Evaluation of Black Cowpea (*Vigna unguiculata* L.) as Intercropped with Maize (*Zea mays* L.) under Kashmir Valley Condition

Ramesa Jan

(2011-A-871-M)

Division of Agronomy

Faculty of Postgraduate Studies

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

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The Faculty of Postgraduate Studies
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in partial fulfilment of requirement for the award of the degree of

Master of Science in Agriculture
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2013

Dedicated

to my beloved Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Agronomy, Shalimar Campus, Srinagar – 190 025

Certificate – I

This is to certify that the thesis entitled, **"Evaluation of Black Cowpea (*Vigna unguiculata* L.) as Intercropped with Maize (*Zea mays* L.) under Kashmir Valley Condition"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)**, to the **Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Ramesa Jan (Regd. No. 2011-A-871-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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Advisory Committee

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Prof. & Head,
Division of Agronomy

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Agronomy, Shalimar Campus Srinagar – 190 025

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We, the members of the Advisory Committee of **Ms. Ramesa Jan (Regd. No. 2011-A-871-M)**, a candidate for the degree of **Master of Science in Agriculture (Agronomy)** have gone through the manuscript of the thesis entitled, **"Evaluation of Black Cowpea (*Vigna unguiculata* L.) as Intercropped with Maize (*Zea mays* L.) under Kashmir Valley Condition"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

Advisory Committee

Chairman

Dr. Amal Saxena
Associate Professor (Sr. Extension Specialist),
Division of Agronomy, SKUAST-Kashmir

Members

Dr. Raihana Habib Kanth,
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Dean PG Nominee

Dr. M. Maqbool Mir
Associate Professor, Division of Fruit Science, SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar Campus, Srinagar – 190 025

Certificate – III

This is to certify that the thesis entitled, **"Evaluation of Black Cowpea (*Vigna unguiculata* L.) as Intercropped with Maize (*Zea mays* L.) under Kashmir Valley Condition"** submitted by **Ms. Ramesa Jan (Regd. No. 2011-A-871-M)** to the **Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)** was examined and approved by the Advisory Committee and External Examiner on …………….

Chairman
Advisory Committee

External Examiner

Prof. & Head,
Division of Agronomy

Director Resident Instruction-cum-Dean
Postgraduate Studies, SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Agronomy, Shalimar campus-190 025

Name of the student	:	**Ramesa Jan**
Registration No.	:	2011-A-871-M
Major Subject	:	Agronomy
Minor Subject	:	Plant Physiology/Soil Science
Major Advisor	:	**Dr. Amal Saxena** Associate Professor (Sr. Extension Specialist), Division of Agronomy, SKUAST-Kashmir
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ABSTRACT

Present investigation on "Evaluation of Black cowpea (*Vigna unguiculata* L.) as intercrop with maize (*Zea mays* L.) under Kashmir valley condition" was conducted at Agronomy Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *Kharif* season 2012. The soil of the experiment was silty clay loam in texture, neutral in reaction, with medium available carbon, nitrogen, phosphorus and potassium. The experimental field was laid out in randomized block design with four replications. There were seven treatment comprising Maize sole, Black cowpea sole, Maize +Black cowpea (Broadcast), Maize + Black cowpea (1:1), Maize + Black cowpea (2:1), Maize + Black cowpea (2:2) and Maize + Black cowpea (2:3).The experimental findings on black cowpea revealed that highest plant population (m^{-2}) at maturity, number of nodules per plant, fresh weight (g) of nodules per plant and higher dry matter accumulation(g $plant^{-1}$) was recorded in sole black cowpea. Highest number of pods $plant^{-1}$, number of seed pod^{-1} and 100-grain weight (g), harvest index (%), grain, stover and biological yields (q ha^{-1}) was recorded in black cowpea sole. Among different intercropping patterns of maize and black cowpea, 2:2 row ratio showed higher values of yield attributes and yield of black cowpea. Highest dry matter accumulation (g $plant^{-1}$), number of cobs $plant^{-1}$, grain weight cob^{-1},100 seed weight(g), harvest index (%) grain, stover and biological yields (q ha^{-1}) was recorded in sole maize cropping. Maize equivalent yield (q ha^{-1}), land equivalent ratio (LER), area time equivalent ratio(ATER), production efficiency(PE) and aggressivity of black cowpea was highest in 2:2 row ratio of maize and black cowpea intercropping pattern among different treatments, whereas, relative crowding coefficient (RCC) was higher in 2:1 row ratio. Planting patterns having black cowpea in the system resulted in maintaining soil reaction, organic carbon (%) and available nitrogen. Whereas, available phosphorus and potassium both were slightly reduced in all planting patterns. Maize and black cowpea in the row ratio of 2:2 recorded highest gross return (Rs. 140085.90 ha^{-1}), net return (Rs. 96653.40 ha^{-1}) and benefit: cost ratio (2.23).

