SOIL PROPERTIES AND AGRONOMIC PERFORMANCE UNDER MAIZE KIDNEY BEAN INTERCROP IN BENIN CITY

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF SOIL SCIENCE AND LAND MANAGEMENT, FACULTY OF AGICULTURE, UNIVERSITY OF BENIN, BENIN CITY, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIRMENT FOR THE AWARD OF BACHELOR OF AGRICULTURE (B. AGRIC) DEGREE IN SOIL SCIENCE

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CERTIFICATION

This is to certify that **Gloria Praise ETTA (Miss)** carried out this project work in the Department of Soil Science and land management, Faculty of Agriculture, University of Benin, Benin City.

Mr. E.O. Airueghian **Date**
(Project supervisor)

Dr. (Mrs.) V.I.O. Edosa **Date**
(Project supervisor)

DEDICATION

This project work is dedicated to God Almighty, my source, my best friend, my strength. and inspiration. To my parents, Pst. and Mrs. Joshua Etta, and my siblings who have been supportive all the way.

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My most profound gratitude goes to God almighty for His love that has kept me through my studies and by whose strength I am able to see the completion of my degree programme. To the best supervisor I could ever wish for; Mr. E.O. Airueghian, I am eternally grateful to God and to you for every time you have supported, corrected and guided me through the course of this project. I really want to say a big thank you Sir. I acknowledge my amiable Head of Department Dr. (Mrs.) V.I.O. Edosa, the Dean of the faculty of Agriculture, Prof. Emokaro C.O, and other wonderful lecturers of the department of soil science and land management for their various contributions to the success of their project.

My gratitude goes to my lovely parents, Pst. and Mrs. Joshua Etta for their prayers, moral encouragement, unending love, financial support and prayers. I want to specially say thank you to Pst Sam Osas for his love and support thus far, to Augustine Chukwuma, God bless you. Finally, I say a special thank you to my friends Osasere Osaro, Ebiuwa Precious Aigbe, Iweluegim Faith Ogechi, Blessing Odikpo, who in one way or the other contributed to the success of my degree, and made my experience in the University of Benin worth reminiscing.

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ABSTRACT

This field experiment was conducted in the Experimental Field of Faculty of Agriculture, University of Benin, Benin City, to ascertain the physical and chemical properties of soil and agronomic performance of Kidney bean (*Phaseolus vulgaris*) and Maize (*Zea Mays*) in monoculture and intercrop. The experiment was laid out in a randomized complete block design (RCBD) with three levels of treatment and three replicates. Soil samples were collected before and after experiment for determination of parameters: pH, total organic carbon (TOC), total nitrogen (TN), available phosphorus, potassium, calcium, magnesium, sodium, hydrogen, aluminium, sand, silt and clay. Also plant parameters like, stem girth, number of leaves, vine length, weight of 100 grains and yield were also determined. Data collected were subjected to analysis of variance and Duncan Multiple Range Test was used to separate means at 5% level of significance. Results show that the total nitrogen content of the soil in the sole maize plot reduced to 0.54 g/kg from the 0.63 g/kg recorded in the soil before sowing while the kidney bean + maize intercrop plot increased to 0.73 g/kg and the sole kidney bean pot was 0.80 g/kg. Furthermore, the soils in the area were generally acidic in nature and belong to the loamy sand textural class. The effect of intercropping on yield varied between kidney bean and maize. For kidney bean and intercropping, there was a slight increase in grain weight (32.8 g under intercropping compared to 31.9g in monoculture) and a minor improvement in total yield (0.72 t/ha in intercropping relative to 0.70 t/ha in monocropping). This suggests that intercropping had positive effect on yield of kidney bean. The nutrient (nitrogen, phosphorus, potassium, calcium and magnesium) content of the grains of maize and kidney bean were not affected by intercropping. However, intercropping resulted in a decrease in yield components (stem girth, number of leaves, plant height, weight of 100 grains average weight of cob and grain yield) of maize while kidney bean recorded increment in growth and yield parameters.

CHAPTER ONE

1.0 INTRODUCTION

Intercropping is an ancient agricultural practice that involves planting two or more crop species together in the same space and at the same time (Dai *et al*., 2019). Compared to sole cropping systems, intercropping productivity has a great potential, to substantially optimize cropping systems under limiting resources like light, water, and nutrients (Yin *et al*., 2020) offering heightened crop yield and stability compared with monocropping/sole cropping (Parvin *et al*., 2023). This agricultural practice mitigates the adverse environmental impacts associated with modern farming methods while simultaneously optimizing soil nutrient, water, and resource utilization (Chen *et al*., 2017). Chowdhury and Rosario (2014) also reported greater efficiency of intercrops than that of the sole crops in converting absorbed nutrients to seeds/grains also contributed to the yield advantage. Morris and Garrity (2023) reported that on average intercrops took up 43% more phosphorus and 35% more potassium than the sole crops. The larger and longer duration of functional root systems under intercrops than either sole crop was postulated by researchers for the greater capture of nonmobile nutrients like phosphorus and potassium. Enlarged root systems provided an expanded root surface area to which non-mobile nutrients diffused (Morris and Garrity, 2023).

The important reason for intercropping is the improvement and maintenance of soil fertility. This is reached when a cereal crop (such as maize or sorghum) or a tuber crop (such as cassava) is grown in association with a pulse (beans, peas, etc.) (Geno and Geno, 2021). They also reported that deep-rooting pulse crops, such as pigeon pea, also take up nutrients from deeper soil layers; thereby recycle nutrients leached from the surface. Legumes also grow well in soils low in phosphate (Geno and Geno, 2021); after the intercrop is harvested, decaying roots and fallen leaves provide nitrogen and other nutrients for the next crop. This residual effect of the pulse crop on the next crop is largest when the remains of the pulse are left on the field and ploughed under after harvest. However, when a large amount of nitrogen is removed in the grain harvest, more nitrogen is removed from the field than fixed by the pulse crop (Geno and Geno, 2021). Thus, soil depletion can still occur in a grainpulse intercrop when the nutrients taken up by the crops are not replaced with manure or fertilizers (Giller, 2021).

