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Performance of Maize-Bean Intercropping Assessed Through Varied Spatial Arrangements and Nutrient Phosphorus Levels in Tanzania

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Abstract. Erratic climatic conditions, inherent low fertility and nutrient depletion are among the most important biophysical constraints of food crops production in semi-arid African regions. This study aimed to elucidate the impact of different crop spatial arrangements associated with different levels of Phosphorus on the performance of maize-bean intercropping in Tanzania. The experiment was laid in a complete randomized design of factorial-split arrangement and three factors in different levels. Sowing patterns were randomly assigned to all experimental plots whereas Phosphorus rates were randomly assigned within a specific sowing pattern one after another. Data were subjected to statistical analysis using GenStat software of a generalized treatment structure in a randomized design. Results of the interaction between cropping pattern and the P-rates on beans and maize at a 5% level of significance indicated that grain yield, pods/plant, and biological yield did not differ significantly ($P>0.05$) while plant height, leaf area index, and plants per plot differed significantly ($P<0.05$). Intercropping affects the growth and development of component crops depending on the cropping pattern and the nutrients applied. The choice of compatible crops for an intercropping system should not exempt growth habits of the crops, land size, light, water fertilizer utilization. and other agronomic practices.

Keywords: intercropping, N_2 fixation, soil fertility

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1. Introduction

Poor soil fertility is one of the important constraints of food crops production in tropical soils of the soil nutrients, erratic climatic conditions associated with low soil moisture have been the major concern in arid and semi-arid climates. Water is required for the solubilization, and translocation of essential nutrients required for crop growth and development [1]. In the tropics of humid and sub-humid climates, soil moisture is not a problem but rather the high level of nutrient transformations, leaching, washout, fixation, and removal by crops. The depletion of nutrients in the soils of these areas is attributed to the continuous cultivation with/without deliberate replenishment through industrial fertilizers and/or incorporation of organic resources such as

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manures and crop residues. Nutrient absorption is governed by the interaction at the soil-root interface, which is associated with root morphology and growth rate, nutrient absorption kinetics of the root and nutrient supply of the soil [2].

Phosphorus (P) is a major nutrient limiting plant growth in many soils because of its low levels in parent-source material and its chemical transformations in the soil system [3], [4]. This observation suggests that there is a high need of identifying alternative options for optimizing the use of P nutrient elements by the crop and assess their significance in improving agricultural production in the context of increasing food demand and its security at the household level. Food security depends on the global climate change, the balance between food production and its quality (calories, proteins, vitamins, micronutrients), and people's access to food [5]. According to [5], the world can produce sufficient food but many people cannot easily access it due to lack/low purchasing power, absence of markets and/or poor infrastructure. Alternative strategies of improving and/or intensifying agro-ecosystems that optimize P bioavailability remain the main viable and feasible option in highly weathered soils of tropics[3], [6]. P bioavailability as the amount or flux of P taken up by biota, over a given time period [3], [7]. P availability can vary amongst different plant species and their rhizosphere [8]. The P-mobilizing compounds of agricultural importance which can alter soil P availability in the rhizosphere are protons/hydroxyls (H+/OH-), carboxylates and extracellular phosphatase-like enzymes[8], [9].

Field crops are mostly grown in an intercrop system in cropping potential areas of Tanzania because of marginal lands owned by smallholders [10]. Field legumes such as Phaseolus bean among other legumes are intercropped in almost all cropping systems for the advantage of improving soil fertility but mainly because of their nutritive value and high market prices. However, the production of Phaseolus bean in Tanzania is very low (< 3 t ha-1) (Hillocks et al., 2006) and this is attributed to the influence of environment, genotypes, and management practices [11]. Improvement of soil fertility would serve one side of the problem while breeders are still busy realizing environmentally adapted bean cultivars. Application of inorganic fertilizers improves crop production, in Tanzania, their applications are still very low (8 kg ha^{-1}) and this attributed to the low purchasing power of smallholder farmers who dominate agricultural sector [12]. A study conducted by [3] revealed that cereal-legume intercropping can promote plant growth through the facilitation of increased P uptake by the partner crops in low P soils.

Coexisting plants compete for the restricted resources such as nutrients, moisture and radiant energy [13]. The ecological theory that strong competition could lead to so-called 'competitive exclusion under limiting similarity' from a community of plants [12]. This explains that co-existing species are more likely to go extinct from the community as a consequence of competition with species having similar traits. Co-existing plants interact with each other negatively that is competition and positively that is facilitation. For instance [12], co-existence of maize-bean could result into over-yielding of maize/bean because of synergies among shoot architectures attributed to the large long leaves of maize as opposed to the small round leaves of bean which easily occupy the gaps under maize canopy [14].