Key words : Maize, black cowpea, intercropping, yield, equivalent yield, land equivalent ratio (LER).

Signature of Student | Signature of Major Advisor

Dated____________ | Dated _________________

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INTRODUCTION

Pulses are the basic ingredient in the diets of a vast majority of the Indian population, as they provide a perfect mix of vegetarian protein component of high biological value when supplemented with cereals. Pulses are also an excellent feed and fodder for livestock. Endowed with the unique ability of biological nitrogen fixation, carbon sequestration, soil amelioration, low water requirement and capacity to withstand harsh climate, pulses have remained an integral component of sustainable crop production system since time immemorial, especially in the dry areas. They also offer good scope for crop diversification (grow profitably in relatively low-input management conditions) and intensification (short growing period). India is the largest producer of pulses in the world with 24% share in the global production and consumes about 36% of global pulse production (Ali and Gupta, 2012). However, because of increase in irrigation potential in the country, Indian agriculture has achieved a great stride in the production of cereals but stagnation in the production of pulses remains as an issue of primary concern. The paradox is that the pulses are energy rich crops but are grown in energy stress condition resulting in poor production. Moreover, 92 per cent area of pulses is under rain-fed condition (Vyas and Rai, 1993). The pulses production does not keep pace with the domestic requirement and consequently, the nation has to import 2.5-3.5 million tones every year. Per capita availability of pulses has declined over the years from 85 to 37 g/day as per FAO/WHO standards. At present in India, the total area under pulses is 24.80 million ha with a total production of 17.20 million tones with a productivity of 694 kg ha^{-1} and the per capita availability of pulses is 39.4 g day^{-1} (Economic Survey, 2012-2013).

Cowpea (*Vigna unguiculata* L.) is cultivated worldwide plays a critical role as major source of dietary protein that produces income for farmers and traders (Singh, 2002). In India, cowpea is grown on about 0.5 million ha with average productivity of 6.0 to 7.5 q grain ha^{-1} (FAOSTAT, 2010). The cultivation of Black-cowpea in Kashmir Valley mostly done as intercrop broadcasted in K*harif* maize with a low productivity. However, its market value is more than any other pulses. Black-cowpea used as *dal, snacks*, and *chat* etc. Cowpea produces high quality and quantity herbage for animal feed (Duke 1983). Cowpea also has the ability to be intercropped with cereals such as millets and sorghum. Its diversity of uses, nutritive content and storage qualities have made cowpeas an integral part of the farming system in West African region (Eaglesham *et al.*, 1992). Among the different pulses, the area, production and productivity of cowpea is very low against the total pulse area 54.52 thousand ha with a production of 590.3 thousand quintal and the productivity of about 10.67 q ha^{-1} in Jammu and Kashmir State (Economic Survey, Govt. J&K, 2012-13).

Small-scale farmers throughout the region grow cowpeas and because cowpeas are naturally drought tolerant they are extremely important in semi-arid areas. Cowpea contain more than 18% crude protein (Khan *et al.*, 1987) and its intercropping with cereal fodder i.e. maize or sorghum etc. seems to be logical technique to increase fodder yield as well as its nutritive value in terms of its crude protein.