1.1 Objectives of the study

The specific objectives of this study were to determine:

i. Some physical and chemical properties of soil under maize- Kidney bean intercrop.

ii. the nutrient concentration of the grains of maize and kidney bean

iii. the growth and yield of maize when intercropped with kidney bean

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 What is intercropping?

Intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage (Gomez and Gomez, 2018). Intercropping, double cropping and other mixed cropping practices that allow more efficient uses of on farm resources are among the agricultural practices associated with sustainable crop production (NRC, 2014; Tolera, 2023). Intercropping provides year-round ground cover, or at least for a longer period than monocultures, in order to protect the soil from desiccation and erosion. By growing more than one crop at a time in the same field, farmers maximize water use efficiency, maintain soil fertility, and minimize soil erosion, which are the serious drawbacks of mono-cropping (Hoshikawa, 2021). It also reduces seasonal work peaks as a result of the different planting and harvesting times of intercropping crops. Moreover, it could serve to increase output per unit area, particularly with low levels of external inputs since a mix of species makes better use of available nutrients and water in the soil (Kotschi *et al.,* 2016).

Besides the benefit of yield and income, intercropping can be seen to produce social benefits to both the land-holder and the surrounding community (Geno and Geno, 2021). Bradfield (2016) noted that updating traditional intercropping practices (as opposed to promoting monocultures) offers the potential of scale specific technologies that favor the small farmer. Addressing the question of equity, Willey (2021) found that the advantages of multiple cropping, that the benefits are achieved not by means of costly inputs but by the simple suitability of growing crops together. Thus, intercropping offers a very genuine way in which the poorer or smaller farmer can benefit at least as much as the better return one.

Similarly, Jodha (2021) noted that research reveals its potential for greater employment. Because intercropping is often a system used on small farms, any breakthrough in intercropping technology will help poor farmers more than the rich, thus better serving equity goals.

2.2 Features of Intercropping System

2.2.1 Competition Indices in Intercropping

A yield advantage of intercropping can be indicated by using different methods, among which Land Equivalent Ratio (LER) is the most commonly used to indicate the biological efficiency and yield per unit area of land as compared to mono-cropping system; an LER greater than 1.0 implies that for that particular crop combination, intercropping yielded more than growing the same number of stands of each crop as sole crops. An LER of less than 1.0 implies that intercropping was less beneficial than sole cropping (Onwueme and Sinha, 2021). In a study that was conducted in the field at Kenya Agriculture Research Institute Njoro, Kenya, in both years (2004 and 2006) of the study, land equivalent ratio was >1 in all the intercropping systems (tomato/maize, tomato/kale and tomato/onion) (Ramkat *et al.,* 2018).

Area time equivalent ratio (ATER) also provides more realistic comparison of the yield advantage of intercropping over mono-cropping in terms of time taken by component crops in the intercropping systems. ATER can be calculated by the formula of area time equivalent ratio, (ATER) = LER x Dc / Dt (Heibsch, 2028), where LER is land equivalent ratio of crop, Dc is time taken by crop, Dt is time taken by whole system. Relative crowding coefficient (RCC or K) is another index that measures the relative dominance of one species over the other in intercropping system (De Witt, 2014). For example, the K can be calculated for tomato intercropping as: K = (K tomato x K intercrop) K tomato = {Yab Zba} / {(Yaa – Yab) Zab } K intercrop = {Yba Zab} /{ (Ybb – Yba) Zba }, where Zab is sown proportion of tomato in intercropping, Zba is sown proportion of intercrop in intercropping, Yab is the yield of tomato in intercropping, Yba is the yield of intercrop in intercropping, Yaa is the yield of tomato in mono-cropping and Ybb is the yield of intercrops in intercropping. When the product of two coefficients (K tomato x K intercrop) is greater than one, there is a yield advantage, if the value of K is one there is no yield advantage and if less than one there is no yield advantage and the system has disadvantage.

Efficiency of intercropping can also be measured by using the index called Aggressivity (A), the relative yield increase in "a" crop is greater than of "b" crop in an intercropping system (McGilchrist, 2015). The aggressivity can be derived from the following formula. A tomato = {Yab / (Yaa X Zab)} – {Yba / (Ybb X Zba)}. If the value of A is zero, both crops are equal. If the value of A is positive, then tomato is dominant over intercrops. If the value is negative, then intercrops are dominant species over tomato. Similarly, aggressivity of intercrops can also be calculated by the Formula. An intercrop = {Yba / (Ybb X Zba)} – {Yab / (Yaa X Zab)} Competitive ratio (CR) gives better measure of competitive ability of the crops and is also advantageous as an index over K and A (Willey and Rao,2015). The CR simply represents the ratio of individual LERs of the component crops and takes into account the proportion of the crops in which CR tomato (LER tomato / LER intercrops) (Zba / Zab) CR intercrops = (LER intercrops / LER tomato) (Zab / Zba).

2.2.2 Interactions in Intercropping

Competition and complementarities are the two most important interactions in intercropping. Willey (2019a) suggested three broad categories of competitive relationships in intercropping: Firstly, when the actual yield of each species is less than expected, termed mutual inhibition. Secondly, where the yield of each species is greater than expected (mutualism), and thirdly, the most common situation, where one species yields less than expected and the other more; termed compensation. Complementarity is a key feature of intercrops and natural vegetation. According to Willey (2019a), yield advantage in multiple cropping occurs when component crops differ in their use of growth resources in such a way that when they are grown in combination, they are better able to complement each other and so make better overall use of resources than when grown separately in terms of competition. The component crops are not competing for exactly the same resources (in space or time) and intercrop competition is less than intercrop competition.

Temporal and spatial complementarities can be differentiated from one another (Willey 2019a). In temporal complementarities, growth patterns differ in time (typically at least 30-40 days maturity difference); crops use water at different times, particularly where the system is moisture limited. It involves a time displacement that results in the capture of more resources by the intercrop rather than a change in the efficiency of utilization. Spatial complementarity is the combined leaf canopy or root system of an intercrop that makes better use of available resources when grown together, such as total light interception, water and nutrient uptake because component crops exploit different soil layers or canopy heights in intercropping. Component crops differ in their nutrient requirements, the form of nutrients which they can readily exploit and their ability to extract them from the soil. One crop exploits a greater volume of soil. Where the total quantities of resource captured is relatively similar, the efficiency of utilization of the resources captured is increased in intercrops compared to the sole crops.

