiliser rates showed significant differences in soybean plant height across all the sampled ages in cropping seasons except at 2 and 4 WAP in 2018, respectively. This is consistent with previous studies that reported a positive correlation between fertiliser rate and plant height of soybeans [23, 24]. This implies that the higher the fertiliser rate, the taller the plant, which can be attributed to the increase in nutrient availability.

The result showed that fertiliser rates' effect on soybean plant height varied in different cropping seasons. This can be due to the variation in environmental conditions such as temperature, rainfall and sunlight, which can affect the uptake and utilisation of nutrients.

Among the fertiliser rates of 0 kg (control), N:P:K consistently gave the lowest soybean plant height at 2 and 6 WAP in 2018 and 2019. Statistically, 400 kg of N:P:K produced the highest soybean plant height across all the sampled ages in both cropping seasons except at 10 WAP in 2019.

The interaction of soybean and fertiliser showed significant differences across all the sampled ages in both cropping seasons except at 2WAP in 2018. However, soybean and fertiliser interaction in sole soybean indicated that 0 kg N:P:K produced the lowest soybean plant height across

all the sample ages in 2018, except at 4 WAP. Although the trend was not consistent in 2019, in the intercrop crop interaction, 400 kg consistent-

ly gave the highest plant height of soybeans across the sampled ages in both cropping seasons, except for 4 and 6 WAP in 2018.

Table 6 – Effect of the cropping system and fertiliser rate on yield and yield components of rice in the 2018 and 2019 cropping seasons

Treatment	Length of panicles, cm	Number of panicles / plant	Number of seeds / plant	Length of panicle (cm)	Number of panicles / plant	Number of seeds / plant
Cropping system (C)						
Sole rice	33.79	5.99	597.	27.87	8.4	1061.
Intercrop rice	34.11	6.02	656.	27.05	19.3	956.
LSD _(0.05)	ns	ns	ns	ns	ns	ns
NPK-15:15:15 Fertilizer rate (F) (kg ha⁻¹)						
0 (Control)	32.99	4.22	395.	26.93	6.6	645.
100	30.89	5.85	596.	26.95	31.9	884.
200	35.61	6.21	629.	28.09	10.7	987.
300	34.07	6.84	778.	27.06	10.1	1088.
400	36.20	6.92	815.	28.27	9.9	1439.
LSD _(0.05)	3.107	0.747	ns	ns	ns	411.3
Interaction (C × F)						
Sole rice × 0 kg ha ⁻¹	33.05	3.97	376.	27.49	5.4	619.
Sole rice × 100 kg ha ⁻¹	28.95	6.24	516.	25.74	6.5	665.
Sole rice × 200 kg ha ⁻¹	36.05	5.69	527.	28.40	9.2	1172.
Sole rice × 300 kg ha ⁻¹	34.35	7.01	767.	28.65	10.4	1221.
Sole rice × 400 kg ha ⁻¹	36.57	7.06	798	29.05	10.3	1629.
Intercrop rice × 0 kg ha ⁻¹	32.94	4.47	414	26.36	7.8	671.
Intercrop rice × 100 kg ha ⁻¹	32.80	5.47	516.	28.16	57.4	1102.
Intercrop rice × 200 kg ha ⁻¹	35.18	6.73	732	27.79	12.2	803.
Intercrop rice × 300 kg ha ⁻¹	33.79	6.67	789	25.47	9.8	954.
Intercrop rice × 400 kg ha ⁻¹	35.84	6.79	832	27.49	9.5	1249.
LSD _(0.05)	4.393	1.056	127.9	ns	46.50	581.7

Table 7 shows that the cropping system showed no significant difference in the length of panicles, number of panicles per plant, and number of seeds per rice in both years. Intercrop rice produced the most extended length of panicles and the highest number of seeds per plant in 2018. The NPK fertiliser rates showed significant differences in the size of panicles per plant and the number of panicles per plant of rice in 2018, but the trend was not consistent in 2019 (Table 7). However, among the N:P:K fertiliser rates, 400 kg NPK produced the highest panicle length per plant, the highest number of panicles per plant, and the highest number of seeds per plant in 2018, consistent in 2019 except for several panicles per plant.