Maize (*Zea mays* L.), the "Queen of Cereals" is the third most important cereal crop in India after rice and wheat and cultivated on 8.7 million ha. Total maize production is 21.6 m tons, with an average yield of 24.76 q ha^{-1} (Economic Survey, 2012-2013). Maize is one of the oldest food source and is fully domesticated plant. Modern maize does not grow in the wild, cannot survive in nature and is completely dependent on human husbandry (Galiant, 1988; Doswell, *et al.*, 1996). It is a productive food plant and has highest potential for carbohydrate accumulation per $unit^{-1}$ day^{-1} (Alderch *et al.*, 1975). Maize is of greatest economic significance worldwide, both for human and animal consumption and is the source of a large number of industrial products. Maize has multifarious uses and the diversity of environments under which it is grown, therefore, unmatched by any other crop (Doswell *et al.*, 1996). Maize is grown under wide range of climatic conditions, mostly in warmer parts of the temperate region and areas of humid sub-tropical climate. It is grown practically at all altitudes except where it is too cold or the growing season is too short. The crop requires considerable moisture and warmth from the time of planting to the termination of flowering period. Maize crop is categorized as a very exhaustive crop because of its very high demand of the nutrients specially nitrogen, phosphorus and potassium from the soil.

In Jammu and Kashmir maize is the most important cereal crop for human and animal consumption. The area of Maize is 306.4 thousand ha with a production of 9116.6 thousand quintal and the productivity of about 27.3 q ha^{-1} in Jammu and Kashmir State (Economic Survey, Govt. J&K, 2012-13). In Kashmir Valley, maize is intercropped with pulses especially cowpea and yielded poorly. It is, therefore, necessary to develop a suitable technology by way of combining a proper planting pattern to boost up their production and productivity. Productivity along with sustainability unit $area^{-1}$ can be increased through suitable crops with higher potential and adaptation of intercropping system.

Intercropping is one of the ways to increase the ways to increase the productivity $unit^{-1}$ area of land under the supply of limited resources. This system not only provides certain insurance against biotic and abiotic stress but also helps in the maximization of productivity and profit by efficient utilization of natural resources (Thakur *et al.*, 2000). Cereal-legume intercropping plays an important role in subsistence food production in both undeveloped and developing countries, especially in situations of limited water resources (Tsubo *et al.,* 2005). Yields of Intercropping are often higher than in sole cropping systems (Lithourgidis *et al.*, 2006). Das and Mathur (1980) reported residual effects of cowpea, and blackgram and greengram as intercrop with maize up to 50 kg N ha^{-1}.

A further strategy for improving food security would be the inclusion of grain legumes, such as black-cowpea, intercropped either with maize or in rotation with it. Grain legumes are a valuable source of protein for humans. Furthermore, from an agronomic point of view, there are numerous advantages in the inclusion of legumes in cropping systems. These include reduced insect and disease problems, nitrogen fixation by the legumes, reduced risk of crop failure and possibility increased yield unit area^{-1}.

Keeping in view, the above consideration, the present investigation is to be conducted on "Evaluation of Black-Cowpea (*Vigna unguiculata* L.) as intercrop with Maize (*Zea mays* L.) under Kashmir Valley condition" with the following objectives:

- To study the effect of different row ratio on growth parameters, yield attributes and yields of black-cowpea and maize.
- To evaluate the total productivity of intercropping system.
- To evaluate the relative economic of different row combinations of black-cowpea and maize.

Chapter – 2

REVIEW OF LITERAUTRE

Intercropping system is an ancient practice in Indian agriculture. About 40 years ago, the attention of agricultural scientist turned up towards the intercropping to explore the possibilities of getting higher productivity and net returns from intercrops. In this chapter, therefore, an attempt has been made to review the research information available on cowpea (*Vigna unguiculata* L.) and maize (*Zea mays* L.) intercropping system. It covered the effect of intercropping system on growth, development, yield and yield attributing characters, quality and nutrient uptake by sole and inter crops. Similarly, the economic aspects of cropping systems are also reviewed here.

2.1 Intercropping

Several workers have defined the intercropping in different situations. The importance of intercropping was highlighted by Aiyer (1949). He suggested that the intercropping system may get greater stability in yield, better use of growth resources, better control of weeds, pest and diseases, one crop provided physical support and shelter to the other crop, erosion control and more remunerative to small farmers. Donald (1963) stated that two species of contrasting habits in intercropping system will be able to exploit the total environmental resources more efficiently than monoculture. In Nigeria, intercropping maize with legumes, particularly cowpea, has gone a long way to improve the already limited fertility profile of many farming plots (Agboola and Fayeni, 1972).

The crops may or may not be grown or harvested exactly at the same time, but usually grew together for a significant part of their growing period. Andrews and Kassam (1975) stated that the intercropping should also imply in such a way the crop are grown in separate rows and not grown mixed. When two or more crop are raised as intercrop, the two situations occurs, the intercrop grows better in the presence of another and exceed in yield advantages over the sole crop (Willy, 1975).