Willey (2019a) concluded that the greater the difference in maturity and growth factor demands of the crop components either because of genetic difference or manipulation of planting dates, the more opportunity for greater total exploitation of growth factors and subsequent over-yielding. In another report, Willey (2019b) concluded that better use of growth resources as a result of complementary effects between component crops is the major sources of yield advantage.

2.2.3 Plant Population in Intercropping

Plant population is the number of plants per unit area, and it would be useful to know optimum or critical population densities to avoid population as limiting factor for crop yield. Establishing of the plant population ensures that the crop produced is of acceptable quality (Balasubramaniyan and Palaniappan, 2021). The authors further stated that plant population depends on type and growth habit of crops, soil fertility, rainfall and other growth requirements. There is negative effect of very high population density particularly in branching crops due to competition for sun light under dense situation (Balasubramaniyan and Palaniappan, 2021). According to Willey (1979b), intercropping gives a yield advantage when the total plant density is higher than that of either of the sole crops.

In terms of total population pressure, two broad classes of intercropping systems can be distinguished (Geno and Geno, 2021). One is substitutive or replacement series of intercropping in which proportional populations are related to sole crop of the series and whatever the population is added the two proportions must always add up to 100%. The second is additive or superimposed intercropping in which one component crop is added to the other so that the final plant population is generally more than either crops sown sole. Substitutive intercropping generally consists of crops from the same phenological group and the yield gain in such mixture is from a simple response to reduced population because of complementary in space and to some extent to time or both. The challenge comes in knowing how much to be substituted to optimize the yield (Sullivan, 2023). Additive refers to a situation where the component crops are plastic enough to take advantage of their lower plant population in intercrop and when specific objectives of the farmers is a particular proportion of the product which consists of crops from different phenological groups (Cannell, 2018).

2.3 The Benefits of Intercropping

2.3.1 Resource Use Efficiency in Intercropping

Increased crop production (over-yielding) often observed in intercrops compared to sole crops has been attributed to enhanced resource use (Szumigalski and Van-Acker, 2008). Francis (2016) and Sivakumar (2023) also reported that efficient and complete use of growth resources such as solar energy, soil nutrients and water is one of the advantages of intercropping system over sole crops. Intercrops are most productive when their component crops differ greatly in growth duration so that their maximum requirement for growth resources occur at different times (Fukai and Trenbath, 2013). Baker (2015) and Anitha et al. (2021) reported that to have yield advantages in intercropping system, there should be minimum of 25 percent difference in duration of crops. For high intercrop productivity, plants of the early maturing component should grow with little interference from the late maturing crop. The latter may be affected by the associated crop, but a long time period for further growth after the harvest of the first crop should ensure good recovery and full use of available resources (Fukai and Trenbath, 2018).

Intercropping allows effective utilization of growth resources through crop intensification both in space and time dimensions. The conventional ways of intensifying crop production are vertical and horizontal expansions. Intercropping offers two additional dimensions, time and space (Francis, 2016a). The intensification of land and resource use in space dimension is an important aspect of intercropping. For example, enhanced and efficient use of light is possible with two or more species that occupy the same land during a significant part of the growing season and have different pattern of foliage display. Different rooting patterns can explore a greater total soil volume because of the roots being at different depths (Francis, 2016a). These differences in foliage display and rooting patterns create the space dimension of intercropping. Nutrient use efficiency of the individual crops in an intercrop is mostly lower than their respective sole crops.

However, the cumulative nutrient use efficiency of an intercropping system was in most cases higher than either of the sole crops (Chowdhury and Rosario, 2014). Solar radiation, water and some nutrients would be wasted during early growth stages of long-term crops, but they can be utilized by an associated crop growing between the rows (Midmore, 2023). They reported that in maize/mung bean intercropping the nutrient absorption by both maize and mung bean was reduced due to intercropping, mung bean being more affected than maize. Similarly, higher land equivalent ratio over unity was largely done to a higher total uptake of nutrients by the component crops in the mixture than the sole crops. Chowdhury and Rosario (2014) also reported greater efficiency of intercrops than that of the sole crops in converting absorbed nutrients to seeds/grains also contributed to the yield advantage. Morris and Garrity (2023) reported that on average intercrops took up 43% more phosphorus and 35% more potassium than the sole crops. The larger and longer duration of functional root systems under intercrops than either sole crop was postulated by researchers for the greater capture of nonmobile nutrients like phosphorus and potassium. Enlarged root systems provided an expanded root surface area to which non-mobile nutrients diffused (Morris and Garrity, 2023).

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Experimental evidence showed that plant interactions below ground are normally more intense than those above ground and competition may limit uptake. According to Snaydon and Harris (2021) nutrients often occur in specific zones of the soil due to particular environmental conditions (i.e. leaching), management practices (i.e. surface applied phosphates), or nutrient solubility. Parallel to these differences, and often partially in response to them, there are differences in root distribution patterns between plants and throughout the soil profile. The authors, further indicated as roots can also use soil resources differently: In the way that the nutrient requirement is satisfied (legumes use N, non-legumes use NO-3 or NH+4). Different species may differ in their requirement for a resource. There is fourfold difference between species for calcium concentration, twofold for potassium and phosphate and threefold difference for nitrogen concentration.

Water use efficiency is also another importance of intercropping system. Dunn et al. (2019) suggested greater water resource capture was essential to solving environmental water leakage. They reported that Lucerne in rotation with wheat crops helped through summer uptake from a rooting depth double that of wheat. However, they caution that too much water use too quickly can jeopardize persistence and note the case of blue gum plantations in south Western Australia where loss of growth rate midterm in the rotation and ultimate death of the plantation is common, due to the need for carryover of soil water to maintain root infrastructure.

2.3.2 Light Interception and Radiation Use Efficiency

Willey (2019a) thought that light was the most important factor and noted that it was different from other growth resources in that it is only instantaneously available and thus must be instantaneously intercepted to be of benefit while other resources are typically pools awaiting plant exploitation. It has been suggested that light transmission through the canopy is affected by row orientation in addition to plant population density (Jaya et al., 2021).

