
Biological Benefits of Intercropping Maize (*Zea mays L*) with Fenugreek, Field Pea and Haricot Bean Under Irrigation in *Fogera* Plain, South *Gonder* Zone, Ethiopia

Molla Abate^{1,*}, Getachew Alemayehu²

¹Ethiopian Biodiversity Institute, Bahir Dar Center, Bahir Dar City, Ethiopia

²Department of Plant Sciences, Bahir Dar University, Bahir Dar City, Ethiopia

Email address:

mollaabate79@yahoo.com (M. Abate)

*Corresponding author

To cite this article:

Molla Abate, Getachew Alemayehu. Biological Benefits of Intercropping Maize (*Zea mays L*) with Fenugreek, Field Pea and Haricot Bean Under Irrigation in *Fogera* Plain, South *Gonder* Zone, Ethiopia. *Agriculture, Forestry and Fisheries*. Vol. 7, No. 1, 2018, pp. 19-35.

doi: 10.11648/j.aff.20180701.14

Received: August 5, 2017; Accepted: August 25, 2017; Published: February 5, 2018

Abstract: An on-farm experiment was conducted in the dry season of 2012/2013 under irrigation at Jigna rural village of Dera District, South Gonder Zone/Ethiopia. The experiment was conducted to assess the biological benefits of intercropping maize with fenugreek, field pea and haricot bean. A field have a total of 7 treatments, namely three intercropping of fenugreek, field pea and haricot bean with maize and their four sole cropping, were laid out in randomized complete block design (RCBD) with three replications. Gross plot size of each treatment was 3m × 2.7m (8.1m²), but net plot size varied up on the crop types. Spacing between adjacent replications and plots was 1.5m and 1.0m, respectively. Fenugreek, field pea and haricot bean as sole crops were planted at inter-row and intra-row spacing of 20cm × 5cm, 20cm × 5cm and 40cm × 10cm, respectively. In both intercropping and sole cropping maize was planted at 75cm × 30cm inter- and intra- row spacing, while fenugreek, field pea and haricot bean were intercropped in the middle of two maize rows at their recommended intra-spacing. Varieties used for the present study were BH-540 maize hybrid, "Challa" fenugreek, "Burkitu" field pea and "Awash Melkassa" haricot bean. Data of phenological, vegetative growth and, yield related crop parameters were timely collected following their respective standard methods and procedures, and further subjected to analysis of variance (ANOVA) using SAS version 9.2. Whenever the ANOVA result showed significant difference among treatments for a parameter mean separation was further done using Duncan's New Multiple Range Test (DNMRT). Intercropping didn't show any significant effect statistically (p<0.05) on phenological, vegetative growth and yield related parameters of the component crops. However, concerning biomass of fenugreek, field pea and haricot bean, the analysis of variance showed that there has significant difference (p≤0.05) between intercropping and sole cropping. On the contrary, intercropped field pea produced higher pod per plant, plant height and seed per pod than that of sole field pea. Intercropped Haricot bean was also produced slightly higher plant height, seed per pod and thousand grain weights than its sole crops. Therefore, in the present study area during dry season under irrigation, maize intercropping with haricot bean and field pea was more advantageous than their respective sole crops.

Keywords: Intercropping, Sole Cropping, Biomass, Yield

1. Introduction

The limited land areas are facing pressure to meet basic demands of human being for food, fiber and oil. Because of rapid human population explosion, the size of cultivable land at household level is gradually decreasing and most farmers own very small plots of land, especially in the developing

countries of Asia and Africa. Hence, there is a need for increasing crops production per unit cultivated land using various techniques including multiple cropping. Intercropping for instance is one of the potential strategies of increasing productivity per unit cultivated land for the subsistence farmers who operate with low resources and inputs (Francis, 1986a).

According to Willey (1991), intercropping is the practice of growing two or more crops simultaneously in the same field. Higher productivity per unit cultivated area and insurance against the vagaries of weather, as well as disease and pests damages are the major reasons for the existence of intercropping (Papendic, 1983). 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 (Francis, 1986b; Hoshikawa, 1991). Intercropping also hampers germination and growth of weeds (Palaniapan, 1985). In most instances, intercropping offers the advantages of increasing yield, nutritional diversity and net income (Pal *et al.*, 1981; Aleman, 2000). It is an important practice adopted throughout the tropics and subtropics of Africa, India, and South and Central America (Palaniapan, 1985; Pal *et al.*, 1993; Aleman, 2000). Farmers in different parts of the world intercrop different crops according to their preference based on social and biological needs (Andrew and Kassam, 1983; Francis, 1986a; Francis, 1990).

Intercropping as a method of sustainable agriculture is the growing of two or more crops during the same season on the same area so as to utilize common limiting resources better than the species grown separately, and hence it is as an efficient resource use method (Ghosh *et al.*, 2006). Intercropping of cereals with legumes has been popular in humid tropical environments (Tusbo *et al.*, 2005) and rain-fed areas of the world (Ghosh *et al.*, 2004) due to its advantages for yield increment, weed control (Poggio, 2005), insurance against crop failure, low cost of production and high monetary returns to the farmers (Ofori and Stern, 1987), improvement of soil fertility through the addition of nitrogen by biological fixation (Gosh *et al.*, 2006), improving yield stability, socio-economic and some other merits (Willey, 1979).

Research has been conducted on maize-faba bean intercropping in many parts of the world, especially in the high lands of eastern and southern Africa, and in Mexico (Minale *et al.*, 2001; Mbah *et al.*, 2007). Maize as a third cereal product of the world has been recognized as a common component in most intercropping systems (Adeniyani *et al.*, 2007). Maize is also used as major food source for Ethiopians. Faba bean is a valuable crop for intercropping with maize, while it has several good features such as shade tolerance (Nasrullahzadeh *et al.*, 2007), symbiotically fixing atmospheric nitrogen and thereby adding valuable nitrogen to the soil (Wenxue *et al.*, 2005), and containing high amount of protein among the legumes (Matthews and Hary, 2003). Intercropping of maize (*Zea mays L.*) with legumes crops is a common feature of crop production in densely populated areas of eastern Africa such as the highlands of Ethiopia including the study area. The intercropping system might be important for intensification of crop production and to increase economical and biological returns to smallholder farmers in the study area who have limited land holdings, on average about 0.6 ha per household (personal opinion).

Growing of maize during dry season with irrigation is expanding year after year in the study area of Fogera Plain.

During the dry season, irrigation in the study area is being practiced two times in a year to grow different crops. The first round is carried out from October to end of February so as to grow mainly onion, potato and tomato, while the second round is undertaken between March and June to produce mainly maize and rice. Especially maize is produced during this period for market sale at its milk to dough stage. As the annual report of Agricultural Office of *Dera District* the total irrigated area covered in the first round in the years of 2011, 2012 and 2013 was 5833, 8785 and 10026 hectares, respectively. The same report also indicated that in the second round of irrigation in 2011 and 2012 fiscal years 513.5 and 806.5 hectares of land was covered with crops, respectively in the District. In the study area (*Fogera Plain*), despite of the expansion of maize production during dry season with irrigation mainly as a sole crop, maize production under irrigation has never been intercropped with other crops. Indeed, some farmers in the study area practice maize intercropping with some crops during rainy season. The prominent problems accounted for the low area coverage of intercropping under irrigation during dry season in the country includes lack of proper planting materials and inappropriate agronomic practices as well as no extension working packages prepared for intercropping under irrigation during dry season.

Some years back farmers were practicing crop rotation, fallowing and other sustainable cropping systems. This effort, which helped farmers to maintain their soil fertility, is currently diminished as the increment of the population and the shrinkage of farmers land holding sizes. Now a day, the most dominant farming system or practice is mono-cropping system, which in turn contributes to decrease soil fertility and worsens on the contrary weed, pest and disease infestations. All these ecologically unfriendly practices render to reduce the production and productivity of crops. To averse this situation by using sound cropping system in a given small area of farmers' lands is the issue of sustainability.

In line with this hence, practicing of intercropping during dry season under irrigation would have more advantage to maximize the harvest of solar radiation and increase the high productivity of crops. Also it has an advantage on photosynthesis process than that of rainy season; while high solar radiation favored with clear sky of dry season might be intercepted by intercropping more effectively than sole cropping that might in turn contribute a lot for increasing productivity and diversity of crops per unit irrigated land.

The main Objectives of the present study was therefore to assess biological benefits of maize intercropping with fenugreek, field pea and haricot bean in Fogera plain of Northwest of Ethiopia under irrigation.

2. Literature Review

2.1. Intercropping for Greater Productivity and Risk Avoidance

Intercropping is the planting of more than one crop on the

same land at the same time. In terms of land use, growing crops in mixed stands is regarded as more productive than growing them separately (Andrew and Kassam, 1976; Willey, 1979). Mixed cropping is practiced traditionally in many parts of Africa, Asia, and Latin America (Ahmed *et al.* 1979).

Interest in cereal legume intercropping is also developing in some temperate regions with warm climates such as Australia and the United States (Searle *et al.* 1981; McCollum, 1982; Allen and Obura, 1983). This may be due to some of the established and speculated advantages of intercropping systems such as higher grain yields per unit land area, greater land use efficiency, and improvement of soil fertility through the addition of nitrogen by fixation and excretion from the legume component (Willey, 1979). It seems worthwhile to develop cropping systems that have the capacity to maximize crop yields per unit land area while keeping the fertilizer nitrogen requirement to a minimum. Intercropping of legumes with cereals offers scope for developing energy efficient and sustainable agriculture (Papendick *et al.*, 1976; IAEA, 1980).

Risk avoidance is one of the prominent advantages that intercropping offers (Willem, 1990). It is a system to escape or to avoid the vagaries of nature like drought stress and disease and pest attack (Papendick, 1983; Francis, 1986a; Singh, 1990). It minimizes risk in such a way that the reduced performance of one component crop may be compensated by yield from the remaining component (Rao and Willey, 1980; Andrews and Kassam, 1983). Intercropping systems also minimize risk with respect to water logging and price fluctuations. For instance, Struif (1986) reported that intercropping sorghum with rice alleviated the risk of crop failure in seasons of water logging on vertisols. Njoroge and Kimemia (1995) indicated that as coffee prices fall, intercropping the young trees with vegetables has been suggested as a way of providing farmers with extra income as well as improving their diet.

2.2. Resource Use in Intercropping System

One of the advantages of intercropping system is its efficient and complete use of growth resources such as solar energy, soil nutrients, and water (Francis, 1986a; Sivakumar, 1993). 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, 1993). 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 (Francis, 1990; Siva Kumar, 1993; Fukai and Trenbath, 1993).

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 (Palaniappan, 1985; Francis, 1986a).