Among the interaction of rice and fertiliser in sole rice, 400 kg NPK produced the highest length of panicle, number of panicles and number of seeds/plants in 2018, while in 2019, 100 kilograms NPK produced the highest length of panicles and highest number of panicles, and highest number of seeds/plant.

Table 8 indicates the effect of the cropping system and fertiliser rates on the number of leaves/plants of soybeans at different stages of growth in 2018 and 2019. The cropping system showed no significant difference across all the sampled ages in 2018 and 2019, respectively. The number of leaves under the cropping system produced significantly the highest number of soybean leaves in 2018.

Table 7 – Effect of cropping system and fertiliser rate on plant height of soybean at different stages of growth in 2018 and 2019 cropping seasons

Treatment	2018					2019				
	Plant height (cm)									
	Weeks after planting (WAP)									
Cropping system (C)	2	4	6	8	10	2	4	6	8	10
Sole soybean	9.32	13.78	30.64	37.6	37.6	12.11	21.72	36.39	44.28	46.9
Intercrop soybean	8.71	12.96	28.29	34.8	34.8	11.53	20.13	36.11	44.22	48.2
LSD _(0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
NPK-15:15:15 Fertilizer rate (F) (kg ha ⁻¹)										
0 (Control)	8.23	13.59	26.47	32.2	32.2	10.90	19.98	32.63	39.93	43.9
100	8.94	13.13	30.44	36.6	36.6	11.40	19.75	34.50	42.69	44.2
200	9.19	12.46	29.64	35.1	35.7	11.18	19.32	34.42	39.67	42.7
300	9.12	13.37	28.34	32.5	34.5	12.38	22.08	38.27	47.75	53.7
400	9.58	13.79	32.43	42.1	42.1	13.22	24.08	41.42	51.20	53.3
LSD _(0.05)	ns	ns	5.526	6.97	6.97	1.352	3.797	4.585	6.547	7.41
Interaction (C × F)										
Sole soybean × 0 kg ha ⁻¹	8.70	13.53	25.62	30.7	30.7	12.01	21.27	33.70	42.30	44.6
Sole soybean × 100 kg ha ⁻¹	9.75	13.22	35.27	40.4	40.4	10.97	18.83	32.40	41.73	43.8
Sole soybean × 200 kg ha ⁻¹	9.05	11.39	27.15	36.2	36.2	11.87	19.70	35.03	38.50	42.5
Sole soybean × 300 kg ha ⁻¹	9.47	15.33	30.53	36.4	36.4	11.77	22.90	40.30	45.70	48.7
Sole soybean × 400 kg ha ⁻¹	9.62	15.33	34.65	44.5	44.5	13.93	25.90	40.50	53.17	55.1
Intercrop soybean × 0 kg ha ⁻¹	7.76	13.55	27.32	33.6	33.6	9.80	17.50	31.57	37.57	43.3
Intercrop soybean × 100 kg ha ⁻¹	8.13	13.05	25.62	32.9	32.9	11.83	20.67	36.60	43.65	44.5
Intercrop soybean × 200 kg ha ⁻¹	9.33	13.53	32.13	35.1	35.1	10.50	18.93	33.80	40.83	43.0
Intercrop soybean × 300 kg ha ⁻¹	8.77	12.42	26.15	32.7	32.7	13.00	21.27	36.23	49.80	58.6
Intercrop soybean × 400 kg ha ⁻¹	9.55	12.25	30.22	39.7	39.7	12.50	22.27	42.33	49.23	51.51
LSD _(0.05)	ns	3.432	5.525	2.10	9.54	1.912	5.370	6.484	9.259	10.47

The fertiliser rates produced a significance ($p < 0.05$) on the number of soybean leaves across all the sample dates in both cropping seasons, expected at 4 WAP in 2018 and 2019, respectively, among the N:P:K fertiliser rates, 400 kg produced the highest number of soybean leaves at 2, 8 and 10 WAP in both cropping seasons. This implies that an increasing fertiliser rate on soybeans would significantly increase the number of leaves per soybean plant.