They further showed that maize planted at medium density (7.1 plant m-2) with N-S orientation reduced within canopy maximum temperatures at 40 cm above the ground by 1.2oC. The temperature reduction was associated with a reduction of irradiance up to 70%; the reduction, especially in temperature, was highly sensitive to row orientation and plant density and at some combinations resulted in increased temperature. For cauliflower-maize intercropping in the lowland tropics, a plant density of 7 plants m-2 at N-S orientation was found to be promising with an irradiance of above 300 Wm-2 at midday about 5 weeks after sowing (Jaya et al., 2021). It was also indicated that this must be coordinated with the development of the cauliflower so that curd initiation takes place at this time; early growth of the cauliflowers will take place in higher irradiances to ensure sufficient carbohydrate supply.

Kinet and Peet (2017) showed that the light factor can be both positive and negative on the growth of tomato. High light intensity tends to accelerate flowering in many cultivars of tomato, whereas low light intensity limits vegetative growth and may also delay flowering. Tomatoes grown in protective structures often are provided with supplemental light when intensity is low and day lengths are short but in the tropical lowlands rather there is a high intensity; so, intercropping can maintain yield potential of tomato by reducing the extreme light condition and fluctuation of temperatures that affect yield in the hot dry season periods. Light interception and light use efficiency are powerful concepts for characterizing the resource capture and use efficiency of cropping systems, including intercrops. Improved productivity can result from either greater interception of solar radiation, higher light use efficiency, or a combination of the two (Willey, 2019). Light interception as a result of mixing two species and growing them together instead of alone is sometimes increased, either as a result of a lengthening of the period of soil coverage (temporal advantage), or as a result of a more complete soil cover (spatial advantage) (Keating and Carberry, 2023). When total crop densities are higher in intercrops, they can intercept more light especially early in the growing season. Intercrops composed of non-synchronous patterns of canopy development and different maturation times can display a greater amount of leaf area over the course of the growing season and intercept more total light energy than monocultures. Carandang (2018) thought that intercrops allow maximum utilization of sunlight by increasing light interception by 30-40%.

2.3.3 Temperature Dynamics

There have been many studies on the effects of adverse temperatures on reproductive development of tomato at both low and high temperatures. The critical period appears to be 3-6 and 12-14 days before anthesis (Kinet and Peet, 2017) for low temperature and 9 days before anthesis for high temperature effects. Low temperatures reduce pollen production, shed, viability and tube growth (Fernandez-Munoz et al., 2015). Kinet and Peet (2017) concluded that at high temperatures, flower formation, pollen grain and ovule formation, style elongation, pollen germination, fertilization and seed formation are all adversely affected. High temperature may also reduce sources strength of susceptible plants. Export of assimilated carbon from a tomato leaf was reduced under high temperature regimes (Kinet and Peet, 2017). The degree of injury to the fruit depends on irradiance, spectral quality, temperature and treatment duration (Adegoroye and Jolliffe, 1983). If temperatures are over 30 0C, but under 40 0C, the area straps yellow (Grierson and Kader, 2016) because temperature above 30 0C prevents lycopen formation (Kinet and Peet, 2017). This condition will be controlled by intercropping as the practice modifies the climate within the canopy.

Typical causes of poor fruit set in the field or greenhouse are too high or too low temperature or humidity; low light and winds. For example, (Kinet and Peet, 2017) showed that day temperature over 32 0C and night temperature over 21 0C reduce fruit set. Temperature has profound effects on many growth and development processes in tomato, including leaf growth, photosynthesis and respiration, fruit development and fruit quality (Braden and Smith, 2024). Low temperatures during the seedling phase slow down growth and development (Kinet and Peet, 2017). Therefore, as intercropping modifies the extreme temperatures both in air and in soil, it can be used to improve yield of tomato during the off-season cultivation. Farrell and Altieri (2015) elaborated on the microclimate benefits of intercropping characteristics: microclimate within canopy can moderates temperature extremes, lower temperatures and reduced air movement leads to less evaporation and increased relative humidity versus open sites.

2.3.4 Canopy and Relative Humidity

Compound canopies of component crops that occur due to intercropping of various plants can maintain relative humidity within the canopy which is important in avoiding desiccation and makes good growth condition even during moisture deficit periods. Therefore, intercropping composed of different patterns of canopy development and different maturation times can display a greater amount of leaf area over the course of the growing season and intercept more total light energy than monocultures. Where poly-cultures produce earlier or later canopy, evaporation of soil moisture is reduced, weeds suffer from light and moisture competition, and there is decreased rain impact erosion through canopy filtering and greater root structures. Wilson and Ludlow (2021) reported soil temperatures up to 10 0C cooler on forage under tree plantations in the tropics, assisting seedling survival, soil water relations and possibly affecting the rate of litter breakdown and nitrogen mineralization.

2.3.5 Pest Management

Yield advantage of intercropping is also common to reduce pests of crops. For example, insect and diseases are less when tomato was intercropped with maize (Pino *et al.,* 2014). High densities of Frankliniella occidentals occur on capsicum but not in tomato, Myzus persiceae also found in larger numbers on capsicum but was only in dry colonies on tomato when sweet pepper was intercropped with tomato (Nihoul *et al.,* 2014). Tomato had an auto toxic effect. The aqueous extract significantly inhibited the growth of cucumber, radish, lettuce (Zhou *et al.,* 2017). Intercrops can have a range of effects on weeds beyond allelopathy. Liebman (2015) catalogued numerous mechanisms that resulted in fewer weeds, higher yield, fertility enhancement and favorable environmental impact. This is through elimination of herbicides or hand weeding, earlier and fuller canopy, erosion protection from heavy rain or running water or through a general theory of greater preventative use of resources that are then not available for weed growth. In a study of intercropped wheat and beans in England, Bulson (2014) found that while both intercrops, either spring or winter cropped, produced higher yields and suppressed weeds, total removal of weeds did not significantly increase the yield of either intercrops or sole crops.

Accordance to the study result of Girma et al. (2015), under Melkassa Agricultural Research Center, Ethiopia, the Orobanche (parasitic weed) shoot count was significantly reduced for tomato/maize and tomato/common bean intercropping plots as trap cropped than the check (sole tomato) plot and tomato yield was increased as a result of reduction of Orobanche shoot count; and they recommended that potential trap crops may be the cheapest means of controlling Orobanche parasitic weeds in tomato production; and also concluded that optimum control of parasitic weeds by means of trap crops is by far the most economical method to be practiced by small-scale commercial farmers of vegetable growers in the Central Rift Valley of Ethiopia.