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 (Palaniappan, 1985; Francis, 1986a). These differences in foliage display and rooting patterns create the space dimension of intercropping.

Another important feature is a difference in time of maturity and hence in nutrient demand among different species in intercropping which will create the time dimension of the system. The difference in time dimension will lead to efficient utilization of resources by lessening competition among the intercrop components (Papendick, 1983; Palaniappan, 1985; Trenbath, 1986). The ability of intercrops to intensify resource use both in space and time dimension makes greater total use of available growth resources than mono cropping (Francis, 1986a).

Intercropping increased the amount of solar radiation intercepted due to faster canopy cover, which lead to efficient utilization of light resources (Ramakrishna and Ong, 1994). Keating and Carberry (1993) stated that intercropping offers the advantage of efficient interception and utilization of solar radiation than mono cropping. Improved productivity per unit incident radiation could be achieved by the adoption of an intercropping system that either increase the interception of solar radiation and /or had greater radiation use efficiency. Minimizing the proportion of radiation energy reaching the ground is a simple means of promoting efficient utilization of incident solar radiation (Keating and Carberry, 1993; Ramakrishna and Ong, 1994). Advantages from intercropping of short and long duration species is due to enhanced radiation capture over time. Improved utilization of radiation energy resulted in more efficient production of biomass or increased proportion of biomass partitioned to yield. Azam, *et al.*, (1990) observed an increase in total dry weight of sorghum –groundnut intercrop.

Nutrient Use Efficiency (NUE) of the individual crops in an intercrop is mostly lower than their respective sole crops. However, the cumulative NUE of an intercropping system was in most cases higher than either of the sole crops (Chowdhury and Rosario, 1994). 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 due largely to a higher total uptake of nutrients by the component crops in the mixture than the sole crops. Chowdhury and Rosario (1994) 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 (1993b) 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 were postulated by researchers explaining the greater capture of non mobile nutrients like phosphorus and potassium. Enlarged root systems provided an expanded root surface area to which non-mobile nutrients diffused (Morris and Garrity, 1993b).

Intercrops are also found to be more efficient in water use than mono crops. It was indicated that there was variation in total amount of water used and in water use efficiency among different cropping systems. Morris and Garrity (1993a) computed that mono cropped cowpea used 172 mm, mono cropped sorghum 135mm, the intercrops 162 mm, and fallow 121mm of water. Mean water use efficiency by mono cropped cowpea, mono cropped sorghum, and the intercrops was 11.3, 12.4 and 16.5 kg glucose /ha/mm, respectively and hence the intercrops used water more efficiently.

2.3. Competition Versus Complementarity in Intercropping

Complementary use of resources by intercrop implies minimizing competition. Use of different resource pools by the component crops represents the most common example of complementarity. The temporal use of irradiance within intercrops of contrasting development and phenology is a prime example illustrating the more efficient use of naturally available resources by intercrops than by each crop (Midmore *et al.* 1988a).

The spatial uses of soil moisture by crops of contrasting demand, example chilli pepper and soybean or contrasting root extraction zones also illustrate the efficient use of resources between component crops. Other than complementarity in resource use, component crops can complement each other through other mechanisms. For instance, in a chilli pepper/soybean intercropping intercropped chilli had greater leaf water potential due to the wind break effect of the companion crop, soybean. Relay planting of potato in to the shade of maize in warm climate, showed earlier emergence and represented another complementary effect (Midmore *et al.* 1988a).

Complementary use by component crops of the same resource pool is less common, but exemplified by the mixing of short C3 and tall C4 type plants, which differ in efficiency in use of tropical sun light (Midmore *et al.* 1988a). Complementary use of resources therefore takes place over space, time or combination of the two. The stage at which complementarity evolves in to competition for resources is amenable to manipulation through choice of agronomic management. Optimal use of natural resources is attained when mixture are not comprised of highly competitive crops. Evidence suggests that intercrop stability over space and time is likely to be favored by the choice of less aggressive cultivars (Cenpukdee. U and S. Fukai, 1991).

Under adverse conditions, example nitrogen deficiency or drought, growth is reportedly dominated by the aggressive species (Fukai *et al.* 1990). Previous studies also indicted that low soil nitrogen and phosphorus improved the competitiveness of cowpea and decreased that of the dominant maize (Chang and Shibles, 1985 a, b), resulting in greater complementary in resource use and higher land

equivalent ratio (LER). Competitiveness of component crops therefore depends to a large degree on each crops response to the limiting factors.

2.4. Plant Density in Intercropping System

In spite of the capacity for greater productivity of mixed cropping, farmers do not often realize its beneficial effects partly because they often plant their crops at sub optimal population densities (Pal *et al.* 1993). The associated species and temporal differences between the component crops determine the total plant population required to obtain a yield advantage in intercropping. The total density can also be determined depending on the environmental resources and growth habits of the species.

When there was severe drought, intercropping beans with maize resulted in greater stability of production, since any loss of plant density of one crop tended to be compensated by the other crop which is a major factor influencing the decision to intercrop (Willey, 1979). Component populations mainly determine as how much of the final yield is contributed by each component. When the component crop densities are approximately equal, productivity and efficiency of intercropping appears to be determined by the aggressively dominant crop (Willey and Robert, 1976).

The growth and yield of a legume component is often reduced markedly when intercropped with high densities of a cereal component. For instance, Ofori and Stern (1987b) indicated in a maize/ bean intercropping that increasing maize density from 18000 to 55000 plants/ha reduced leaf area index by 24% and seed yield by 70% in the component bean. An experiment on the effect of plant densities of sorghum, spatial arrangement of component crops and fertilizer on growth and yield components of sorghum and bean (*Phaseolus vulgaris*) also showed significant differences on pod setting, pod retention, pod length, number of branches and nodulation of intercropped bean (Kassu, 1993).

Similarly, intercropping study that involved sorghum and groundnut with different spatial arrangements also showed highly significant differences in dry pod of the associated groundnut due to the effect of spatial arrangements (Gobeze, 1999). Sole cropped groundnut gave better pod yield than intercropped groundnut whereas among the intercrop treatments the highest dry pod yield was obtained from 40% sorghum: 60% groundnut. Days to maturity and plant height of the associated sorghum were not significantly affected by spatial arrangement of sorghum and groundnut. The results of field experiments conducted in Nigeria involving varying densities of sorghum and maize intercropped with soybean indicated that yields of component crops in the intercrop varied significantly with the components population density (Pal *et al.* 1993).

In a maize/faba bean intercropping Tilahun (2002) reported the highest plant height of maize at 75% maize: 25% faba bean planting density in a 1 maize: 2 faba bean rows of planting arrangement. Slightly higher grain yield per plant was also observed in case of 50% maize: 50% faba bean plant density in a 1 maize: 1 faba bean row arrangement.

Significantly higher leaf area index was also recorded at 100% maize: 75% faba bean in a1 maize: 2 faba bean row arrangement.

2.5. Intercropping and Nitrogen Fixation

The overall benefit of growing two crops in a mixture is the net benefit in which the increase in growth of one crop exceeds a small competitive reduction in the growth of the other (Willey, 1979) and this is often seen where a slow growing legume is intercropped with a tall cereal. Competition for soil N between the cereal and legume components of the intercrop often results in the legume deriving a greater proportion of its N from N₂ –fixation, as demonstrated with pigeon pea/cereal intercrops (Tobita *et al.*, 1994; Sakala *et al.*, 2001). The extent to which growth and the total amount of N₂ fixed by the legume crop decreased in the intercrop depends on the degree of complementarity between the crops. A much-quoted example of the benefits of intercropping legume and cereal is that of pigeon pea intercropped with maize or sorghum (Ong *et al.*, 1996).

The early growth of pigeon pea was very slow so that it affords little competition and yields of the cereal crops were unaffected (Sakala *et al.*, 2001). When intercropped with maize or short duration varieties of sorghum, pigeon pea continuous to grow on residual soil moisture long after the cereal crop has been harvested, and the amount of N₂ fixed by pigeon pea was the same when grown in mixture or as sole crops (Sakala *et al.*, 2001). In an experiment conducted on intercropping, it was indicated that nodulation and nitrogen fixation of groundnut were greatly reduced when it was intercropped with maize, sorghum or millet (Nambiar *et al.*, 1983a).

Similarly, growth and nitrogen fixation of soybean were reduced by a tall sorghum intercrop, where as nitrogen fixation per plant was enhanced by a dwarf sorghum (Wahua and Miller, 1978), indicating that the reduction in yield and nitrogen fixation was partly caused by shading. The available evidence indicated that inputs of fixed nitrogen were more likely to benefit subsequent crops. The beneficial effects of the legumes on succeeding crops can often arise due to a variety of other effects such as reduction of disease incidence or by reducing striga damage as well as change in soil fertility (Reddy *et al.*, 1994; Marcellos *et al.*, 1997). For grain legumes to play an important role in the maintenance of soil fertility, they must leave behind more nitrogen from N₂-fixation than the amount of soil nitrogen that is removed in the crop. The amount of nitrogen added to the cropping system is very variable for all of legume species. The largest net benefits tend to found with groundnut and cowpea as some varieties of these crops have small nitrogen harvest index (Bell *et al.*, 1994).

A study in northern Nigeria indicated that maize grain yield was found to be greater following a groundnut than after cowpea, cotton or sorghum. The yield increase was related to an increased availability of mineral nitrogen in the soil after groundnut. The fact that no such beneficial effect was found after growth of cowpea in the same experiment

indicates that residual effects do not always occur. Groundnut and cowpea were found to have roughly equal residual effects on the growth of a subsequent maize crop in northern Ghana, equivalent to the addition to 60 kg fertilizer nitrogen. This was despite the fact that 68 kg N ha⁻¹ was left behind in above ground residues after groundnut and 150 kg N ha⁻¹ after cowpea (Dakora *et al.*, 1987). Direct evidence of the benefits from N₂-fixation was obtained where yield of sorghum grown after nodulating varieties of chickpea were better than yields after non-nodulating chickpea (Kumar Rao and Rupela, 1998).

In India, pigeon pea was found to give a residual benefit to subsequent maize of 38 to 49 kg N ha⁻¹ (Kumar Rao *et al.*, 1983). The amount of nitrogen in leaves that fall during growth of long duration pigeon pea may be as much as 68-84 kg N ha⁻¹ (Kumar Rao *et al.*, 1996b; Sakala *et al.*, 2001). Over 12 years, yields of sorghum were consistently higher following a sorghum/pigeon pea intercrop than after an oil crop safflower (*Carthamnus tinctorius*), and the soil nitrogen content had increased significantly where pigeon pea had been grown (Rego and Rao, 2000). Other legumes may also contribute substantial amount of nitrogen during crop growth. For example, about 81 kg N ha⁻¹ were measured in leaf fall from soybean in Australia (Bergersen *et al.*, 1992). Yield of maize grown after soybean on an Alfisol were increased to 4 tone ha⁻¹, compared with only 1.8 tone in continuous maize cropping where all the legumes stover had been removed (Kasasa *et al.*, 1999).