Willy (1979) mentioned three different situations under which the advantages of intercropping can be evaluated: i) where intercropping system give full yield of main crop and some yield of second crop; ii) the combined intercrop yield exceed the yield of any of component crop grown separately as a sole crop; and iii) the combined intercrop must exceed a combined sole crop yield. He defined the intercropping as “the growing two or more crops simultaneously in alternate rows or otherwise in the same area, where there is a significant amount of intercrop competition”.

At ICRISAT, measurement of light interception showed that intercropping did not intercept more light energy than sole cropping, but this energy was more efficiently converted into dry matter (Reddy *et al.*, 1980).

Intercropping plays a vital role in improving cropping intensity being an important system of multiple cropping. Maize is Africa’s most important cereal, forming a basic part of the cereal-legume intercropping system common to most developing countries’ agriculture (Ofori and Stern, 1987).

Yield advantage from intercropping as compared to sole cropping are often attributed to mutual complimentary effect of component crops, such as better total use of available resources. Such as monoculture legumes have higher yield compared to an intercropping system. However in most cases land productivity measured by land equivalent ratio (LER) clearly shows the advantage of mixed cropping cereals and legumes (Yunusa, 1989 and Mendal *et al.*, 1990).

Intercropping continues to be a prominent system and probably will remains so far years to come because of various benefits associated with it. So research on intercropping has been spurred recently to understand the validity of the system by ways of possible increase in yield efficient use of solar energy and better land use resulting in higher returns (Dhingra *et al.*, 1991).

Langat *et al.* (2000) commenting on the activities of SACRED AFRICA, and Chabi-Olaye *et al.* (2002) in their separate studies, reported that intercropping maize with legumes is one of the common cropping systems in Africa. In West Africa, cereals such as maize, pearl millet and sorghum are traditionally intercropped with cowpea (Subbarao *et al.*, 2000).

Intercropping is one of the ways to increase the productivity per unit area of land under the supply of limited resources. This system not only provides certain insurance against biotic and abiotic stress but also helps in the maximization of productivity and profit by efficient utilization of natural resources (Thakur *et al.*, 2000).

Maize production, therefore, is of strategic importance for food security and the socio-economic stability of countries and sub regions in sub Saharan Africa, including Nigeria. Maize-legume intercropping is currently receiving global attention because of its prime importance in World Agriculture. According to Sullivan (2003), intercropping offers farmers the opportunity to engage nature's principle of diversity on their farms. It is a system of cultivating a cereal as the primary food crop, but on a legume base. Cereals such as maize, millet and sorghum are often intercropped with usually leguminous crops like beans, cowpea, groundnut, pigeon pea and soybean. In fact, this is the dominant food production system in East Africa. Sole cropping is seldom practiced and cereal/legume rotations are rare. The main advantages of intercropping comprises of planting, managing fertilization, weed control, pest control, and harvesting for both crops and it is normally done manually by small scale farmers.

Cereal-legume intercropping plays an important role in subsistence food production in both undeveloped and developing countries, especially in situations of limited water resources (Tsubo *et al.*, 2005). Mainly those resources such as water, light and nutrients can be utilized more effectively than in the respective sole cropping systems (Li *et al.*, 2006). Yields of Intercropping are often higher than in sole cropping systems (Lithourgidis *et al.*, 2006).

Small holder farms in the tropics, which produce over 60% of the food resources of the developing nations, intercrop cereals with a multitude of crops, and including legumes in these systems is most common and researched due to the synergistic effects, with the objective of diversifying food production and household cash incomes (Rao and Mathuva, 2000 and Kimaro *et al.*, 2009). The production of more food for the growing populations in the coming decades, while combating poverty and hunger at present, is a significant challenge to the developing nations. Thus, intercropping principal food crops (eg. cereals) to intensify resource use is considered a key factor in meeting this challenge, in technologies such as evergreen agriculture which is considered a robust approach to sustainable food security in the developing world (Garrity *et al.*, 2010).