Therefore, as many researchers indicated, the main objective of intercropping has been to increase maximize use of resources such as space, light and nutrients (Ndakidemi, 2006), as well as to improve crop quality and quantity (Mpairwe *et al.,* 2002). Other benefits include water quality control through minimal use of inorganic nitrogen fertilizers that pollute the environment (Crew and Peoples, 2004). The current trend in global agriculture is to search for highly productive, sustainable and environmentally friendly cropping systems (Crew and Peoples, 2004). This has resulted into renewed interest in cropping systems research (Vandermeer, 1989).

2.4 Disadvantages of Intercropping

There are, however, some disadvantages in intercropping systems. These includes yield reduction of the main crop, loss of productivity during drought periods, and high labor inputs in regions where labor is scarce and expensive (Gliessman, 2015). It is well documented that in most cases the main crop in an intercropping system will not reach as high a yield as in a monoculture, because there is competition among intercropped plants for light, soil nutrients and water (Willey, 2019b). This yield reduction may be economically significant if the main crop has a high market price than the other intercropped plants.

Another disadvantage that is likely to be occurring is the higher cost of maintenance, in particular, weeding, which may have to be done by hand. This is not a serious problem in countries where excess farm labor is cheap, for example, Ethiopia; but for countries lacking such a labor force, intercropping will result in increased costs. Furthermore, harvesting of one crop may cause damage to the other (Gliessman, 2015). Finally, the intercropped canopy cover may result in a microclimate with a higher relative humidity conducive to disease outbreak, especially of fungal pathogens (Gliessman, 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The experiment was carried out in the Experimental Field of Faculty of Agriculture, University of Benin, Benin City. The area lies between latitude 06° 24′ 02.2″ and 06° 24′ 03.4″ North and longitude 005° 37′ 35.9″ and 005° 37′ 36.8″ East. It is in the rainforest ecological zone of Nigeria (Illoba and Ekrakene, 2008) which is characterized by two distinct seasons: dry (November–March) and wet (April–October) (Molindo and Nwachokor, 2010). It has a mean annual rainfall of 1900 mm and average temperature of 27˚C (NIFOR, 2013). The topography of the land is a gentle slope, which falls eastwards. The soils in the area are ultisols; which are derived from recent coastal plain sands known as Benin formation (Umweni, 2007). The vegetation of the area includes weeds such as: *Panicum maximum, Mimosa pudica, Eleucine indica, Sida acuta, Sporobolus pyramadalis etc.*

3.2 Planting Materials

Oba 80™ hybrid maize seeds was obtained from farmer shop in Benin City while red kidney bean seeds (local variety) which is medium in size, brown in colour and have smooth edges, were bought from local markets in Benin City.

3.3 Cultural Practices

Maize and kidney bean were planted as monocrops using a spacing of 90 cm between rows and 70 cm within rows, while kidney bean was planted at the middle of the spaces between rows, in intercrop. The crops were planted on plots measuring 4.5 m × 2.8 m at the rate of three seeds per hole which was later thinned to two plants per hole while failed plants were supplied. Weeding was done with hoe, while at harvest, fruits were picked for estimation of yield parameters (number and weight of fruits per plant, yield per plot and total yield per hectare).

3.4 Crop Combinations

The crop combinations are: sole maize, sole kidney bean, maize + kidney bean.

3.5 Experimental Design

This experiment was carried out as a Randomized Complete Block Design (RCBD) with three replicates

3.6 Variables Measured

Plant Height/Vine Length (cm): The plant height of maize and vine length of *egusi* melon and kidney bean, from base to tip were measured at 50% flowering, using a tape and the means were determined and recorded.

Number of Leaves: The number of leaves at 50% flowering stage was counted and mean determined and recorded.

Stem Girth (cm): The circumference of stems at collar level at 50% flowering was measured using a tape and recorded.

Fresh Fruit Weight (g): The weight of fresh fruits (ear of maize and pods of kidney bean and *egusi* melon) per plot was taken and made equivalent of a hectare.

Seed weight (g): the weight of 1000 seeds was determined and average weight of seeds was calculated.

Nutrient Content (%): the shoots of crops were analyzed for nutrient content

Figure 1. Crop Arrangement

O K O K O K O K O K O K O

O K O K O K O K O K O K O

O K O K O K O K O K O K O

O K O K O K O K O K O K O

O K O K O K O K O K O K O

Plots with kidney bean in intercrop. (Where K = kidney bean and O = maize)

3.7 Soil Laboratory Analysis

The analysis of the soil physical and chemical properties was carried out at the Faculty of Agriculture main laboratory. Standard laboratory procedures were followed in the analysis of the selected physicochemical properties considered in the study.

Analytical Method

Particle Size Determination

The particle size distribution was determined by the hydrometer method (Boyoucos, 1951) as modified by Gee and Bauder (1986). 50 g of air-dried soil was weighed into shaking bottles and 20 ml of 10% calgon solution (sodium hexameta phosphate) was added to soil. Then 50ml distilled water was added and shaken for 1 hour on a reciprocal shaker. The sample was transferred quantitatively into 100 ml measuring cylinder and made up to mark with distilled water. The first reading was taken when the cylinder was dropped on the platform within 40 seconds, the percentage silt + clay was determined with in the 40 seconds. The second reading was taken after 2 hours. The percentage clay was determined after 2 hours.

pH

The pH of the air-dried soil was determined using a glass electrode pH meter of ratio 1:1 and (20 g soil to 20 ml distilled water) and in 1N KCl solution at a ratio of 1:2 soil to water suspension according to Mclean, (1982) method. 20 g of air-dried soil was weighed into 100 ml beaker, 20 ml of distilled water was added and the mixture was stirred intermittently for 30 minutes with a stirring rod. The pH meter was standardized with buffer pH 4.0 and 7.0, before the pH of the soil was taken. The reading was taken by dipping the electrode into the liquid part of the mixture and the reading recorded.