There is little evidence for direct transfer of significant amount of nitrogen between roots of legumes and cereals in mixtures, and this conclusion is supported by measuring natural N abundance in intercrops of pigeon pea and sorghum (Tobita *et al.*, 1994). Although pigeon pea loses large amount of nitrogen in leaves that fall during crop growth, the leaves cause an initial immobilization of soil nitrogen when they decompose and so little of the nitrogen is available for use by the intercropped cereal (Sakala *et al.*, 2000). Although intercrops can produce greater yields, they generally do so by extracting more nutrients from the soil than sole crops (Mason *et al.*, 1986) and may cause more rapid decline in soil fertility. Similarly, intercrops use more water for growth. When rainfall was adequate a cowpea /maize intercrop gave superior crop yields, but competition for moisture in a drought year caused drastic reduction in yields of intercropped maize (Shumba *et al.*, 1990).

2.6. Effects of Fertilizer Application in Intercropping System

In cereals-legumes intercropping, the legume component is capable of fixing atmospheric nitrogen under favorable conditions and this is thought to reduce competition for nitrogen (Trenbath, 1976). In the absence of an effective nitrogen fixing system, both the cereal and legume components compete for available soil nitrogen (Ofori and Stern, 1987a). In a maize cowpea intercropping system, Wahua (1983) found that at 105 kg N/ha, component crops exerted competition for nitrogen just before flowering. The

competition for nitrogen was severe for cowpea at 40 days after planting and for maize 10 days later. In the same study it was indicated that nitrogen uptake of intercropped maize was reduced by 19% compared to sole maize. Pal and Shehu (2001) reported that the contribution of legumes to the total N uptake of maize in a mixture ranged between 25 to 28 in soybean, 24 to 29 in lablab, 20 to 22 in green gram, 18 to 19 in black gram, 1 to 5 in cowpea and 1 to 5 kg N/ha in groundnut, respectively. Senaratne *et al.* (1995) also reported that when cowpea, mung bean and groundnut were intercropped with maize, the proportion of N uptake by maize in the associated legume varied from 7-11% for mung bean, 11-20% for cowpea and 12-26% for groundnut which was about 19 to 22, 29 to 45 and 33 to 60 mg N/maize plant, respectively. The high N₂ – fixation potential of groundnut and its relatively low harvest index for nitrogen apparently contributed to greater beneficial effect on nitrogen uptake of associated crops.

Intercropping was reported to have an impact on the quality of crops (Gangwar and Kalra, 1988; Chittapur *et al.*, 1993; Bulson *et al.*, 1996; Odoemana, 1997). Odoemana (1997) has found that Yam (*Dioscorea rotundata*) maintained higher value of protein as an intercrop with melon than sole cropping. Similarly, Bulson *et al.*, (1996) reported that in a wheat/faba bean intercropping the nitrogen content of the wheat grain and whole plant biomass increased with the increase in faba bean density, thus resulting in a significant increase in grain protein.

Applications of mineral nutrients to the soil may cause inter specific competition between component crops for the soil based pool of nutrients, may alter the balance in competition between component crops for mineral nutrients and subsequently expressed as competition.

When inter specific competition is less for a nutrient, there will be an increase in LER and total biomass production. This is possible either through enhanced early growth and canopy cover by the mixture or through improved maximum canopy cover or a combination of the two. Data from a pigeon pea /rice mixture showed an increase in LER from 0.85 without phosphorus fertilizer to 1.53 with application of 26.2 kg phosphorus ha⁻¹ and a 60% gain in biomass.

Complementarities in the use of resource which brings about yield advantages in mixture is greater when growth and yield of at least one component crop is somewhat limited and yield potential is low (Chang and Shibles, 1985b). With additional phosphorus in the above-mentioned study, complementarity was less well expressed since increased maize shade caused cowpea yield depression. More attention has been paid to the response of intercropping systems to the application of nitrogen fertilizer because the effect of nitrogen is dramatic particularly in mixture involving legumes. The addition of nitrogen to legume based intercrops generally favors growth of the non-legume at the expense of the legume. With minimal nitrogen, growth of the legume is less restricted than that of the non- legume (Cenpukdee and Fukai, 1991).

Although additional nitrogen directly antagonizes rhizobium N₂- fixation in the legume, it enhances lateral (Cenpukdee and Fukai, 1991) and vertical growth of the non-legume

component. Greater competitiveness, however, does not necessarily result in greater yields, especially in crops or varieties for which the harvest index is very sensitive to high nitrogen (Cenpukdee and Fukai, 1991). However, increased shading over the legume, with increase in competitiveness effected by nitrogen fertilizer application to the non-legume, does reduce the contribution of nitrogen fixation by the legume crop (Chang and Shibles, 1985a), thereby reducing yield compared to mixtures without nitrogen fertilizer. Where the legume is responsive to added nitrogen and has the opportunity to shade the non legume crop, yields of the non-legume may effectively decline at higher nitrogen application rates (Olasantan, 1991), consequently, only at low soil N status (0 to 30 kg N ha⁻¹) was complementarity of intercrops, as indicated by large LER. The response of intercrops to added nitrogen is conditioned by factors such as soil moisture availability, plant population, and canopy structure of component species, and differential temporal demands for nitrogen by component crops. For instance, inconsistent effects of nitrogen fertilization on the relative competitive abilities of maize and soybean across sites have been attributed to difference in soil moisture and nitrogen availability (Russell and Caldwell, 1989). Under limited soil moisture, partial LERs of maize increased, while those of soybean decreased under increased fertilizer nitrogen over range of density combinations. Under the same environmental conditions, where crops exhibited visible signs of stress the optimum density combinations were dependent on N levels, whereas at a contrasting moisture site the optimum combinations were unchanged over N levels.

The combination of high population density of maize and high fertilization caused shading and yield depression of cowpea when intercropped with maize (Chang and Shibles, 1985b). This finding, together with data from the studies of Ofori and Stern (1987) suggest that intercropping efficiency is greater under low than high fertility.

3. Materials and Methods

The experiment was conducted in dry season under irrigation in *Fogera* Plain, South *Gonder* Zone, Ethiopia to study the biological benefits of maize (*Zea mays* L) intercropping with fenugreek, field pea and haricot bean as compared to their sole crops. The materials and methods used during the course of experimentation are described in details in the following sub chapters.

Description of the Study Area

The present study was carried out in *Fogera* Plain, South *Gonder* Zone, Ethiopia. The experiment was specifically conducted *Dera* District in *Jigna* rural village, which is located at 42.16 km North of Bahir Dar city at the longitude, latitude and altitude of 19°37' E, 11°51' N and 1807 m.a.sl, respectively. The mean annual temperature of the experimental site is reported 17.5°C with 10°C and 28°C minimum and maximum temperatures, respectively. The site receives average total rainfall of 1250mm annually with summer main rainy season occurring from May to September, peak in June, July and August (WoRA, annual report 2012).

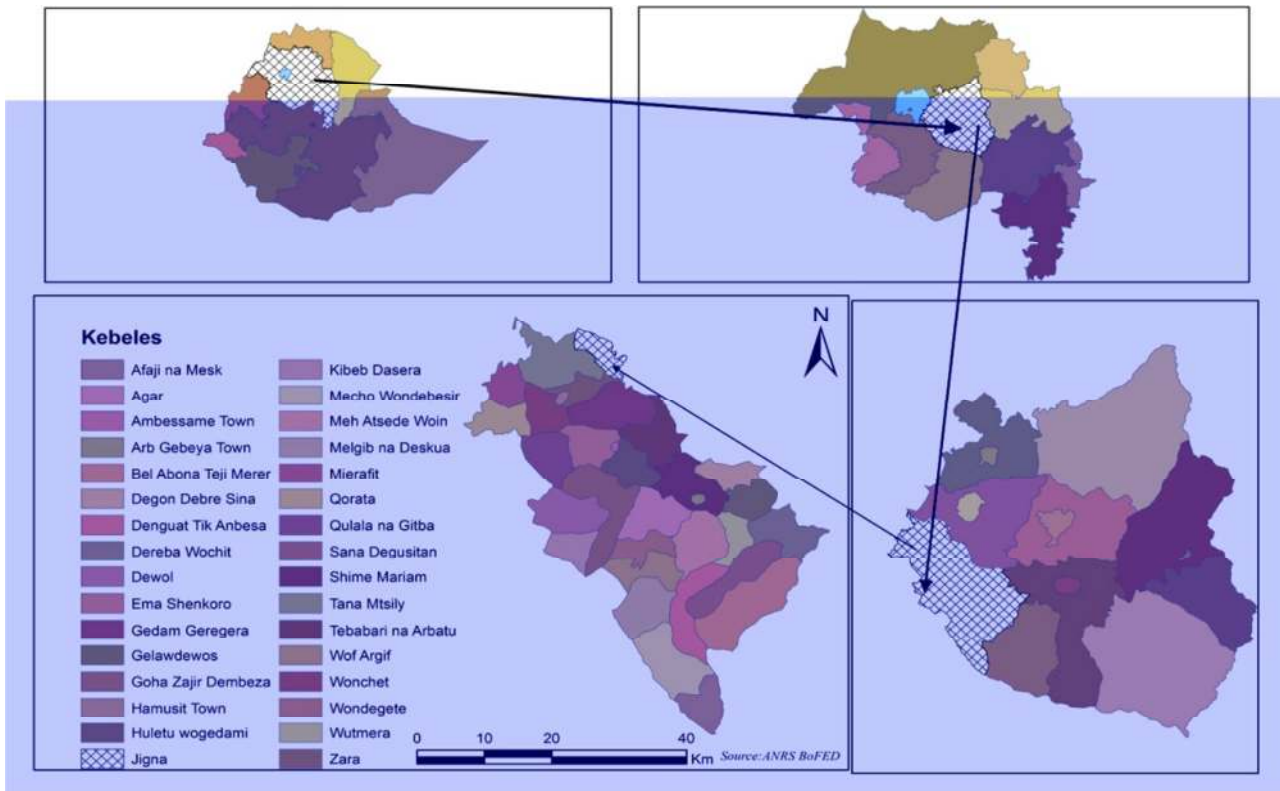


Figure 1. Map of the study area (source BoFED).