The yields in border rows of intercropped wheat in wheat/maize and wheat/soybean were significantly higher than those in inner rows and attributed this to the variation in above-ground and below-ground interactions [15]. The contribution of above-ground and below-ground interactions to the increase of P uptake increased for wheat/maize and for wheat/soybean intercropping [15]. The interspecific competition usually decreases survival, growth or reproduction of at least one plant species [15]. Overlapping of the sowing hence plants' growth period causes intense interspecific interactions between the partner crops [15].

Legume-cereal intercropping is reliably productive and sustainable system because of its nutrient facilitation and contribution to increased N availability and its uptake for the cereal crop via symbiotic nitrogen (N_2) fixation [16]. Grain yield of climbing bean was significantly increased with increased rates of farmyard manure (FYM) and with increase in their population density in a maize-bean intercropping system [17]. However, the system does not explicitly warrant the ultimate performance or rather high production of the partner crops because of inevitable interspecific competition between them. Previous studies have indicated that intercropping results into reduced yields of the partner crops and many arguments have resulted into inconsistent conclusions. [10], [11]. Different findings pertaining to yields of intercrops, which were related with plant density, shading effect, time of introducing legume in the system, and sowing pattern [18], [19]. The contribution of time of introducing a legume in the intercropping system to the yields of partner crops and N_2 fixation has not been documented under Tanzanian conditions. Therefore, the study intended to fill this gap using Phaseolus bean along with application of different rates of phosphorus (P) and a small starter dose of nitrogen (N) to encourage N_2 fixation by the bean.

Maize and bean in Tanzania are produced in sole or mostly mixed between them or with other crops especially in smallholder farmers. Based on the marginal lands owned by most farmers in Tanzania, mixed cropping of two or more crops during the same growing season is because a common practices and this is driven by increases land productivity determined by land equivalent ratio[10], [20], [21]. Intercropping soybean and maize gave land equivalent ratio greater than one, indicating high productivity per unit area achieved by growing the two crops together [21]. 45.7% and 44.4% of land saved in different cropping seasons of different years when maize was intercropped with okra [21]. 60.2% and 59.5% of lands saved in cassava, maize and egusi melon intercropping in a three crop system [21].

Intercropping is common for smallholder farmers worldwide [22]. Intercropping maize with legume crops including soybean, cowpea, French beans and common beans improved productivity [23]. Mixing of legumes with cereal crops helps to enhance subsoil nitrogen retrieval for the growing crops [24].

Bean production in Tanzania is constrained by low soil fertility, diseases, insect pests and unreliable soil moisture. The average Phaseolus bean production in Tanzania stands at 0.5 t ha^{-1} as opposed to potential yields of 1.5 – 3 t ha^{-1} [25], [26]. However, based on the agro-climatic conditions and physiographic features, the average bean yield in Morogoro is 0.3 t ha^{-1}. Low bean yields still remain to be poor seed quality and poor performance of landraces mainly due to their susceptibility to pests and diseases, low soil fertility, drought and poor cropping practices [25]. Low productivity of agricultural systems in Tanzania is mostly due to over-reliance on unpredictable natural precipitation, use of manual labor, limited use of improved seeds, fertilizers and other agro-chemicals [15].

The aim of this study was to assess the effect of maize-bean intercropping systems on the growth, yield, and P uptakes of component crops. The specific objectives of this study were to:

i. Assess the effect of different spatial arrangements of maize-bean on yields of component crops.
ii. Assess the effect of different rates of P on yields of maize and bean under different spatial arrangements.
iii. Assess the interaction effect of spatial arrangements, P rates.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at the Sokoine University of Agriculture (SUA) farm from February 2020 to June 2020, which is located at latitude 6˚ 85` South and longitude 37˚ 64' East and at an elevation of 568 m above mean sea level. Rainfall of the site is bimodal, which ranges between 800 and 950 mm. The soils are characteristically kaolinitic clays low in available P (7.9 mg kg^{-1}), total N (0.11%), organic matter content (1.0%), and extremely acid in reaction (pH = 5.4). The soils are also high in DTPA extractable Zn (1.8 mg kg^{-1}) and Fe (57.8 mg kg^{-1}) but very low exchangeable Al (0.02%) [12].