2.2 Growth and growth characters

Plant population and the arrangement of component crops in the intercropping system have profound effect on performance of the system. Various workers have reported the effect of planting pattern on growth as well as on yield of intercrops. Watiki *et al.* (1993) reported that solar radiation is one of the major resources determining growth and yield of component crop when planted simultaneously and together, especially when other resources are not limiting plant growth.

Jayanthi *et al.* (1994) who stated that maize/cowpea 1:1 intercrop gave the highest dry matter yield. Tripathi *et al.* (1997) revealed that under Bhubaneswar conditions, the dry matter of maize increased in maize + cowpea intercropping system and was highest in 2:2 ratio pattern, followed by 1:1 pattern whereas Ofori and Stern (1986) stated that total dry matter accumulation per plant of maize in intercropping was not different from sole cropping in early stages of growth.

Singh *et al.* (2000) observed that intercropping of maize with vegetable pea and lentil increased the dry matter accumulation in maize. Whereas, Shumba *et al.* (1990), Kumwenda *et al.* (1997) and Jeranyama *et al.* (2000) reported that a competitive main crop such as maize may reduce cowpea growth and hence biological nitrogen fixation (BNF) rates in an intercrop that results in the reduction of dry matter yield and N-fixing nodules on the legume crop due to shading.

Jose *et al.* (2000) and Silwana and Lucas (2002) reported that intercropping affects the vegetative growth of component crops compared to sole cropping, and therefore, it applied to optimize the use of spatial, temporal and physical resources above and below ground with maximum positive and minimum negative interaction. Differences in phenological and morphological characteristics of crop species in mixture may lead to an increased capture of growth limiting resources.

Hussain *et al.* (2003) found that maize intercropping with different legume species delayed the period to earing and silking compared to sole cropping. Ghosh (2004) also reported that maximum resource potential in terms of growth could be obtained through use of different legumes with maize. Improper row space has very low resource use, because of inadequate use of inputs and lack of appropriate crop management technology whereas, Tsubo *et al.* (2003) reported that ratio of decrease in dry matter accumulation of intercropping increases throughout the season as compared to sole cropping.

Sunilkumar *et al.* (2005) indicated that intercropping of maize and cowpea in 2:2 row proportion recorded significantly higher green fodder, dry matter and crude protein yield compared to 1:1, 1:2, 1:3, 1:4, 2:1, 3:1, 3:3 and 4:1 row proportion.

Muoneke (2007) reported that the number of nodules and nodule weight were highest when soybean was intercropped with the lowest maize planting density during the early season. These reduced as maize densities increased, probably because of the depressing effect of high population of maize.

Hugar and Palled (2008) reported that significantly taller plants, leaf area, leaf area index and dry matter production were observed with sole maize. The lowest plant height was recorded on 1: 5 maize+ blackgram intercropping followed by 1: 5 maize + French-bean intercropping. Increase in plant height under maize sole treatment was due to the fact that the wider space available in sole maize reduced the competition of light and nutrients, which probably provided favourable physical environment and helped the plant to grow taller. Increase in plant height under sole maize sowing.

Morgado and Willey (2003) while studying the optimum plant population for maize-bean intercropping system in Brazilian condition observed that variation on patterns of dry matter accumulation of intercropped maize due to bean population was marginal, with no consistent tendency after 33 DAS. Dry matter accumulation in all intercropped maize treatments increased with application of N at 30 kg ha^{-1}. Competitive effect of maize at M_1 (20,000 plants ha^{-1}) and M_2 (40,000 plants ha^{-1}) on total dry matter accumulation of intercropped beans was similar in all three-bean populations at two nitrogen fertilizer levels until 43 DAS.

Javanmard *et al.* (2009), worked on intercropping of maize with different legumes, indicated that dry matter yield and crude protein yield of forage were increased by all intercropping compositions as compared with the maize monoculture. Dahmardeh *et al.* (2009) concluded that intercropping of maize and cowpea resulted in more digestible dry matter and crude protein content than maize sole cropping.

Dahmardeh *et al.* (2010) reported that maize-cowpea intercrops produced greater dry matter yield than either species grown alone. The most productive intercrop concerning yield was for a high density of maize and high density of cowpea (100% maize + 100% cowpea).

Choudhary *et al.* (2012) reported that the highest grain numbers mean of two years was recorded in sole maize followed by 1: 1 maize + cowpea and 1: 5 maize + cowpea. However, the lowest mean grain numbers was recorded in 1: 1

maize+ blackgram. The intercropping of blackgram with maize, all the combinations grain numbers were lower than the respective combinations of other intercrops.