Topography of the experimental site is plain, and its soil type is largely clay loam. Before planting, composite soil sample was collected from the experimental plot and analyzed in the soil laboratory of Amhara Design & Supervision Works Enterprise, Soil Chemistry and Water Quality Section to determine some of its physico-chemical properties. The composite sample was air dried, grounded and sieved for further analyses of soil pH, texture, total nitrogen, organic carbon and available phosphorous using respective standard procedures. The soil pH was measured with digital pH meter potentiometrically in the supernatant suspension of 1: 2.5 soils to distilled water ratio. Total nitrogen was determined following Kjeldahl procedure as described by Cottenie (1980). Organic carbon was determined following wet digestion method as described by Walkley and Black (1934), while the available phosphorus was measured using Olsen II methods (Olsen et al., 1954). The laboratory soil analysis results are presented here below in Table 1.

Table 1. Major soil characteristics of the experimental site.

Soil characteristics	Values
pH	6.18
Total N	0.12%
Organic Matter	1.29%
Available P	36ppm
Soil texture:	
Sand	38%
Clay	26%
Silt	36%
Class category	clay loam

Experimental Treatments and Design

The experimental plot was selected near to Gumara River to ease irrigation. Before planting, uniform seedbed was prepared by plowing the land three times using local oxen plough as the practice of local farmers. Seed sowing was made properly as per the plan of experimental treatments and sowed on 25 December 2012. Three intercrops of maize with fenugreek, haricot bean and field pea, as well as, their four sole crops were the treatments of the experiment (Table 2). The treatments were laid out under randomized complete block design (RCBD) at three replications.

Table 2. Treatments of the present study.

Treatment code	Description
T ₁ (MFg)	Maize intercrop with fenugreek
T ₂ (MFp)	Maize intercrop with field pea
T ₃ (MHb)	Maize intercrop with haricot bean
T ₄ (M)	Sole maize
T ₅ (Fg)	Sole fenugreek
T ₆ (Fp)	Sole field pea
T ₇ (Hb)	Sole haricot bean

Planting materials used for the experimentation were selected based on their height to minimize shade effect and tolerance of hot and high temperature relatively to the other varieties of the same crop to minimize irrigation frequencies. Hence, BH540 hybrid has short height in maize and Challa, Burkitu and Awash Melkassa varieties are relatively tolerance to hot and high temperature of fenugreek, field pea and haricot bean, respectively. The plot size of each treatment was 3 m × 2.7m (8.1m²). Spacing between replications and

plots was 1.5m and 1.0m, respectively. Number of rows per plot for maize in both intercropping and sole cropping was 5, and seed per row was 10 while number of rows per plot for fenugreek, field pea and haricot bean in the sole cropping was 16, 16 and 8, respectively. Seed planted per row for fenugreek and field pea was 55 and for haricot bean was 28. Indeed, all fenugreek, field pea and haricot bean were planted in a single row between maize rows with total 4 rows each per maize intercropping plot. The recommended inter- and intra-row spacing was used for all experimental crops. Maize inter- and intra- row spacing was 75cm × 30cm, while for fenugreek, field pea and haricot bean, inter- and intra row spacing was 20cm × 5cm, 20cm × 5cm and 40cm × 10cm, respectively. Only intra-row spacing was applied for the secondary crops of intercropping plots.

Planting rows were marked with pegs at recommended inter-row spacing of each crop and lined with strings. Sowing of seeds was made manually along stretched strings at recommended intra-row spacing of the crops. All recommended DAP amounted 100kg/ha and half of the recommended Urea (50kg/ha) were applied in side banding of few centimeters away from maize rows at planting. Half of the Urea (50kg/ha) was divided equally into two and side dressed to maize rows at knee height and booting growth stages. In addition to this for secondary crops DAP 100kg/ha and urea as a starter 50kg/ha base were applied at planting time. Crops were irrigated in every week for a month in the early time of growing and later every 10 days as per farmers experience in the study area. However, there was water scarcity due to drying off “*Gumara*” river especially at the blister stage of maize crop and it doesn’t give the expected yield, while the other crops matured earlier and escaped from the water scarcity. Two times of hand weeding were carried out before the flowerings of crops.

Data Collection

Phenological, growth and yield related parameters of experimental crops were recorded following their respective days of emergence, flowering, maturity, number of cob/ pod

per plant, seed per pod/cob, yield per plot, thousand grain and biomass weight following standard methods and procedures. In all cases, plants found on the borders of experimental plots were excluded from any data collection, while border effects would mar the actual effects of the treatments. Parameters were hence collected from 10 randomly selected plants of the net plot areas.

Phenological parameters including day of seedling emergence and day of flowering were recorded when 50% of plants per plot reached their respective phenological stages. Day of maturity was recorded also when 90% of plants per plot attained their physiological maturity of maize at early dent stage and pods of fenugreek, field pea and haricot bean turned yellow to yellowish-brown colour.

Excluding boarder row plant height of 10 randomly selected tagged plants were measured per plot area of each experimental from the ground level to the initiation of tassel and for the second crops from the ground to leaf axils or flower initiations with linear meter (cm) during physiological maturity period and its average value was used for further analysis. Similarly, number of cobs or pods per plant was also counted and averaged from the 10 randomly selected plants. Number of seeds per cob or pod was also counted and averaged from cobs/pods of 10 randomly selected plants per plot. A different 10 randomly selected plants of each crop per plot were harvested at their 90% maturity and sun dried very well to measure their dry biomass with sensitive electrical balance in gram (g) and converted into hectare basis in kilo gram (kg). After measuring their dry biomass, randomly selected plants per plot were threshed manually and their grain yield was measured with sensitive balance in grams and converted into hectare basis to express in kg. Thousand seeds were also selected from grain yield of 10 selected plants and measured with sensitive balance to determine 1000 seeds weight which is expressed in gram. Both grain yield and 1000 seeds weight were adjusted at 12.5% for maize and 10.5% moisture content for all secondary crops (source Ethiopian seed enterprise).



Figure 2. Picture partly depicted the experimental field.

Data Analysis

The analysis of variance (ANOVA) was carried out using statistical packages and procedures outlined by Gomez and Gomez (1984) appropriate to Randomized Complete Block Design using SAS (Statistical Analysis Software) version 9.2. Whenever the ANOVA results showed significant difference between treatments, mean separation was further carried out using Duncan's Multiple Range Test (DMRT) at respective levels of error.

Correlation analysis was also carried out to study the nature and degree of relationship between yield and yield components as influenced by intercropping. Correlation coefficient values (r) were calculated and test of significance was analyzed using Pearson correlation procedure found in SAS software.

Pearson correlation method was selected due to it is widely used in the sciences as measure of the degree of linear dependence between two variables. It measures the strength of the linear relationship between normally distributed variables. In statistics the person correlation coefficient is a measure of the linear correlation between two variables X and Y giving a value between +1 and -1 inclusive, where 1 is a total positive correlation, 0 is no correlation, and -1 is total negative correlation.

4. Results and Discussion

The results and major findings of the present study are presented and discussed below in this chapter. Effect of maize intercropping with fenugreek, field pea and haricot bean on phenology, vegetative growth and yield parameters is separately discussed in this chapter.

Crop Phenology

Effect of maize intercropping with fenugreek, field pea and haricot bean on crop phenology is presented in Table 3. Maize as sole and intercropping with fenugreek, field pea and haricot bean was emerged within 12, 16, 12 and 15 days after sowing, respectively (Table 3.). Similarly, it took 89, 91, 91 & 85 days to flowering and 135, 139, 136 and 132 days for maturation, respectively. Statistically, inter- and sole-cropping did not affect significantly ($p > 0.05$) 50% days of emergence, flowering and maturity of maize (Table 3.). The reason for the lack of significance difference of inter- and

sole-cropping for maize phenology could be due to less competitive effect of the associated legumes on maize.

Similar to the present finding, Karikari *et al.* (1999) in an intercropping experiment involving Bambara groundnut and cereals including sorghum, pearl millet and maize reported that days to flowering was not differed significantly between the sole crop and the intercropped cereals. Similarly, the report of Yesuf (2003) also indicated that the effect of sorghum-haricot bean intercropping on days to 50% flowering of sorghum was not statistically significant.

Likewise, Tilahun (2002) in maize -faba bean intercropping reported also no variation in days to silking and tasseling of maize. Similar results were also reported by Yesuf (2003) and Sisay (2004) that day to 50% maturity of sorghum was not significantly affected by both sorghum-bean and sorghum-green gram intercropping.

The analysis of variance for effect of inter- and sole-cropping on fenugreek phenological parameters didn't show any significant differences at 5% acceptable level of experimental error. However, as compared with that of sole cropping; intercropping caused for the delay of fenugreek emergence on average by six days (Table 3.). Early emergence of fenugreek in sole cropping might be due to the fact that sole fenugreek had advantage over intercropping for reduction of competition for growth factors. On the contrary, all intercropped fenugreek plots flowered and matured earlier than that of sole fenugreek plots.

In disagreement of the present results, Karikari *et al.* (1999) reported that sole Bambara groundnut flowered in a significantly shorter period than that of the intercropped one. Sisay (2004) also reported that though the difference was not significant statistically, sole green gram took the least days (45 days after emergence) to flower, while its mean days to flowering in the intercropping was 51.

The contrast results of the present study to other similar reports on the duration of flowering in sole and intercropped legumes would perhaps be associated with moisture stress that occurred frequently in the present experiment. In a condition where there was moisture stress intermittently, fenugreek as the second crop in the intercropped plots might serve as a live mulch reduce the loss of water relatively better than that of its sole cropping. Besides, the tall maize crop shaded over fenugreek at least partially and thereby fenugreek intercropped with maize might not be affected by moisture stress as worse as that of its sole cropping. Hence, growth of fenugreek plants in maize intercropping might not be retarded equally by intermittent moisture stress as that of sole cropping. This might in turn result in early flowering and maturity of intercropped fenugreek plants more than that of sole fenugreek plants.

Except days of 50% emergence of haricot bean, sole and intercropped field pea and haricot bean surprisingly emerged, flowered and matured in almost respective similar days (Table 3). The sole haricot bean was indeed emerged 5 days earlier than that of intercropped one. Early emergence of haricot bean seedlings in sole cropping might be associated with lower competition for light in sole cropping than in its intercropping with maize.

Indeed, this present result was different from results of similar works reported by Karikari *et al.* (1999) and Sisay (2004) as indicated above on Bambara groundnut and green gram, respectively.

Table 3. Effect of maize intercropping with fenugreek, field pea and haricot bean on phenology.