The interaction of soybean and fertiliser indicated a significant difference in the number of soybean leaves across all the sampled ages in cropping seasons except at 2 and 4 WAP in 2018 (Table 8). To this effect, 400 kg NPK produced consistently the highest number of leaves at 4 and 10 WAP in both cropping seasons in sole soybeans. Intercrop interaction of 400 kg consistently produced the highest soybean leaves at 2, 8, and 10 WAP in both cropping seasons. The intercrop interaction result aligns with [25] findings, which reported that increasing fertiliser rates significantly increased the number of leaves per plant of soybean intercropped with sorghum, pearl millet, and maize. This finding implies that in-

creasing fertiliser rates positively affected the number of leaves per plant of soybean in the intercropping system.

Table 9 shows that the cropping system showed no significant difference in the soybean leaf area index across all the sampled ages in 2018 and 2019 except at 10 WAP in both years. This is consistent with previous studies by [26, 27], who reported no significant difference in the soybean leaf area index in different planting patterns within a cropping system.

The fertiliser rate showed a significant difference in the leaf area index of soybeans across all the sample ages in both cropping seasons except at 2 WAP in 2018. However, 400 kg N:P:K gave consistently the highest leaf area index of soybean at 6 and 8 WAP in both cropping seasons. This is consistent with studies by [28, 29, 30, 31, 32], who reportedly established that increasing the fertiliser rate statistically increased the leaf area index of soybean while it is in disagreement with the finding [33] who noted a decrease in leaf area index of soybean as a result of an increase in Nitrogen fertiliser application.

Table 8 – Effect of cropping system and fertiliser rate on the number of leaves/plant of soybean at different stages of growth in the 2018 and 2019 cropping seasons

Treatment	2018					2019				
	Number of leaves/plant									
	Weeks after planting (WAP)									
Cropping system (C)	2	4	6	8	10	2	4	6	8	10
Sole soybean	9.32	13.78	23.45	37.57	42.8	5.335	10.14	19.00	29.7	41.26
Intercrop soybean	8.71	12.96	23.17	35.14	42.1	5.473	9.85	19.60	32.1	42.25
LSD _(0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
NPK-15:15:15 Fertilizer rate (F) (kg ha ⁻¹)										
0 (Control)	8.22	13.59	20.21	32.15	38.4	5.370	9.54	14.70	28.3	36.47
100	8.94	13.13	22.77	36.65	42.1	5.500	8.99	15.65	25.7	43.52
200	9.19	12.46	25.29	35.50	40.9	5.367	10.73	21.75	28.8	38.52
300	9.58	13.87	23.46	34.55	42.3	5.067	10.24	21.36	35.7	42.70
400	10.2	13.79	24.82	42.90	48.8	5.717	10.47	23.02	36.1	47.57
LSD _(0.05)	1.646	ns	4.143	6.348	7.87	0.595	ns	4.436	8.23	6.018
Interaction (C × F)										
Sole soybean × 0 kg ha ⁻¹	8.70	13.63	18.78	30.70	34.4	5.307	10.57	17.43	28.8	34.23
Sole soybean × 100 kg ha ⁻¹	9.75	13.22	26.53	40.40	45.1	5.400	8.07	13.67	25.0	44.40
Sole soybean × 200 kg ha ⁻¹	9.05	11.39	23.55	35.87	41.4	4.967	10.77	20.20	27.9	37.21
Sole soybean × 300 kg ha ⁻¹	9.47	15.33	23.50	36.37	42.3	5.433	9.60	21.13	33.8	44.07
Sole soybean × 400 kg ha ⁻¹	9.62	15.33	24.88	44.50	50.8	5.567	11.68	22.55	33.0	46.41
Intercrop soybean × 0 kg ha ⁻¹	7.75	13.55	21.63	33.61	42.4	5.433	8.51	11.97	27.7	38.70
Intercrop soybean × 100 kg ha ⁻¹	8.13	13.05	19.00	32.90	39.2	5.600	9.91	17.64	26.3	42.63
Intercrop soybean × 200 kg ha ⁻¹	9.33	13.53	27.03	35.13	40.5	5.767	10.70	23.30	29.7	39.83
Intercrop soybean × 300 kg ha ⁻¹	8.77	12.42	23.42	32.73	41.7	4.700	10.87	21.58	37.7	41.33
Intercrop soybean × 400 kg ha ⁻¹	9.55	12.25	24.75	41.31	46.9	5.867	9.27	23.50	39.2	48.73
LSD _(0.05)	ns	ns	5.859	8.977	11.13	0.841	2.565	6.274	11.63	8.511