2.2. Experimental Area, Design, Treatments, and Planting

The experiment was laid in a complete randomized design (CRD) in a 2 × 2 × 4 factorial-split arrangement. There were three factors in different levels: (1) Plant types: (i) Maize, (ii) Bean; (2) Spatial arrangements of the component crops in the intercrop system: (i) 1:1 and (ii) 2:2; and (3) Nutrient phosphorus (P) levels (kg ha^{-1}): (i) 0, (ii) 7.5, (iii) 15, (iv) 30. Sowing patterns were randomly assigned to all experimental plots whereas P rates were randomly assigned within a specific sowing pattern one after another. This exclusively assigning of these treatments to their respective experimental settings helped to avoid the same P rate from being assigned twice to the same sowing pattern in a plot.

2.3. Routine Management of Crops in the Trial Field

2.3.1. Seed sowing

Maize variety TMV-1 and Beans variety Lyamungu 85 from Tanzania Official Seed Certification Institute (TOSCI) were sown simultaneously in all plots at the onset of the cropping season. For maize, 2 seeds were sown per hole while 3 seeds of Lyamungu 85 bushy bean cultivar were sown per hole in all plots. The sowing spacing for inter-row and intra-row were 30 cm × 30 cm. Thinning was done at 14 days after sowing of each seed crop to give plant population of 144 plants per plot for maize and 288 plants for common beans because only maize standing crop was left while two bean plants were left per hole.

2.3.2. Nutrient phosphorus application

Based on the level of P applied to a certain cropping pattern, each P rate was applied at once as a sowing dose of fertilizer. The rates of P applied were equivalent to 7.5, 15 and 30 kg P ha^{-1} except the control plots equivalent to 0.3, 0.6 and 1.2 g TSP per hole, respectively. These TSP rates were applied in a hole at a depth of 6 cm followed by covering with soil to about 2.5 cm deep before sowing.

2.3.3. Management of crops in the field

Urea (46% N) was applied to all experimental plots at a rate of 20 kg N ha^{-1} in two equal splits at 14 and 28 days after. For each split of N (10 kg ha^{-1}) 0.2 g of Urea was applied per planting station in all plots. Small starter dose of N (20 kg N ha^{-1}) stimulates legume growth as well as atmospheric nitrogen (N_2) fixation. Weeds were controlled mechanically by hand hoe weeding and hand pulling [27], [28].

A systemic insecticide Amekan 344 EC (Cypermethrin 144g/L+ Imidacloprid 200g/L) at a rate of 10 mL in 20 L of water in a pressurized knapsack sprayer was used to control (leaf beetles) *C. trifurcate* at 15 days of plant age and spraying activity was done 4 times after every 3 days.

2.4. Data Collection

Crops were harvested at complete maturity (60 days after sowing) for each plant type, spatial arrangement and P levels. At this stage, the data collected from maize and Phaseolus bean include plant height, leaf area, leaf area index, number of plants per plot at harvest, biological/Stover yield, and number of pods per bean plant, number of seeds per pod and grain yield which was expressed in t/ha.

2.4.1. Approaches of sampling

In a 1:1 maize-bean intercrop, one row of maize was excluded on each side of the plot and data collected from 3 rows of maize within a plot as there were only total of 5 rows. However, for the bean, only 1 row on any side of the plot was excluded from data collection. Irrespective of the plant species, plants in the first 3 planting holes in each side of the row were excluded indicating that only 10 plants were assessed within a row.

In a 2:2 maize-bean intercrop, one row of maize was excluded on each side of the plot and one row of bean adjacent to the last row of maize on only one side of the plot was discarded in data collection. Other approaches of data collection were as described for 1:1 maize-bean intercrop.

2.5. Data Analysis

Data were subjected to statistical analysis using GenStat software of a generalized treatment structure in randomized design. All interactions between spatial arrangement of bean and/or maize plants (1:1, 2:2) and P rates (check, 7.5, 15 and 30 kg ha^{-1}) were assessed using Tukey's honestly test at 95% CI interval of means. The significant variable means were only compared for P rates depending on the crop type (being it bean or maize) because the levels of P were more than two hence not easy to ascertain feasible statistical significance of a variable mean and the corresponding exact P rate. Shapiro-Wilk test for normality distribution of residuals and Bartlett's test for homogeneity of variances were performed to ascertain reliability of the data so collected.