Treatment	Days to 50% Emergency	Days to 50% Flowering	Days to 90% Maturity
A. Maize			
M with Fg	15.67	91.00	138.67
M with Fp	12.00	91.33	136.33
M with Hb	15.33	85.00	132.33
SM	12.33	89.33	135.33
SE ±	0.51	1.36	16.24
CV	13.79	7.95	1.95
Sign.diff.	NS	NS	NS
B. Fenugreek			
Fg +	14.67	56.67	85.00
SFg	9.33	59.00	92.67
SE ±	0.74	1.64	1.00
CV	9.00	16.69	2.00
Sign.diff.	NS	NS	NS
C. Field Pea			
Fp +	11.00	69.33	92.67
SFp	11.67	70.33	93.33
SE ±	0.33	0.26	0.42
CV	14.41	1.01	1.76
Sign.diff.	NS	NS	NS
D. Haricot Bean			
Hb +	15.00	69.33	102.67
SHb	9.67	69.33	102.67
SE ±	0.78	0.12	0.23
CV	14.43	0.74	1.38
Sign.diff.	**	NS	NS

Key: M=maize, SM=Sole maize, Fg=fenugreek, SFg=Sole fenugreek, Fp=field pea, SFp=sole field Pea, Hb=haricot bean, SHb=sloe haricot bean, Fg+, FP+, Hb+= intercropped fenugreek, field pea & haricot bean with maize respectively, NS=Non significant, *=significant, **=highly significant. *Treatment means with the same letters are not significantly different.

Growth and Yield Components

The analysis of variance indicated that effects of intercropping had no significant difference ($p>0.05$) on plant

height, cob number per plant and seed per cob of maize. However, thousand grain weight of maize was affected significantly ($p<0.05$) by intercropping (Table 4).

Table 4. Effect of maize intercropping with fenugreek, field pea and haricot bean on growth and yield components.

Treatment	Plant Height (cm)	Cob/ Pod per Plant	Seed per Pod / Cob	Thousand Grain Weight (gm)
M with Fg	155.97	1.10	270.67	328.28b
M with Fp	153.13	1.06	263.00	340.36a
M with Hb	131.70	0.97	196.00	334.58ab
SM	179.03	1.20	316.00	332.62b
SE ±	6.59	0.03	16.24	1.30
CV	14.43	10.51	20.77	1.00
Sign.diff.	NS	NS	NS	*
B. Fenugreek				
Fg +	23.67	2.07	3.08	11.48
SFg	24.10	3.70	6.26	14.34
SE ±	0.15	0.32	0.47	0.47
CV	3.75	33.48	26.12	14.64
Sign.diff.	NS	NS	NS	NS
C. Field Pea				
Fp +	109.97	4.60	3.70	232.37
SFp	106.40	4.20	3.61	240.15
SE ±	1.21	0.09	0.06	4.09
CV	5.68	11.59	3.58	7.72
Sign.diff.	NS	NS	NS	NS
D. Haricot Bean				
Hb +	72.00	14.70	4.85	184.22
SHb	62.30	14.80	4.23	170.32
SE ±	1.94	0.44	0.12	3.45
CV	13.60	15.84	14.14	6.86
Sign.diff.	NS	NS	NS	NS

Key: M=Maize, SM=Sole maize, Fg=Fenugreek, SFg=Sole fenugreek, Fp=Field pea, SFp=sole field Pea, Hb=haricot bean, SHb=sloe haricot bean, Fg+, FP+, Hb+= intercropped fenugreek, field pea & haricot bean with maize, NS=Non significant, *=significant, **=highly significant.

*treatments with the same letters are not significantly different.

Similar to this finding, Zewdu (2002) and Sisay (2004) reported the non-significant effect of intercropping on plant height of sorghum at harvest. Yesuf (2003) also found that plant height of sorghum was not statistically different in intercropped and sole sorghum. In a maize and cowpea intercropping experiment, Wanki and Fuwusi (1982) discovered that plant height of maize was not affected due to intercropping. Amare (1992) also reported that in maize haricot bean intercropping, plant height of maize in intercropped treatments did not differ significantly with that of sole maize.

In contrary to these findings, Ibrahim *et al.* (1993) found that growth parameters such as plant height and number of internodes were significantly higher in intercropped sorghum with lablab (*Lablab purpureus L.*) than in sole sorghum cropping.

In other studies, it was also reported that the difference in plant height of the cereals in intercropping was not significant in Bambara groundnut + sorghum and Bambara groundnut + maize mixtures but it was significant in Bambara groundnut + pearl millet intercropping (Karikari *et al.*, 1999).

This contradiction could be due to the difference in the nature of intercrops involved particularly of legumes species incorporated to the system because legumes differ in their competitive abilities against to the cereal component for the limited growth factors.

The difference in plant height, pod number per plant, seed per pod and thousand grain weight of the sole and intercropped fenugreek was not significant ($p > 0.05$) (Table 4.). However, the sole fenugreek produced higher number of pods or seed per plant and slightly greater in plant height and thousand grain weight compared to the intercropped fenugreek (Table 4.).

The difference in plant height, pod per plant, seed per pod and thousand grain weight of the sole field pea and haricot bean with intercropped field pea and haricot bean was not statistically significant ($P > 0.05$) (Table 4.). However, there was slight difference in height between the intercropped field pea and sole field pea. The intercropped field pea was greater than that of sole for height. This could be associated with less moisture stress effect of intercropping on field pea than that of sole field pea, while maize might partially be having shade effect on the soil and on the secondary crop field pea that might not be subjected to serious moisture stress caused by shortage of irrigation water during the growing period as compared to that of sole field bean. Similarly, this condition was also observed on plant height and thousand grain weight of intercropped haricot bean that were slightly greater than that of the sole cropping (Table 4.).

The results obtained in this study are in agreement with that of Davis and Garcia (1987) who reported reduction in hundred seed weight of haricot bean in maize intercropping as compared to that of sole cropping perhaps due to competition exerted by maize plants.

In agreement with the present finding, Sisay (2004) reported that seed weight of green gram per plant in the intercropping was 93.0mg as compared to that of 52.0mg in the sole cropping.

Biomass and Grain Yields

Grain yield and biomass of maize, fenugreek, field pea and haricot bean as influenced by intercropping and sole cropping are presented below in Table 5. The analysis of variance revealed that intercropping of maize with fenugreek, field pea and haricot bean didn't significantly ($P > 0.05$) affect the grain yield, however significant effect on biomass of maize was observed (Table 5.).

The grain yield and biomass of sole maize were superior than that of intercropping (Table 5.). These higher differences between the sole- and inter-cropping for maize grain yield and biomass would be associated with competition between the main and secondary crops in the intercropping for limited growth resources.

Similar to the current finding, Shehu *et al.* (1999) reported that monocropping resulted in superior grain yield of maize/sorghum compared with different intercropping treatments. Also, Pal *et al.* (1993) reported that seed yields of monocrops of soybean, maize and sorghum were higher than their respective encounters in the intercropping. They ascribed this yield variation in the intercropping to the high plant density per unit cultivated area. The finding of Tamado and Eshetu (2000) also revealed that sorghum grain yield in sole cropping was higher than that of the intercropping. Yesuf (2003) reported also that significant grain yield reduction on sorghum crop was recorded in the intercropping compared to that of sole cropping.

According to him, sorghum suffered with yield reduction due to its intercropping with beans. Sisay (2004) also reported that the effect of sorghum planting patterns and its interaction with green gram density on sorghum panicle weight per plant was not significant. The same author reported no significant difference between intercropping and sole cropping for sorghum yields.

Likewise, Tamado and Eshetu (2000) reported that panicle weight per plant of maize/sorghum was not significantly affected by intercropping with haricot bean. Similarly, Carr *et al.* (1992) reported that grain yield of sorghum was similar whether monocropped or intercropped with varying population of beans. In an intercropping experiment involving 50% and 100% the normal population of sorghum and the legumes green gram, red gram, and soybean, in a paired row system, Hunshal and Malik (1985) reported that the different intercrops did not have any adverse effect on yield and yield components of sorghum.

A study on the effect of population density and planting arrangement on maize or sorghum-pigeon pea intercropping also indicated that row spacing and planting methods did not show significant effect on maize/sorghum yield at an optimum plant population of 180,000 plants/ha. Rather, intercropping pigeon pea in maize/sorghum rows, gave an additional 342 kg/ha of pigeon pea without causing significant yield reduction in sorghum (Balearic and Pathway, 1981).

However, Bandyopadhyay and De (1986) reported higher maize/sorghum yields in their mixture with green gram or cowpeas than that of their sole cropping due to greater

panicle, more grain per panicle, and weight. The authors attributed this highest sorghum grain yield in the intercropping to greater panicle and thousand-grain weight.

In addition, Sharanappa and Hosmani (1987) reported that highest grain yield of sorghum was obtained in sorghum intercropping with paired rows of green gram.

Table 5. Effect of maize intercropping with fenugreek, field pea and haricot bean on grain yield & biomass.

Treatment	Grain yield (Kg/ha)	Biomass (Kg/ha)
A. Maize		
M with Fg	3984 ab	9853.10b
M with Fp	3978 ab	9960.50b
M with Hb	2904 b	7367.90c
SM	4671a	11134.10a
SE ±	2.37	30.37
CV	20.46	0.75
Sign.diff.	NS	*
B. Fenugreek		
Fg +	31b	56.50 b
SFg	328a	352.60a
SE ±	0.39	1.10
CV	30.78	0.27
Sign.diff.	NS	*
C. Field Pea		
Fp +	930 b	1068.80b
SFp	2826a	2667.90a
SE ±	2.38	3.75
CV	18.14	0.30
Sign.diff.	NS	*
D. Haricot Bean		
Hb +	1553	1704.70b
SHb	2399	2596.00a
SE ±	1.40	4.55
CV	14.70	0.05
Sign.diff.	NS	*

Key: M=Maize, SM=Sole Maize, Fg=Fenugreek, SFg=Sole fenugreek, Fp=Field pea, SFp=sole field Pea, Hb=haricot bean, SHb=sloe haricot bean, Fg+, FP+, Hb+= intercropped fenugreek, field pea & haricot bean with maize, NS=Non significant, *=significant, **=highly significant.

*treatment means with the same letters are not significantly different.

Concerning biomass of fenugreek, field pea and haricot bean, the analysis of variance showed that there has significant difference ($p \leq 0.05$) between intercropping and sole cropping while for grain yield had no significant difference on fenugreek, field pea and haricot bean intercropping (Table 5).

The sole fenugreek, field pea and haricot bean produced slightly higher grain yield and biomass per hectare compared to the intercropped ones. The highest yields and biomass of field pea and haricot bean amounted for yield 2826kg/ha and 2399kg/ha, and 2667.9kg/ha and 2596kg/ha for biomass respectively, were recorded in the sole crops. High grain yield of fenugreek, field pea and haricot bean in the sole cropping more than that of intercropping could be due to competition exerted by maize component for growth factors (Table 5.).

However, thousand grain weight of haricot bean in the sole cropping was less than that of the intercropping (Table 4).