The interaction of soybean and fertiliser consistently showed significant differences in the leaf area index of sole soybean in both years (Table 9). This is consistent with the findings [15], which reported that the leaf area index increased with the fertiliser application rate. To these ef-

fects, 400 kg N:P:K produced consistently the lowest leaf area index of soybean at 6 and 8 WAP in both cropping seasons in intercrop soybean. In Intercrop interaction, 400 kg consistently gave the highest leaf area index at 2 and 10 WA in both cropping seasons, respectively.

Table 9 – Effect of cropping system and fertiliser rate on Leaf area index of soybean at different stages of growth in 2018 and 2019 cropping seasons

Treatment	2018					2019				
	Leaf area index									
	Weeks after planting (WAP)									
Cropping system (C)	2	4	6	8	10	2	4	6	8	10
Sole soybean	0.155	0.443	1.157	3.99	5.48	0.355	1.202	3.070	5.27	6.43
Intercrop soybean	0.134	0.402	1.200	3.46	6.48	0.321	1.215	3.206	5.03	7.51
LSD _(0.05)	ns	ns	ns	ns	0.666	ns	ns	ns	ns	0.525
NPK-15:15:15 Fertilizer rate (F) (kg ha ⁻¹)										
0 (Control)	0.137	0.543	0.761	3.14	5.57	0.308	0.883	2.082	4.14	6.14
100	0.137	0.420	0.833	3.88	5.66	0.306	0.998	2.607	4.86	6.46
200	0.133	0.447	1.250	2.93	5.22	0.300	1.214	3.224	4.90	6.02
300	0.169	0.340	1.284	3.74	5.95	0.324	1.279	3.411	5.87	7.32
400	0.143	0.363	1.764	4.95	7.50	0.401	1.670	4.367	6.00	8.91
LSD _(0.05)	ns	0.201	0.434	1.047	1.052	0.083	0.564	0.422	1.087	0.830
Interaction (C × F)										
Sole soybean × 0 kg ha ⁻¹	0.146	0.694	0.675	3.50	4.89	0.320	0.997	2.230	4.32	5.25

	2018					2019				
	Leaf area index									
Sole soybean× 100 kg ha ⁻¹	0.154	0.375	0.751	4.22	5.22	0.307	0.805	2.220	4.86	6.23
Sole soybean× 200 kg ha ⁻¹	0.145	0.391	0.989	2.85	4.50	0.298	1.267	3.177	4.92	5.73
Sole soybean × 300 kg ha ⁻¹	0.192	0.321	1.306	4.37	6.09	0.358	1.218	3.385	5.91	6.88
Sole soybean x 400 kg ha ⁻¹	0.136	0.434	2.063	5.03	6.70	0.390	1.725	4.338	6.36	8.07
Intercrop soybean× 0 kg ha ⁻¹	0.128	0.393	0.847	2.79	6.25	0.297	0.769	1.935	3.96	7.04
Intercrop soybean× 100 kg ha ⁻¹	0.122	0.466	0.914	3.54	6.10	0.304	1.191	2.993	4.86	6.69
Intercrop soybean × 200 kg ha ⁻¹	0.121	0.502	1.511	3.02	5.94	0.302	1.160	3.271	4.88	6.32
Intercrop soybean× 300 kg ha ⁻¹	0.146	0.359	1.263	3.10	5.81	0.289	1.340	3.436	5.82	7.76
Intercrop soybean× 400 kg ha ⁻¹	0.150	0.291	1.465	4.87	8.31	0.412	1.616	4.396	5.64	9.75
LSD _(0.05)	0.060	0.285	0.613	1.481	1.488	0.117	0.798	0.597	1.537	1.174