3. Results and Discussion

3.1. Effect of Cropping Patterns and P-rates on Performance of Bean

Tables 1 and 2 present the results of the effect of P-rates on performance of bean and analysis of variance (ANOVA) and mean sum square of cropping pattern (CP), P-rates (PR) and their interaction (CP×PR) of the studied response variables of bean, respectively.

Table 1. Effect of P-rates on Performance of Bean

Treatment	Response Variables						
P-Rates	**Yield (t/ha)**	**Plant height (cm)**	**Leaf area (cm^2)**	**LAI**	**Plants/plot**	**Pods/plot**	**BY (t/ha)**
Check	0.21a*	45.71a	113.60a	0.06a	36.67a	8.17a	663.6b
7.5	0.21a	55.95c	129.01b	0.06a	36.30a	10.83b	756.2b
15	0.23a	54.26c	125.32b	0.06a	36.33a	12.50c	444.4a
30	0.18a	49.06b	119.30a	0.06a	36.83a	15.17d	623.5b

*Means with the same letter(s) along the column are insignificant due to Turkey's 95% Confidence Interval of means

Results of the two-way interaction between cropping pattern and the P-rates on bean plants indicated that grain yield, pods/plant and biological yield did not differ significantly (P>0.05) while plant height, leaf area index and plants per plot differed significantly (P<0.05). In addition, results indicated that cropping pattern had no significant effect on yield (P=0.7), plant height (P=0.14), plants/plot (P=0.184) and biological yield (t/ha) (P=0.66). However, cropping pattern was significant for leaf area (P=0.004) and leaf area index (P=0.001). Results indicated that P rates had no significant effect on yield (P=0.65) and plants per plot (P=0.43) whereas the significant effects were noted on the rest of the response variables (P< 0.05) (Table 2).

Table 2. Analysis of Variance (ANOVA) and Mean Sum Square of Cropping Pattern (CP), P-Rates (PR) and Their Interaction (CPxPR) of Response Variables of Been

Source of variation	**d.f**	**Variables and Values of Mean Sum Square**		
		Yield	**Plant height**	**Leaf area**
Replication	2	0.002	5.86	18.40
Cropping pattern (CP)	1	0.001ns	32.81ns	1812.56**
Residual/error (R1)	2	0.003	5.91	6.54
P rates (PR)	3	0.002ns	133.13***	276.01***
Interaction (CP×PR)	3	0.006ns	27.86***	177.27***
Residual/error (R2)	12	0.003	2.22	17.97
Total	23			
P- value	CP	0.7	0.14	0.004
	PR	0.65	0.001	<.001
	CP×PR	0.2	<.001	0.001

Source of variation	**d.f**	**Variables and Values of Mean Sum Square**			
		LAI	**Plants/plot**	**Pods/plant**	**BY**
Replication	2	1.25×10^{-5}	0.17	0.29	14676
Cropping pattern (CP)	1	$6.02\times10^{-6***}$	0.67ns	17ns	18521ns
Residual/error (R1)	2	4.17×10^{-6}	1.17	0.04	71030
P rates (PR)	3	$2.78\times10^{-5**}$	0.28ns	51.78***	102519*
Interaction (CP×PR)	3	$7.22\times10^{-6***}$	0.78ns	0.17ns	11317ns
Residual/error (R2)	12	8.33×10^{-6}	0.28	0.22	18866
Total	23				
P- value	CP	<.001	0.53	0.184	0.66
	PR	0.06	0.43	<.0.001	0.01
	CP×PR	0.002	0.09	0.543	0.63

Key: Significance levels: n.s= P>0.05; *P = 0.01–0.05; **P = 0.001 – P<0.01; ***P<0.001
LAI = Leaf Area Index; BY = Biological yield

Results indicated that there was significant (P<0.05) variation among pods per plant and the mean number of pods were obtained in the decreasing order of 30 kg P ha^{-1} (15.17 pods/plant), 15 kg P ha-1 (12.50 pods/plant), 7.5 kg P ha^{-1} (10.83 pods/plant) and check (8.17 pods/plant) (Table 1). High grain yield of bean (0.23 t/ha) though insignificant (P=0.7; Table 2) was obtained after application of 15 kg P ha^{-1} compared with the check and 7.5 kg P ha^{-1} (0.21 t/ha) and 30 kg P ha-1 (0.18 t/ha) (Table 2). Results also indicated that large number of pods per plot (15) was obtained when P was applied at 30 kg P ha^{-1}. Significantly (P=0.001) tall bean plants of 55.95 cm and 54.26 cm and leaf areas of 129 cm^2 and 125.3 cm^2 were obtained when P was applied at 7.5 and 15 kg P ha^{-1}, respectively. (Table 1).