Similar to this finding, Demesew (2002) reported that grain yield per hectare of haricot bean was not affected significantly ($P > 0.05$) by intercropping. The results obtained in this study are in disagreement with that of Davis and Garcia (1987) who reported reduction in hundred seed weight of haricot bean in maize intercropping as compared to that of sole cropping. This was perhaps associated with competition exerted by maize plants for resources.

The combined analysis of variance of maize, fenugreek, field pea and haricot bean as influenced by intercropping showed no significant difference ($p > 0.05$) both in biomass and yield (Table 6).

Table 6. Combined or sum effect of maize intercropping with fenugreek, field pea and haricot bean on grain yield & biomass.

Treatment	Grain yield (Kg/ha)	Biomass (Kg/ha)
M with Fg	4015	8026.80ab
M with Fp	4908	8933.70a
M with Hb	4457	7348.80b
SM	4671	9019.00a
SE ±	2.21	23.69
CV	21.13	8.72
Sign.diff.	NS	NS

Key: M=Maize, SM=Sole Maize, Fg=Fenugreek, SFg=Sole fenugreek, Fp=Field pea, SFp=sole field Pea, Hb=haricot bean, SHb=sloe haricot bean, Fg+, FP+, Hb+= intercropped fenugreek, field pea & haricot bean with maize, NS=Non significant, *=significant, **=highly significant.

*treatments with the same letters are not significantly different

5. Conclusion and Recommendations

This experiment was conducted to assess the biological benefits of intercropping maize with fenugreek, field pea and haricot bean in irrigated fields of *Fogera* Plain during the dry season. There were no any significant differences between sole and intercropping of maize with fenugreek, field pea and haricot bean for phenological parameters including days to 50% crop emergence, flowering and maturity. Except dry biomass yield most growth and yield components including pod/cob per plant, plant height and seed per pod were not significantly influenced by maize intercropped with fenugreek, field pea and haricot bean.

Generally, the sole maize was slightly higher than the intercropped one in all parameters except thousand grain weight. Sole fenugreek was also slightly higher than the intercropped one in all parameters. On the contrary,

intercropped field pea produced higher pod per plant, plant height and seed per pod than that of sole field pea, although it was vice versa in all other parameters. Haricot bean in the intercropping produced also slightly higher plant height, seed per pod and thousand grain weights than its sole crops. Indeed, sole haricot bean was slightly higher than the intercropped one in all other parameters. Generally, in this experiment the biological (biomass) benefit was observed.

However, from the forgoing results, intercropping on biological parameters of main crop (maize) and the secondary crops (fenugreek, field pea and haricot bean) yield per hectare was improved by the use of intercropping of maize with haricot bean and field pea at *Jigna* rural village *Dera* District, south *Gonder* area under irrigation in dry season.

Similar studies are strongly recommended for further to develop extension packages.

Acronyms and Abbreviations

AARC	Adet Agricultural Research Center
ANOVA	Analysis of Variance
ATER	Area Time Equivalent Ratio
CSA	Central Statistical Agency
CV	Coefficient of Variation
DAP	Di ammonium phosphate
DMTRT	Duncan's Multiple Range Test
DARC	Debre Zeit Agricultural Research Center
E.C.	Ethiopian Calendar
ETB	Ethiopian Birr
GMV	Gross Monetary Value
GLM	General Linear Model
GY	Grain Yield
ha	Hectare
IRRI	International Rice Research Center
Kg/ha	Kilogram per Hectare
LER	Land Equivalent Ratio
LSD	Least Significant Deference
M.a.sl	Meter above sea level
MV	Monetary Value
Qt/ha	Quintal per Hectare
RCBD	Randomized Complete Block Design
RCC	Relative Crowding Coefficient
RYT	Relative Yield Total
SAS	Statistical Analysis Software
SE±	Standard Error of Measurement
TSW	Thousand seed weight
WoRD & A	Woreda Office of Rural Development and Agriculture

References

- [1] Adeniyani ON, Akande SR, Baloyum O, Saka JO, 2007. Evaluation of crop yield of African Yam bean Maize and Kenaf under intercropping system. *American-Eurasian J. Agric. Environ. Sci.*, 2: 99-102.
- [2] Ahmed, S., H. P. M. Gunasena and Y. H. Yang, 1979. Proc. Final Inputs Rev. Meet. 20-24 Aug, Honolulu, 251P
- [3] Aleman, F., 2000. Intercropping of Common Bean and Maize with different Plant Proportions, Effects on Land Equivalent Ratio, Competitive Ratio and Monetary Return. In: studies on Bean/Maize Production Systems in Nicaragua. Swedish University of Agricultural Sciences. PP. 3-97.

- [4] Aleman, Z. F and L. Ohlander, 2000. Intercropping of common bean (*Phaseolus vulgaris* (L) and Maize at different Densities. Effects on Yield, Land Equivalent Ratio, and Net Income. In: Studies on Bean/Maize Production Systems in Nicaragua. Doctorial Thesis, Swedish University of Agricultural Science, Uppsala. Sweden. PP. 76-79.
- [5] Allen, J. R and R. K. Obura. 1983. The Science of Sustainable Agriculture. 2nd. West view Press II Publication. United Kingdom. Agronomy Journal. 75, 1005-1009.
- [6] Amare, B, 1992. Effect of Maize (*Zea mays*) and Bean (*Phaseolus vulgaris*) intercropping and Yield Components of the Companion Crops. M.Sc. Thesis, AUA. PP. 24-27.
- [7] Andrews, D. J and A. H. Kassam. 1976. The importance of Multiple Cropping in increasing World Food Supplies. In: R. I. Papendic, P. A. Sanchez, and G. B. Triplett (Ed.). Multiple Cropping. Sp. pub. No. 27. American Society of Agronomy Madison, Wisconsin, USA.
- [8] Andrew, D. J and A. H. Kassam. 1983. The importance of multiple cropping in increasing world food supply. In: Papendic, R. I. (ed.) Multiple Cropping. American Society of Agronomy, 677 South Segoe Road Madison, Wisconsin 53711. PP. 7-32.
- [9] Azam -Ali, S. N., R. B. Mathews., J. H. Williams and J. M. Pealock, 1990. Liftg Use, Watre Uptake and Performance of Individual Components of Sorghum/Groundnut Intercrop. Experimental Agriculture. 26: 413-427.
- [10] Balearic, S. S and U. C. Pathway. 1981. Crop geometry Studies in Sorghum in Association with Pigeon pea varieties. Indian Journal of Agricultural Science. V. 51 (11). P. 77.
- [11] Bandyopadhyay, S. K and R. De. 1986. Nitrogen Relationship and Residual Effects of intercropping with Legumes. Journal of Agricultural Science 107, 629-632.
- [12] Beets, W. C. 1982. Multiple cropping and tropical farming systems, west views Press, Colorado, and USA. PP. 35-36.
- [13] Bell, M. J., R. C. Muchow and G. L. Wilson. 1994. The Effect of Plant Population on Peanuts (*Arachis hypogaea*) in a Monsoonal Tropical Environment. Field Crops Research, 17: 91-107.
- [14] Bergersen, F. J., G. L. Turner., M. B. Gault., R. R. Peoples., L. J. Morthorpeand J. Brockwell. 1992. Contribution of nitrogen in soybean crop residues to subsequent crops and to soils. Australian Journal of Agricultural Research 43, 155-169.
- [15] Besong, M. T., S. W. Almy and B. Bakia. 1993. The Land productivity of the Small Farm holders in southwest Province of Cameroon. International Journal of Tropical Agriculture. 11 (2): 81-87.
- [16] Bulson, H. A. J., R. W. Snaydon and C. E. Stopes. 1996. Effects of Plant Density on intercropped wheat and Field beans (*Vica faba*) in an Organic Farming System. Journal of Agricultural Science. 128: 69-73.
- [17] Carr, P. M., B. G. Schatz., J. C. Gander and S. F. Zwinger. 1992. Intercropping Sorghum and Pintio bean in a cool Semi-Arid Region. Journal of the American Society of Agronomy. 84 (5): 810-812.
- [18] Cenpukdee, U and S. Fukai. 1991. Effect of nitrogen supply on Cassava /pigeon pea intercropping with three contrasting Cassava cultivars. Fert. Res. 29: 275-280.
- [19] Chang, J. F and R. M. Shibles, 1985b. An Analysis of Competition between intercropped Cowpea and Maize. II. The Effect of Fertilization and Population Density. Field Crops Res. 12, 145-152.
- [20] Chang, J. F and R. M. Shibles. 1985a. An analysis of Competition between intercropped Cowpea and Maize. I. Soil N and P Levels and Their Relationships with Dry matter and Seed Productivity. Field crops Re. 12: 133-143.
- [21] Chetty C. K. R and M. N. Reddy. 1984. Analysis of intercropping Experiments in Dry land Agriculture. Experimental Agriculture 20: 31-40.
- [22] Chittapur, B. M., S. M. Hiremath., H. B. Babalad and G. S. Patil. 1993. Intercropping of Forage Legume in Maize. Farming Systems. 9 (3&4): 108-110.
- [23] Chowachury, M. K. 1989. Utilization Efficiency of Nitrogen, Phosphorus and Potassium as related to Yield Advantage in Corn and Mung bean intercrops. College Laguna, Philippines. P. 236.
- [24] Chowdhury, M. K and E. L. Rosario. 1994. Comparison of Nitrogen, Phosphorous and Potassium Utilization Efficiency in Maize /Mung bean intercropping. Journal of Agricultural Science, Cambridge. 122 (2): 193-199.
- [25] Cotteinie, A. 1980. Soil and Plant Testing as a Base of Fertilizer Recommendations. Soils Bulletins, No. 38, FAO, Rome. P. 22.3, 389-399.
- [26] Dakora, F. D., R. A. Aboyinga., Y. Mohama and J. Apaseku. 1987. Assessment of N₂ fixation in groundnut (*Arachis haypogaea*) and cowpea (*Vigna unguiculata* L. walp) and their relative N contribution to a succeeding major crop in Northern Ghana. MIRCEN Journal 3, 389-399.
- [27] Davis, J. H. C and S. Garcia, 1987. The effect of Plant arrangement Density on Intercropped Bean (*Phaseolus vulgaris* and Maize. 1. Traits related to dry matter and seed Productivity. Field Crops Research. 12 (2): 105-115.
- [28] Demesew, M. 2002. Effect of Plant Density of Haricot bean and Nitrogen Fertilization on Productivity of Maize and Haricot Bean Additive Inter Crop System. MSc. Thesis, Alemaya University. P. 45-50.
- [29] Enyi, B. A. C. 1973. Effects of intercropping Maize or Sorghum with Cowpea, Pigeon pea or Beans. Experimental Agriculture 9, 83-90.
- [30] Fawusi, B. A. C., S. B. C. Wanki and D. Nangju, 1982. Pod and Grain Yield from intercropped Maize and *Vigna unguiculata* (L) Walp. Journal of Agricultural Science 99: 13-17.
- [31] Fisher, N. M. 1977. Studies in Mixed Cropping. I. Seasonal Differences in Relative Productivity of Crop Mixtures and Pure Stands in the Kenya Highlands. Exp. Agric. 13: 177-184.
- [32] Francis, C. A. 1986a. Distribution and Importance of Multiplying Cropping. In: Francis, C. A (ed.), 1986. Multiple Cropping. Macmillan Publishing Company, New York. PP. 1-19.
- [33] Francis, C. A, 1986b. Perspectives for the Future of Multiple Cropping. Macmillan Publishing Company, New York. PP. 351-370.