Organic Carbon Content

This was determined by the chromic acid wet oxidation procedure of Walkley and Black as described by (Black 1965). 1g air dried soil was weighed into 250 ml conical flask, 10ml of 1N potassium heptaoxodichromate (vi) $K_2Cr_2O_7$ solution was added using a 10 ml pipette and the flask gently swirled to effect proper mixing. Thereafter, 20 ml of concentrated tetraoxosulphate (vi) acid H_2SO_4 was added violently but carefully to avoid dissipation of heat of the reaction and to enhance complete oxidation, after 30 minutes, 100 ml of distilled water was added with 100 ml measuring cylinder followed by 6 drops of ferroine indicator. The content of the flask was titrated with 0.5N iron (ii) tetraxosulphate (vi) pentahydrate solution ($FeSO_4.5H_2O$) the colour changed from dirty brown to a wine color. A blank titration was carried out (without soil samples). Thus, organic carbon is calculated as;

$$\frac{(Bml - Tml) \times 1.33 \times 0.03f \times N}{\text{Weight of soil sample}} \times \frac{100}{1}$$

Where Bml = titre value of blank

Tml = titration value

N = normality of $FeSO_4$ Solution

Exchangeable Base (Ca, K and Mg) determination

Calcium and magnesium were determined volumetrically by the EDTA titration procedure described by Black (1965). 10 g of air cried soil was weighed into shaking bottle. 70 ml of 1N ammonium acetate solution of pH 7 was added with 100 ml measuring cylinder to extract the exchangeable bases. The bottle was covered tightly and shaken for 1 hour on reciprocal shaker thereafter, the soil suspension was filtered through Whatman No 42 filter paper into 100 ml volumetric flask and residue washed into three 10ml aliquots of 1N ammonium acetate of pH 7 solutions 25 ml aliquot of the filtrate was withdrawn with pipette into 250 ml conical flask, 20 ml of concentrated ammonia solution was added followed by 6 drops of eriochrome blank T indicator, the content of the flask was titrated with 0.01 ml of disodium salt of ethylenediaminetera acetic acid (EDTA) solution and the colour change was sky blue colour as end point. Potassium was determined from the filtrate by flame photometry as described by Black (1965).

Exchangeable Acidity Determination

10 g soil sample was shaken with 100 ml 1N KCl for 1 hour on a reciprocal shaker and thereafter filtered through Whatman No 1 filter paper. 25 ml aliquot of the filtrate was pipetted into a 250 ml conical flask and titrated to a permanent pink end point using 0.01N NaOH and 4 drops of phenolphthalein indicator. Results were expressed as $cmolkg^{-1}$.

Calculation

$$Meg/100g = \frac{N \times V \times 100}{2.5}$$

Where: N = Normality

V = Litre Volume

2.5 = Weight of soil in aliquot meg/100 = $cmolkg^{-1}$.

Available Phosphorus Determination

The available phosphorus in the soil samples was determined using Bray and Kurtz (1945) solution. Here a 5 g soil sample that passed through 2 mm sieve was weighed into a shaking bottle in duplicate. 35 ml of Bray (1945) No. 1 solution was added into the shaking bottle and suspension was shaken for 1 minute. The suspension was then filtered through Whatman 42 filter paper. The phosphorus content of the filtrate was determined using the colorimetric molybdenum blue procedure of Riley and Murphy (1992). The phosphorus content of aliquot was extrapolated from a standard curve prepared alongside the samples.

Total Nitrogen

1 g of finely ground soil sample was weighed into a Micro–Kjedahl flask followed by 1.33 g of catalyst mixture. Few drops of distilled water were added to moisten the soil/catalyst mixture. 10 ml concentrated H_2SO_4 was added and the flask was heated in a fume cupboard until digestion was completed and the digest had become green in colour. The flask was cooled slightly and the content diluted to about 50 ml with distilled water. The digest was filtered through Whatman No. 42 filter paper into 100 ml volumetric residue and filter paper several times with aliquot of distilled water. The nitrogen in the filtrate was determined by the alkaline phenate procedure of Fiore and O Brien (1962). A set of standards were prepared and the nitrogen content used for the extrapolation of nitrogen content of the samples.

3.8 Plant Analysis

At harvest, 5 plants were randomly selected from each plot and oven dried for forty–eight hours at 75℃. The plants were ground to powder and placed in Muffle furnace for about forty-eight hours at 450℃ to completely turn samples into ashes. Ashes were treated with both 0.1 M HCl and 1 M HCl and filtered (A.O.A.C., 1990). The filtrates were used for determination of P, K, Ca and Mg.

P was determined by the molybdenum–blue colorimetric procedure of Murphy and Riley, (1962).

K was determined using flame photometer while Ca and Mg content will be determined volumetrically by EDTA titration procedure (Black, 1965).

The N content was determined by Micro–Kjedahl digestion method (Bremner, 1996).

3.9 Statistical Analysis

Data collected were subjected to statistical analysis using Genstat version 12 (2012) and Duncan New Multiple Range Test (DNMRT) was used to separate the means at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1.1 Soil pH

The results on table 1 shows the pH of the soil before sowing was 5.45. It was reduced to 5.23 in sole kidney plot and increased to 5.46 and 5.56 in the sole maize and kidney bean + maize intercrop plot. All the plots were strongly acidic (Using the ratings reported by Chude *et al*., 2011). Ehigiator *et al*. (2015) also reported that the soils in this study area are strongly acidic. There was no significant difference between the pH values recorded in the plots.

4.1.2 Total Organic Carbon

The results on Table 1 show total organic carbon content (TOC) in soils before and after sowing. The TOC was 14.20 g/kg in the soil before sowing. It reduced to 11.50 g/kg ,13.70 g/kg and 12.30 g/kg respectively in the sole maize, sole kidney bean and maize + kidney bean intercrop plot respectively. This disagrees with the findings of Ehigiator *et al* (2015); Chen *et al* (2019); Ma *et al* (2022) who reported higher total organic carbon content after sowing which was significantly higher than before sowing.