3.2. Effect of Growing Pattern and P-rates on Performance of Maize

Tables 3 and 4 present the results of the effect of P-rates on performance of maize and analysis of variance (ANOVA) and mean sum square of cropping pattern (CP), P-rates (PR) and their interaction (CP×PR) for the response variables of maize plants, respectively.

Table 3. Effect of P-rates on Performance of Maize

Treatment	**Response Variables**					
P-Rates	**Yield (t/ha)**	**Plant height (cm)**	**Leaf area (cm^2)**	**LAI**	**Plants/plot**	**BY (t/ha)**
Check	6.02a*	222.1a	866.6a	0.41a	17.8a	15.7ab
7.5	6.57a	221.4a	908.3c	0.42ab	17.7a	14.7a
15	5.60a	222.3a	921.9c	0.43c	17.8a	14.4a
30	5.93a	221.8a	903ab	0.42ab	17.8a	14.4a

Key: LAI = Leaf Area Index; BY = Biological yield. *means with the same letter(s) along the column are insignificant due to Turkey's 95% Confidence Interval of means

Results of the two–way interaction between cropping pattern and P-rates had no significant effect on plant height (P=0.63), plants per plot (P=0.303) and biological yield (P=0.62). The interaction effect was observed in maize grain yield (P=0.007), leaf area (P=0.003) and leaf area index (P=0.016) (Table 4). Results of the response variables generated based on P rates indicated their insignificant (P>0.05) effect on grain yield, plant height, leaf area index, plants per plot and biological yield but the significant (P=0.05) of P rates effect was obtained on leaf area.

In addition, results indicated that cropping pattern had significant (P< 0.05) effect on leaf area index while the rest of the response variables were not significantly (P>0.05) affected by the cropping pattern. Furthermore, results indicated that though maize grain yield was insignificantly affected by certain P rates, high yield (6.57 t/ha) was recorded when P was at applied at 7.5 kg P ha^{-1}. This was followed by other rates of P at decreasing order of check (6.02 t/ha), 30 kg P ha^{-1} (5.93 t/ha), and 15 kg P ha^{-1} (5.6 t/ha). At the same rate of P (7.5 kg P ha^{-1}) also the tallest height (222.3 cm) of maize was recorded. Results also indicated that significantly (P=0.05; Table 4) large leaf area was obtained at an application of P-rates of 15 kg P ha^{-1} (921.9 cm2) and 7.5 kg P ha^{-1} (908.3 cm^2) followed by application of P at 30 kg ha^{-1} (903 cm^2) and check (866.6 cm^2) which were statistically at par (Table 3).

Table 4. Analysis of Variance (ANOVA) and Mean Sum Square of Cropping Pattern (CP), P-Rates (PR) and Their Interaction (CP×PR) of Response Variables of Maize

Source of Variation	d.f	Variables and Values of Mean Sum Square					
		Yield	Plant Height	Leaf Area	LAI	Plants/plot	BY
Replication	2	2.82	0.67	289.3	5.4×10^{-5}	0.04	12.32
Cropping pattern (CP)	1	3.94ns	0.18ns	1034.2ns	$1.76\times10^{-1***}$	0.38ns	0.37ns
Residual/error (R1)	2	2.94	1.58	326.9	4.2×10^{-5}	0.13	63.32
P rates (PR)	3	0.98ns	1.06ns	3342.6*	4.78×10^{-4}ns	0.04ns	11.31ns
Interaction (CP×PR)	3	7.32**	0.61ns	8167.4**	1.272×10^{-3}*	0.26ns	6.90ns
Residual/error (R2)	12	1.1	1.03	987.5	2.46×10^{-4}	0.19	11.14
Total	23						
P- value	CP	0.37	0.77	0.184	<.001	0.225	0.946
	PR	0.47	0.41	0.05	0.176	0.885	0.42
	CP×PR	0.007	0.63	0.003	0.016	0.303	0.62

Key: LAI = Leaf Area Index; BY = Biological yield. *means with the same letter(s) along the column are insignificant due to Turkey's 95% Confidence Interval of means

3.3. Discussion

3.3.1. Bean plants

The study indicated that two–way interaction between cropping pattern and P rates had no significant effect on bean plant height. The number of pods per plant was not significantly (P> 0.05) affected by the cropping pattern and the interaction, but these were very highly significantly affected by the P rates. The number of pods per plant is reduced in intercropping system [29]. The number of pods and seed yield was significantly reduced when cowpea was intercropped with maize [30]. This study shows that grain yield of bean was not significantly affected by cropping pattern, P rates and by the interaction between cropping pattern and P rates, which is contrary to [29]. Further studies by [29] revealed that maize leaves form canopy and obstruct light from reaching the cowpea leaves and this reduced the ability of cowpea to make more food for the formation of flowers and pods.