- [34] Francis, C. A, 1990. Sustainability Issues with Intercrops. In: Wadding ton, S. R. (Ed.). Centro Internacional de mejoramiento de Maize Trigo, Mexico, DF (Mexico). Research Methods for Cereal Legume Intercropping: Proceedings of a Workshop. Mexico, DF (Mexico). CIMMYT. 1990. PP. 194-199.
- [35] Fukai, S. and B. R. Trenbath. 1993. Presses of Determining Intercrop Productivity and Yield of Component Crops. Field Crops Research, 34: 247-271.
- [36] Fukai, S., J. S. Tsay., G. L. Wilson., U. Cenkudee and D. P. C. Grady. 1990. Cassava legume intercropping in the sub tropics. In: R. H. Howeler (Editor), Proceedings 8th Symposium of the International Society for Tropical Root Crops. ISTRC, Bangkok, Thailand, pp. 293-300.
- [37] Gangwar, B and G. S. Kalra. 1988. Influence of Maize Legume Associations and Nitrogen Levels on Maturity, Grain quality and Protein Productivity. Legume Research 11 (1): 6-10.
- [38] Gobeze L, 1999. Effect of Spatial Arrangement and Nitrogen Fertilizer Application on Sorghum (*sorghum bicolor* (L) Moench) and Groundnut (*Arachi hypogea* L.) intercrop System in Eastern Ethiopia. M.Sc. Alemaya University. PP. 50-52.
- [39] Gomez, A. K and A. A. Gomez. 1984. Statistical Procedures for Agricultural Research. Second Edition. John Wiley and Sons Inc. Inter-Science Publications. New York. PP. 180-225.
- [40] Ghosh PK, Manna MC, Bandyopadhyay KK, Ajay TAK, Wanjari RH, Hati KM, Misra AK, Acharya CL, Subba RA (2006). Inter-specific interaction and nutrient use in soybean sorghum intercropping system. Agro. J., 98: 1097-1108.
- [41] Hall, R. C. 1974a. Analysis of Nature of Interference between Plants of Different Species. Concepts and Extension of the Dewitt Analysis to Explain Effects. Australian Journal of Agricultural Research, 25: 739-747.
- [42] Hoshikawa, K., 1991. Significance of Legumes Crops in intercropping, the Productivity and Stability of Cropping System. In: Johanson, C., K. K. Lee and K. L. Saharawat, (Ed.). Phosphorus Nutrition of Grain Legume in the Semi Arid Tropics. ICRISAT. PP. 173-176.
- [43] Hunshal, C. S and D. S. Malik. 1985. Intercropping in Sorghum with Special Reference to Plant Population. Journal of Farming Systems. 1 (3/4): 73 79.
- [44] IAEA. 1980. Nuclear Techniques in the Development of Management Practice for Multiple Cropping Systems. Vienna, P. 154.
- [45] Ibrahim, Y. M., M. O. Gaffar and D. A. A. Wahab. 1993. Intercropping of Pioneer Sorghum with Lablab purpureus (L) under Irrigation at Shambat. Annals of Arid Zone. 32 (3): 157-159.
- [46] IRRI. 1974. Annual Report for 1973. International Rice Research Institute. Los Bonos, Philippines. P. 25.
- [47] Karikari, S. K., O. Chaba., B. Molosiwa. 1999. Effects of intercropping Bambara Groundnut on Pearl Millet, Sorghum and Maize in Botswana. African Crop Science Journal, 7 (2): 143-152.
- [48] Kasasa, P., S. M. Pepereki., K. Musiyiwa., F. Makonese and K. E. Giller. 1999. Residual Nitrogen Benefits of Promiscuous Soybean to Maize under Field Conditions. African Crop Science Journal 7, 375-382.
- [49] Kassu K, 1993. Studies on Plant Population and Spatial Arrangements on Sorghum (*Sorghum bicolor*) and bean (*Phaseolus vulgaris*) Intercropping as Influenced by NP Application in Eastern Ethiopia. M.Sc Thesis, Alemaya University of Agriculture. PP. 40-45.
- [50] Keating, B. A. and P. S. Carberry. 1993. Resource Capture and Use in intercropping –Solar Radiation. Field Crops Research. 34: 273-301.
- [51] Khola, O. P. S and D. P. Singh. 1996. Comparative Performance of Swedge rape (*Brassica napus*) and Ethiopian mustard (*Brassica carinata*) in intercropping with French bean (*Phaseolus vulgaris*). Indian Journal of Soil Conservation. 24 (1). 68-73.
- [52] Kumar Rao, J. V. D. K., C. Johansen., T. Yonegama., S. Tobita, and O. Ito. 1996b. Estimation of Nitrogen Fixation by the 15 N Abundance Techniques and Nitrogen Uptake by Rigengeo Genotypes of Different Maturity Groups Grown in an Inceptisol. Journal of Agronomy and Crop Science 177, 129-138.
- [53] Kumar Rao, J. V. D. K., P. J Dart and P. V. S. S. Sastry. 1983. Residual Effects of Pigeon pea (*Cajanus Cajan*) on Yield and Nitrogen Response of Maize. Experimental Agriculture 19, 131-141.
- [54] Mandal, B. K., C. D. Madhab., B. M. Barrid., K. D. Swapanand. 1990. Rice, Soybean, Peanut, Rice Bean, and Black gram Yields under Different Intercropping Systems. Agronomy Journal, 82: 1063-1066.
- [55] Marcellos, H., W. L. Felton and D. F. Herridge. 1997. Rotational Benefits of Chickpea in Cereal based Cropping Systems of the Northern New South Wales Regions of Australia. In: Rupela, O. P., Johanen, C. and Herridge, D. F. (Eds.) Extending Nitrogen Fixation Research to Farmers Fields. Proceedings of an International Workshop on Managing Legume Nitrogen Fixation in Cropping Systems of Asia. ICRISAT, Hyderabad, India, PP. 117-126.
- [56] Mason, S. C., D. E. Leihner and J. J. Vort. 1986. Cassava/cowpea and Cassava Peanut intercropping. III. Nutrient concentration and removal. Agronomy Journal 78, 441-444.
- [57] Matthews P, Harry T (2003). Faba bean Res. Agro. Aust., pp. 1-23.
- [58] Mbah EU, Muoneke CO, Dkpara DA (2007). Effect of compound fertilizer on the yield and productivity of soybean maize intercrop in south eastern Nigeria. Trop. Subtrop. Agro. Ecos., 7: 87-95.
- [59] McCollum, R. E. 1982. Expert Consults. Fertilizer Use in Multiple Crops. Syst. FAO, 1-6 Feb., New Delhi. P. 35.
- [60] Midmore, D. J., J. Roca and D. Berrios. 1988a. Potato (*Solanum* spp.) in the Hot Tropics. IV. Intercropping with Maize and the Influence of Shade on Potato Microenvironment and Crop Growth. Field crops Res., 18: 145-157.
- [61] Minale L, Tilahun T, Alemayehu A (2001). Determination of nitrogen and phosphorus fertilizer levels in different maize-faba bean intercropping patterns in northwestern Ethiopia. Seventh Eastern and Southern Africa Regional Maize Conference, pp. 513-518.
- [62] Moris, R. A and D. P. Garrity. 1993a. Resource Capture and Utilization in intercropping: Water. Field Crops Research, 34 (3): 303-317.