4.1.3 Total Nitrogen

The results on Table 1 shows that the total nitrogen content on the soil in the sole maize plot reduced to 0.54 g/kg from the 0.63 g/kg recorded in the soil before sowing while the kidney bean + maize intercrop plot increased to 0.73 g/kg and the sole kidney bean pot was 0.80 g/kg. The increment in total nitrogen content of the plots where kidney bean was cultivated may be due to biological nitrogen fixation by the kidney bean (Ali *et al*., 2019). Guo *et al.*, (2021) reported increased total nitrogen content in soils after legumes were harvested. The 0.80 g/kg

Table 4.1: Chemical properties and particle size distribution of soil used in the experiment

Crop Mixture	pH 1 : 1 In water	TOC (g/kg)	TN (g/kg)	Av. P (mg/kg)	Exchangeable Bases K (cmol/kg)	Ca	Mg	Na	Exch. Acidity H	Al	Sand (g/kg)	Silt	Clay	TC
Before	5.45[a]	14.20[a]	0.63[b]	14.41[a]	0.21[a]	0.54[a]	0.39[a]	0.18[b]	1.89[b]	0.33[a]	856.66	79.34	60.00	LS
Sole C	5.46[a]	11.50[b]	0.54[b]	11.78[bc]	0.19[b]	0.42[bc]	0.32[b]	0.21[b]	1.02[ab]	0.30[a]	862.00	72.67	65.33	LS
Sole KB	5.23[a]	13.70[a]	0.80[a]	12.04[b]	0.19[b]	0.46[b]	0.29[b]	0.24[a]	1.10	0.25[b]	868.67	68.33	63.00	LS
KB+C	5.56[a]	12.30[b]	0.73[ab]	11.56[c]	0.18[b]	0.39[c]	0.25[c]	0.19[b]	1.14[a]	0.23[b]	867.33	70.33	62.34	LS
LSD	0.451	1.013	0.157	0.456	0.016	0.044	0.035	0.023	0.216	0.041				

Means with same alphabet(s) in the same column are not significantly different ($P \leq 0.05$)
Where: before = before experiment, KB = kidney bean, C = maize, KB+C = kidney bean + maize, LS = Loamy sand

recorded in the sole kidney bean plot was significantly higher than the values recorded in the other plots at 5% level of significance.

4.1.4 Available Phosphorus

The available phosphorus of the soil after the experiment was reduced significantly ($p < 0.05$) by the intercropped treatments (11.56 mg/kg) compared to the initial available phosphorus of the soil (14.1 mg/kg). Although, the sole maize and sole kidney bean also had a decreased value of 11.78 mg/kg and 12.04 mg/kg, however, they were not significantly different ($p < 0.05$) from the initial available phosphorus content (14.1 mg/kg) and the intercropped treatments (11.56 mg/kg). This in contrast with the study of Guo *et al*. (2021) who reported changes in the soil accessible phosphorus when intercropped with legumes due to root-releasing compounds (e.g., acid phosphates and phytases) and availability of phosphorus solubilizing bacteria (Olayole *et al*., 2018).

4.1.5 Exchangeable Potassium

The K content of the soil was significantly reduced ($P < 0.05$) by the intercropping (0.39 cmol/kg) compared to the initial K content of the soil (0.54 cmol/kg) and other treatments. Sole maize (0.42 col/kg) and sole kidney bean (0.46 cmol/kg) also reduced the K content of the soil relative to the initial K content (0.54 cmol/kg), however, only the sole kidney bean was significantly different ($p < 0.05$). This indicates that the cropping systems had a depleting effect on the K content, contrary to some previous studies (Osakue *et al*., 2023). In high rainfall areas K is prone to leaching, reducing the availability regardless of cropping system (Singh *et al*., 2020).

4.1.6 Exchangeable Calcium

The results in Table 1 shows that the Ca content of the soil was reduced by all treatments compared to the initial Ca content of the soil (0.54 cmol/kg). The intercropped treatments had the lowest value of 0.39 cmol/kg which is significantly different ($P<0.05$) from the sole maize (0.42 cmol/kg) but similar to the sole kidney bean (0.46 cmol/kg). This reduction suggests that crop uptake and possible leaching contributed to Ca depletion in both systems. This is supported by Adedokun *et al*. (2024) in the report that the nutrient uptake (K, Ca, Fe and Zn) was enhanced by legumes intercropping.

4.1.7 Exchangeable Magnesium and Sodium

The results from Table 1 shows that both the intercropping and monocropping systems reduced the magnesium (Mg) and sodium (Na) levels from the initial soil level of 0.39 mg/kg to 0.25 mg/kg and 0.28 cmol/kg to 0.25 cmol/kg respectively. This reduction, however was not significant ($P \leq 0.05$). This indicates a significant absorption of the nutrients by both the maize and kidney bean. In contrast, Nasr *et al*. (2024) in their research reported that intercropping maize with legumes can improve soil nutrient availability.

4.1.8 Particle Size Distribution

Table 1 shows particle size distribution before and after sowing. The soils were dominated by the sand fraction. The Sand fraction range from 856.66 g/ kg in the soil before experiment to 868.87 g/kg in the kidney bean + maize intercrop plot. While silt content increased from 68. 33 g/kg in the kidney bean plot to 79.34 g/kg in the soil before sowing. The clay content increased from 60.00 g/kg in the soil before sowing to 65.33 g/kg in the sole maize plot. All the plots belong to the textural class, Loamy sand. Omokaro *et al*. (2023) reported that the

Table 4.2. Nutrient Concentration of Grains

	Kidney bean			Maize		
	Monoculture	**Intercrop**	**LSD**	**Monoculture**	**Intercrop**	**LSD**
Nitrogen (%)	2.79[b]	2.86[a]	0.0723	1.48[a]	1.37[b]	0.0633
Phosphorus (%)	0.47	0.48	ns	0.25	0.24	ns
Potassium (%)	1.51	1.49	ns	0.26	0.25	ns
Calcium (%)	0.13	0.14	ns	0.02	0.02	ns
Magnesium (%)	0.17	0.17	ns	0.10	0.08	ns

Means with same alphabets in same row are not significantly different at ($P \leq 0.05$)
Where: ns = not significant, LSD = Least Significant Difference

soils in the four land uses studied were dominated by the sand fraction and belong to the Loamy sand textural class.