The cropping system indicated a significant difference in the number of seeds/plants in 2018, while in 2019, the number of seeds per plant and the number of seeds/pods gave significant differences (Table 10). This is consistent with the findings of [16], who reported that the number of

seeds per plant in intercropping gave statically a higher number of seeds per plant of soybean. These could be attributed to efficient resource utilisation, leading to better plant growth and a higher seed production/pod.

Table 10 – Effect of cropping system and fertiliser rate on yield components of Soybeans in 2018 and 2019 cropping seasons

Treatment	Number of seeds per plant	2018 Number of seeds per pod	Number of seeds per plant	2019 Number of seeds per pod
Cropping system (C)				
Sole rice	134.1	1.942	1.834	130.5
Intercrop rice	159.8	2.122	2.086	139.0
LSD _(0.05)	8.09	ns	0.205	8.31
NPK-15:15:15 Fertilizer rate (F) (kg ha ⁻¹)				
0 (Control)	120.0	1.690	1.739	95.9
100	136.7	1.989	1.919	126.5
200	152.0	2.141	2.039	145.4
300	157.9	2.207	1.901	135.4
400	168.2	2.133	2.202	170.5
LSD _(0.05)	12.79	0.337	0.325	13.13
Interaction (C × F)				
Sole rice × 0 kg ha ⁻¹	110.4	1.466	1.554	91.1
Sole rice × 100 kg ha ⁻¹	120.5	1.862	1.599	115.8
Sole rice × 200 kg ha ⁻¹	139.1	2.036	1.923	135.9
Sole rice × 300 kg ha ⁻¹	145.5	2.255	1.888	143.4
Sole rice x 400 kg ha ⁻¹	155.3	2.092	2.206	166.2
Intercrop rice × 0 kg ha ⁻¹	129.7	1.914	1.924	100.7
Intercrop rice × 100 kg ha ⁻¹	152.8	2.116	2.239	137.2
Intercrop rice× 200 kg ha ⁻¹	165.0	2.247	2.155	154.8
Intercrop rice × 300 kg ha ⁻¹	170.4	2.159	1.913	127.3
Intercrop rice × 400 kg ha ⁻¹	181.0	2.175	2.198	170.5
LSD _(0.05)	18.09	0.477	0.459	18.57

The fertiliser showed significant differences across all the yield components of soybeans in 2018 and 2019, while 0 kg NPK consistently produced the lowest yield component in 2018 and

2019. This implies that the higher the fertiliser rate, the higher the yield component. On the other hand, 400 kg NPK fertiliser produced a static yield component of soybeans in both cropping

seasons, with the expected number of seeds/pods of soybeans in 2018. The interaction of soybean and fertiliser rates produced significant differences in all yield components of soybeans (Table 10) in both cropping seasons. Interaction of soybean and fertiliser rates in sole and intercrop indicated 0 kg in sole and intercrop produced consistently, the lowest yield component in both the 2018 and 2019 cropping seasons except on the number of seeds/plant in 0 kg (control) and soybean intercrop.

CONCLUSIONS

Based on the result of this investigation, it was observed that the cropping system and increased fertiliser rates positively affected upland rice's growth and yield component. It was noted that the N:P:K fertiliser rate (400 kg) gave the highest growth and yield component of upland rice in the rice/soybean intercropping system.

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