- [63] Morris, R. A. and D. P. Garrity. 1993b. Resource Capture and Utilization in intercropping: Non Nitrogen Nutrients. *Field Crops Research* 34, 319-334.
- [64] Nambiar, P. T. C., M. R. Rao., M. S. Reddy., C. N. Floyd., P. J. Dart and R. W. Willey. 1983a. Effect of intercropping on Nodulation and N₂ Fixation by Groundnut. *Experimental Agriculture* 19, 79-86.
- [65] Nasrullahzadeh S, Ghassemi – Golezani K, Javanshir A, Valizadeh M, Shakiba MR (2007). Effects of shade stress on ground cover and grain yield of faba bean (*Vicia faba*). *J. Food Agric. Environ.*, 1: 337-340.
- [66] Natarajan, M., and R. W. Willey. 1980. Sorghum/Pigeon pea intercropping and the Effect of Plant Population Density. II. Resource Use. *Journal of Agricultural Science* 95, 51-58.
- [67] Njoroge, J. M. and J. K. Kimemia. 1995. Economic Benefits of Intercropping Young Arabica and Robusta coffee with Food Crops in Kenya. *Out look on Agriculture*. 24 (1): 27-34.
- [68] Odoemana, C. S. 1997. Yield and Yield Component Responses of Intercropping Yam (*Dioscorea rotundata*) and Melon (*Colocyntris Vulgaris*) in South and Eastern Nigeria. *Tropical Agriculture*. 74 (3): 192-196.
- [69] Ofori, F and W. R. Stern. 1987b. The Combined Effects of Nitrogen Fertilizer and Density of the Legume Component on Production Efficiency in a Maize /Cowpea Intercrop System. *Field Crops Res.*, 16: 43-52.
- [70] Ofori, F., and W. R. Stern. 1987a. Evaluation of N₂ Fixation and Nitrogen Economy of a Maize Cowpea intercropping system using 15N Dilution Methods. *Plant and Soil* 102, 149-160.
- [71] Olanitan, F. O., 1991. Repone of Tomato and Okra to Nitrogen Fertilizer in Sole cropping and intercropping with Cowpea. *J. Hortic. Sci.* 66: 1191-199.
- [72] Olsen, S. R., C. V. Cole., F. S. Watanabe and L. A. Dean. 1954. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. *USDA Circular* 939: 1-19.
- [73] Ong, C. K., C. R. Black., F. M. Marhall and J. E. Corlett. 1996. Principles of Resource Capture and Utilization of Light and Water. In: Ong, C. K. and Huxley, P. (Eds) *Tree-Crop Interaction: a Physiological Approach*. CAB International, Wallingford, UK, PP. 73-158.
- [74] Pal, U. R and Y. Shehu. 2001. Direct and Residual Contribution of Symbiotic Nitrogen Fixation by Legume to the Yield and Nitrogen Uptake of Maize (*Zea mays L.*) in the Nigerian Savannah. *Journal of Agronomy and Crop Sciences*, 187: 53-58.
- [75] Pal, U. R., A. R. Rao., R. Singh and S. S. Verma. 1981. Intercropping with Grain Sorghum: Compatible Intercrops and Spatial Arrangements. *Indian Journal of Genetics and Plant Breeding*. 40: 44-50.
- [76] Pal, U. R., T. O. Oseni and J. C. Norman. 1993. Effect of Component Densities on the Productivity of Soybean /Maize and Soybean /Sorghum Intercrop *Journal of Agronomy and Crop Sciences*, 170: 66-70.
- [77] Palaniapan, S. P., 1985. *Cropping Systems in the Tropics, Principles and Management*. Wiley Eastern Limited. Tamil Nadu Agricultural University. PP. 75-80.
- [78] Papendic, R. I., P. A. Sanchez and G. B. Triplett. 1976. Multiple Cropping. *Am. Soc. of Agron. Madison, Wisconsin* 27. 378P.
- [79] Papendic, R. I. 1983. *Multiple Cropping*. American Society of Agronomy, Crop Sciences Society of America, Soil Science Society of America. 677 South Segoe Road, Madison, Wisconsin. PP. 7-32.
- [80] Poggio SL (2005). Structure of weed communities occurring in monoculture and intercropping of field pea and barley. *Agric. Ecosyst. Environ.*, 109: 48-58.
- [81] Ramakrishna, A and C. K. Ong. 1994. Productivity and Light Interception in Up Land Rice /Legume intercropping Systems. *Tropical Agriculture*. 71 (1): 5-11.
- [82] Rao, A. V and B. Venkateswarlu. 1987. Nitrogen Fixation as Influenced by Water Stress in Selected Crop Legumes of the Indian Arid Zone. *Arid Soil Research and Rehabilitations* 1, 89-96.
- [83] Rao, M. R. and R. W. Willey. 1980. Evaluation of Yield Stability in Intercropping Studies on Sorghum /Pigeon pea. *Experimental Agriculture*. 16 (2): 105-116.
- [84] Reddy, M. S., Nigusse. T., Kidane, G. and Chanyalew. T, 1994. Developing Improved Cropping Systems for Dry Land Areas of Ethiopia. PP. 116-129. In: *Proceedings of the First National work shop on Dry Land Farming Research in Ethiopia*.
- [85] Rees, D. J. 1986. Crop Growth, Development and Yield in Semi Arid Conditions in Botswana, The Effect of intercropping sorghum bicolor with *Vina unguiculata*. *Experimental Agriculture* 22, 169-177.
- [86] Rego, T. J. and V. N. Rao. 2000. Long-term Effects of Grain legumes on Rainy Season Sorghum Productivity in a Semi arid Tropical Vertisol. *Experimental Agriculture* 36, 205-221.
- [87] Russell, J. T and R. M. Caldwell. 1989. Effects of Component Densities and Nitrogen Fertilizations on Efficiency and Yield of Maize /Soybean intercrop. *Exp. Agric*, 25: 529-540.
- [88] Sakala, W., G. Cadisch and K. E. Giller. 2000. Interactions between Residues of Maize and Pigeon pea and Mineral Fertilizers during Decomposition and N Mineralization. *Soil Biology and Biochemistry* 32, 699-706.
- [89] Sakala, W. D., G. Cadisch and K. E. Giller. 2001. Productivity, Nitrogen Fixation and Nitrogen balances in Pigeon pea –Maize intercrops in Malawi. *Plant and Soil*, in Press. P. 15.
- [90] Searle, P. G. E., Y. Comandom, D. C. Shedden and R. A. Nance. 1981. Effect of Maize Legume Intercropping System and Fertilizer Nitrogen on Crop Yields and Residual Nitrogen. *Field Crops Research*. 4: 133-145.
- [91] Senaratne, R., N. D. L. Liyanage and R. J. Soper. 1995. Nitrogen Fixation and N Transfer from Cowpea, Mung bean and Groundnut when Intercropped with Maize. *Fertilizer Research*. 40 (1): 41-48.
- [92] Shehu, Y., W. S. Alhasan., U. R. Pal and C. J. C. Phillips. 1999. The Effect of intercropping *Lablab purpureus L.* with Sorghum on Yield and Chemical Composition of Fodder. *Journal of Agronomy and Crop Science*, 183: 73-79.

- [93] Shumba, E. M., H. H. Dhiwayo and O. Z. Mukoko. 1990. The Potential of Maize /Cowpea intercropping in low Rain fall Areas of Zimbabwe. *Zimbabwe Journal of Agricultural Research* 28, 33-38.
- [94] Singh, R. P. 1990. Research Efforts to Mitigate the Adverse Effects of drought. *Dry land resources and Technology* 5, 117-136.
- [95] Sisay, T, 2004. Effects of Planting Pattern and Proportions of Green gram (*Vigna radiata* (L) on Productivity of Sorghum/Green gram Intercropping System in Kewet Woreda, Amhara Region. MSc. Thesis, Alemaya University. PP. 25-40.
- [96] Siva Kumar, M. V. K. 1993. Growth and Yield of Millet and Cowpea in Rely and intercrop Systems in the Sahelian Zones in Years when the On Set of the Rainy Season is Early. *Experimental Agriculture*. 29 (4): 417-427.
- [97] Struif, B. T. E. 1986. Sorghum/Rice intercropping, a security System for Poorly Drained Soils of Southern Sudan. *Netherlands Journal of Agricultural Science*. 34 (2): 193-198.
- [98] Tamado, T and Eshetu. M. 2000. Evaluation of Sorghum, Maize and Common Bean cropping Systems in East Hararge, Ethiopia. *Ethiopian Journal of Agricultural Science*. 17: 33-45.
- [99] Tarhalkar, P. P. and N. G. P. Rao, 1981. Genotype-Plant Density Considerations in the Development of an Efficient intercropping System for Sorghum. In: *Proceeding of International Workshop on Intercropping 10-13 January 1979*. ICRISAT, Hydra bad, India. PP. 35-40.
- [100] Tilahun T, 2002. Effect of plant density and arrangement of component crops on productivity of maize /faba bean intercropping system. MSc. Thesis. Alemaya University. PP. 30-40.
- [101] Tobita, S., O. Ito., R. Matsunaga., T. P. Rao., T. J. Rego., C. Johansen, and T. Yoneyama. 1994. Field Evaluation of Nitrogen Fixation and Use of Nitrogen Fertilizer by Sorghum/pigeon pea intercropping on an Alfisole in the Indian Semi-arid Tropics. *Biology and Fertility of soils* 17, 241-248.
- [102] Trenbath, B. R. 1976. Plant interactions in Mixed Crop Communities. PP. In: Pependic, R. I., P. A. Sanchez and G. B. Triplett (eds.), *Multiple Cropping*. ASA Special Publication No. 27. Am. Soc. Agron. Madison, WI, USA. PP. 129-170.
- [103] Trenbath, B. R., 1986. Resource Use by Intercrops. In: C. A. Francis. (Ed.), *Multiple Cropping*. Macmillan Publishing Company, New York. PP. 57-81.
- [104] Tsubo M, walker S, Ogindo HOA (2005). Simulation model of cerealleghume intercropping systems for semi-arid regions II Model application. *Field Crops Res.*, 93: 23-33.
- [105] Umrani, N. K., S. H. Shinde and P. M. Dhonde. 1984. Studies on Intercropping of Pulses in Kharif Sorghum. *Indian Journal of Agronomy*, 29 (1): 27-30.
- [106] Waghmare, A. B. and S. P. Singh. 1982. Total Productivity and Net Returns of Different Sorghum/legume intercropping systems under varying Nitrogen Levels. *Indian Journal of Agronomy*, 27 (4): 423-428.
- [107] Wahua, T. A. 1983. Nutrient up take by intercropped Maize and Cowpea and concept of Nutrient Supplementation Index (NSI). *Experimental Agriculture*, 191: 263-275.
- [108] Wahua, T. A. T and D. A. Miller. 1978. Effect of intercropping on Soybean N2 Fixation and Plant Composition on Associated Sorghum and Soybeans. *Agronomy Journal* 70, 292-295.
- [109] Wanki, S. B. C and M. O. A. Fuwusi. 1982. Pod and Grain Yields from Intercropping Maize and Bean (*Vigna unguiculata* (L) walp) in Nigeria. *Journal of Agricultural Sciences, (Cambridge)* 99: 13-17.
- [110] Wenxue Li, Long L, Jianhao S, Tianwen G, Fusuo Z, Xingguo B, Peng A, Tang C (2005). Effects of inter cropping and nitrogen application on nitrate presentin the profile of orthicanorthicanthrosol west China. *Agric. Ecosyst. Environ.*, 105: 483-491.
- [111] Willem, C. 1990. Raising and sustaining productivity of smallholder farming systems in the tropics. AgBe publishing, Alkamar, Holland. PP. 90-117.
- [112] Willey, R. W, 1979. Intercropping –its importance and research needs. Part I. Competition and yield advantages. *Field Crops Abstr.* 32, 1-10.
- [113] Willey, R. W. 1985. Evaluation and Presentation of intercropping Advantages. *Experimental Agriculture* 21, 119-133.
- [114] Willey, R. W. and D. S Osiru. 1972. Studies on Mixtures of Maize and Beans (*Phaseolus vulgaries* with Particular Reference to Plant Population. *J. Agric. Sci. Caamb.* 79, 517-529.
- [115] Willey, R. W, 1991. Evaluation and Presentation of Intercropping Advantages. *Experimental Agriculture*, 21: 119-123.
- [116] Yesuf, M, 2003. Effects of Plant Arrangement and Population Densities of Haricot bean on Productivity of Sorghum/Haricot bean Additive mixtures. MSc. Thesis in Agriculture (Agronomy). Alemaya University.
- [117] Zewdu, Y, 2002. Effect of Cropping System, Nitrogen Levels, and Bacteria Fertilization on Yield and Quality of Fodder Sorghum (*Sorghum bicolor*). Ph.D Thesis, Rajas than College of Agriculture, Uduipus, India.

Biography



Molla Abate was born in 1964 at West Gojam, Ethiopia. He attended his elementary at Shindi Primary school and junior at Ras Bitwoded Mengesha Atikem School, Burie (1971-1977). He also learned secondary education at Damot Compressive Secondary High School (F/Selam) (1978-1981). And he joins in different college and University and obtained Diploma and Bachelor of Science degree. Then he served in different organization more than twenty five years. Lately he graduated from Collage of Agriculture and Environmental Science, School of Graduate at Bahir Dar University majoring in Agronomy and now working at Bahir Dar Bio diversity Center.