4.2.1 Nitrogen Concentration in grains

The nitrogen content of kidney bean grains was: 2.70% and 2.86% respectively in monoculture and intercrop plots. The 2.86% recorded in intercrop plot was significantly higher than the 2.70% recorded in the sole kidney bean plot at 5% level of significance. Schwerdtner and Spohn (2021) reported higher nitrogen Concentration in the grains from intercrop plots. Meanwhile the nitrogen content of maize grains was 1.48% and 1.37% in the sole maize and kidney bean + maize plots respectively. The 1.48% recorded in the sole maize plot was significantly higher than the 1.37% recorded in the intercrop plot at 5% Level of probability. Singh *et al.* (2018); Batista *et al.* (2020) also reported less nitrogen content in the grains from intercrop plots.

4.2.2 Phosphorus Concentration in grains

The phosphorus content of kidney bean grains was 0.47% and 0.48% respectively in monoculture and intercrop plot. The 0.48% recorded in intercrop plot was not significantly higher than the 0.47% recorded in the sole kidney bean plot at 5% level of significance. Schwerdtner and spohn (2021) reported higher phosphorus concentration in the grains from intercrop plots. Meanwhile the phosphorus content of maize grains was 0.25% and 0.24% in the sole maize and kidney bean + maize plots respectively. The 0.25 % recorded in the sole maize plot was not significantly higher than the 0.24% recorded in the intercrop plot at 5% level of probability. Singh *et al*. (2018); Batista *et al*. (2020) also reported less phosphorus content in the grains from intercrop plots.

4.2.3 Potassium Concentration in grains

The Potassium content of kidney bean grains are 1.51% and 1.49% respectively in monoculture and intercrop. The 1.49% recorded in intercrop plot was significantly lower than the 1.51 % recorded in the sole kidney bean plot at 5% level of significance. Adewale (2021) reported higher potassium concentration in the grains from intercrop plots. Meanwhile the potassium content of maize grains was 0.26% and 0.25% in the sole maize and kidney bean + maize plots respectively. The 0.26% recorded in the sole maize plot was not significantly higher than the 0.25% recorded in the intercrop plot at 5% level of probability. Singh e*t al*. (2018); Batista *et al*. (2020) also reported less Potassium content in the grains from intercrop plots.

4.2.4 Calcium Concentration in grains

The calcium content of kidney bean grains was 0.13 % and 0.14 % respectively in monoculture and intercrop. The 0.14% recorded in intercrop plot was significantly higher than the 0.13% recorded in the sole kidney bean plot at 5% level of significance. Law-Ogbomo (2019) reported higher calcium concentration in the grains from intercrop plots. Meanwhile the calcium content of maize grains was 0.02% in the sole maize and kidney bean + maize plots respectively. There was no significant difference between calcium content in both monoculture and intercrop plot at 5% level of significance. Singh *et al*. (2018); Batista *et al* (2020) also reported less calcium content in the grains from intercrop plots.

4. 3 Growth and Yield Parameters

4.3.1 Effect of Intercropping on Growth Parameters

The results in Table 3 shows that the growth performance of kidney and maize was influenced by the cropping system. Intercropping improved the growth characteristics of kidney bean compared to monoculture. The stem girth increased form 3.70 cm to 4.10 cm, and the number of leaves increased from 26 to 38 under intercropping. The vine length also showed a slight increase from 242.0 cm to 264.0 cm, although these differences were not statistically significant. This suggests the kidney bean was not negatively affected by intercropping. In contrast, maize experienced a reduction in growth under intercropping. The stem girth decreased from 7.40 cm in monoculture to 6.60 cm, while the number of leaves dropped from 11 to 8. Similarly, maize plant height declined from 194.5 cm to 165.3 cm under intercropping.

4.3.2 Effect of Intercropping on Yield

The effect of intercropping on yield varied between kidney bean and maize. For kidney bean and intercropping, there was a slight increase in grain weight (32.8 g under intercropping compared to 31.9 g in monoculture) and a minor improvement in total yield (0.72 t/ha in intercropping relative to 0.70 t/ha in monocropping). This suggests that intercropping had positive effect on yield of kidney bean. However, for maize, intercropping resulted in a decrease in yield components. The weight of 100 grains per plant reduced from 29.5 g in monoculture to 20.6 g under intercropping. Additionally, the total maize yield decreased from 7.23 t/ha in monoculture to 6.45 t/ha in intercropping. The reduction in yield may be attributed to possible nutrient competition effects.

Table 4.3 Growth and Yield Parameters

		Stem girth (cm)	Number of leaves	Plant height/ vine length (cm)	Weight of 100 grains (g)	Weight of pod/ear (g)	Yield (t/ha)
Kidney bean	Monoculture	3.70^b	26^b	242.0^b	31.9^b	1.02	0.70
	Intercrop	4.10^a	38^a	264.0^a	32.8^a	1.04	0.72
	LSD	0.3521	8.416	20.190	1.715	ns	ns
Maize	Monoculture	7.40^a	11	194.5^a	29.5^a	135.0^a	7.23^a
	Intercrop	6.60^b	8	165.3^b	20.6^b	114.5^b	6.45^b
	LSD	0.5718	ns	15.64	6.854	9.351	0.532

Means with same alphabet(s) in the same column are not significantly different ($P \leq 0.05$)
Where; ns = not significant

These results disagree with Oyelola *et al*. (2022), who reported that intercropping maize with kidney bean and pigeon pea led to significant higher maize grain yields than sole cropping. However, in this study, maize yield declined, which may be due to short term competition effects rather than long-term fertility improvements. This contrast with the findings from Law-Ogbomo *et al*. (2021), who observed that intercropping in calcareous soils led to sustained yield increased over time.

CHAPTER FIVE

5.0 CONCLUSION

The physical and chemical properties of the soil such as sand, silt, pH, total organic carbon, available Phosphorus, exchangeable bases, were not significantly affected by the sowing of maize and kidney bean intercrop and mono cropping, rather, Nitrogen increased.

The effect of intercropping on growth and yield varied between kidney bean and maize. For the Kidney bean, the vine length Increased from 242.0cm to 264.0cm, while that of maize reduced from 194.5cm to 165.3cm. The weight of Kidney bean grains also increased from 31.9g to 32.8g and there was no significant increase on the weight of maize grains.

This shows that after Intercropping, the kidney bean suppressed the growth of the maize

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