Many pods were obtained following application of P in the decreasing order of 30 kg P ha^{-1}, 15 kg P ha^{-1}, 7.5 kg P ha^{-1} and the check. This indicates that high rate of P applied favours formation of many pods per individual bean plant. However, these pods did not reflect their potential on grain formation and formation of health grains. This is evidenced from seed grain yield obtained from different rates of P applied which was in the decreasing order of 15 kg P ha^{-1}, the check and 7.5 kg P ha^{-1} and 30 kg P ha^{-1}. This implies that no and/or too little (7.5 kg ha^{-1}) or too much (30 kg P ha^{-1}) application of P does not suit formation of potential pods for production of healthy seeds. This suggests that under similar environmental conditions and given no more variations in climatic factors, application of P at 15 kg P ha^{-1} suits bean pod formation and hence good grain yield.

Significantly tall bean plants of 55.95 cm and 54.26 cm and leaf areas of 129 cm^2 and 125.3 cm^2 were obtained when P was applied at 7.5 and 15 kg P ha^{-1}, respectively. The height and large leaf area indicates high chances of the plant to capture sunlight which is important during photosynthesis. The differences in plant height and leaf area between the two P rates consistently suggest that 15 kg P ha^{-1} is pertinent as opposed to other rates of P applied. This is attributed to the ability of 15 kg P ha^{-1} to potentially accommodate many studied response variables for bean plant performance.

3.3.2. Maize plant

This study revealed that the two–way interaction between cropping pattern and P rates had no significant effect on plant height, plants per plot and biological yield. The interaction effect was observed in maize grain yield, leaf area and leaf area index. Cropping pattern had significant ($P< 0.05$) effect on leaf area index while the rest of the response variables were not significantly ($P>0.05$) affected by the cropping pattern. Based on P rates high maize grain yield (6.57 t/ha) was recorded when P was at applied at 7.5 kg P ha^{-1}. Although the difference from other P rates was not significant ($P>0.05$), the so recorded high grain yield was followed by other rates of P at decreasing order of check (6.02 t/ha), 30 kg P ha-1 (5.93 t/ha), and 15 kg P ha^{-1} (5.6 t/ha). Interestingly, at the same rate of P (7.5 kg P ha^{-1}) also the tallest height (222.3 cm) of maize plant was recorded. This suggests that application of P at 7.5 kg P ha-1 to maize plants in the study area outperformed other rates of P used (15 and 30 kg P ha^{-1}) and the check in this study.

Followed closely in their significant ($P=0.05$) variations, large leaf area was obtained at an application of 15 kg P ha^{-1} (921.9 cm^2) and 7.5 kg P ha^{-1} (908.3 cm^2), which both outperformed P at 30 kg ha^{-1} (903 cm^2) and the check (866.6 cm^2) which were statistically at par. large leaf area is very important in plant production of assimilates during photosynthesis. This observation suggests that application of 7.5 kg P ha^{-1} suits for maize production in the studied area under optimal growth and development conditions. The increase in leaf area is attributed to spatial arrangement and increase in plant population hence extended canopy for ground coverage. Physiological structure of the plant helps it in capturing sunlight and prevents it from being lost to the ground. According to Prasad and Brook (2005), with increasing maize density, the accumulation of dry matter and leaf area index also increased thereby decreasing transmission of light to the intercropped legume.

4. Conclusion and Recommendation

The findings of the study suggest that intercropping can have a significant impact on the growth and development of component crops, and that the choice of compatible crops should take into account a range of agronomic factors. Specifically, the study found that a combination of 15 kg P ha^{-1} for maize and 7.5 kg P ha^{-1} for beans was optimal for production in the studied area.

However, the study also highlights the need for further research into the effects of intercropping on factors such as shading, timing of introduction, and N_2 fixation under different spatial arrangements of component crops. Such research could help to refine our understanding of the best practices for intercropping and could inform future recommendations for farmers and agricultural policy makers.

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