A field study conducted at Indian Grassland fodder and Agroforestry Research Institute, Dharwad, revealed that intercropping of maize with cowpea recorded higher green and dry fodder yield compared to other cereal-legume intercropping system (Gangaiah, 2004).

Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize alone (Ghanbari *et al.*, 2010). This yield advantage occurs when the component crops do not compete for the same ecological niches and the inter-specific competition for a given resource is weaker than the intra-specific competition.

2.3 Yield and yield Attributes

Tomar (1976) reported that in India cowpea is generally is grown mixed with jowar, bajra and maize etc. to enhance the grain fodder yield and supplement the nutritive value of non-leguminous fodder. Nair *et al.* (1979) reported that when maize + cowpea, maize + soybean and maize + groundnut were sown in a system, the yields were increased by 34, 27 and 19%, respectively.

Kalra and Gangwar (1980) reported that there was increase in growth attributes like length of cob, girth of cob, seeds per cob and 1000-grain weight of maize when it was intercropped with cowpea.

In maize based intercropping system, decrease in interception of solar radiation from top of maize crop to top of legume intercrop was observed due to shading by maize canopy. This reduced receipt of light energy by legumes reduced the yield of intercrops in maize (Scarle *et al.*, 1981).

Mandal *et al.* (1990) reported higher maize yield due to legume association that with non-legumes. Bhunia *et al.* (1991) reported that the yield components increased in intercropped system that in pure stand of maize. Cardoso *et al.* (1993) reported an increase of 37% in grain yield for the same rate of plant population in a maize-cowpea intercropping under irrigation condition. Grain yield per plant was significantly higher in M_1 (20,000 plants ha^{-1}) than in M_2 (40,000 plants ha^{-1}).

Myaka (1995) found that cowpea grain yield were 75% more when intercropped with maize in alternating double rows than in alternating single rows. Pandita *et al.* (1998) stated that maize + legume intercrops (1:2) produced higher stover yield as compared to sole maize.

In a field study on an experiment field of Maize Research Institute Zemun Poly-Belgrade, Yugoslov, Oljaca *et al.* (2000) observed that intercropping of bean with maize had a great influence on yield components of maize. The component combination of ½ : ½ (maize: bean) was the most effective on all yield components of maize.

Pereirafitho *et al.* (2000) reported that, maize grown in double rows at density of 40,000 or 60,000 plants ha^{-1} with single row of French bean at a density of 40,000 plants ha^{-1} or with French bean sown in the maize rows at 1,20,000 plants ha^{-1} did not indicate any significant variation on maize yield. Where French bean yield decreased when intercropped with double rows of maize, and in single row of maize French bean yield increased.

Yield attributes *viz.*, length, girth of cob, number of grains, weight of grains per cob, 1000 grain weight and the yield of maize were found increased over sole maize in intercropping of maize with vegetable pea and lentil (Singh *et al.*, 2000).

Differences in phenological and morphological characteristics of crop species in mixture may lead to an increased capture of growth limiting resources and leading to greater potential to acquire higher total yields than when crops are grown separately on the same area of land (Rao and Mathuva, 2000; Olufermi *et al.*, 2001 and Dapaah *et al.*, 2003).

At Kalimela, in maize based cropping system it was observed that maize grain yields with Runner bean, cowpea and cluster bean were 2461, 2571 and 2474 kg ha^{-1} respectively under 1:1 ratio and 2633, 2495 and 2439 kg ha^{-1}, respectively under 2:2 ratios, compared to sole maize 2928 kg ha^{-1} (Padhi, 2001). Further, intercropping of maize with runner bean at 2:2 row ratio realized the maximum production efficiency followed by maize with cowpea at 1:1 row ratio.

Patel and Rajagopal (2001) reported that increase in forage yield with maize + cowpea in 5:2 row ratio intercropping was 9.69 and 17.31 percent over the yield of sole maize forage during the two consecutive years, respectively. The grain yield of maize increased to the extent of 2.32 to 7.5 per cent over sole cropping when it was intercropped with grain legumes (soybean, urdbean, cowpea and groundnut). In addition, there was bonus yield from legume component (Rana *et al.*, 2001).

Rana *et al.* (2001) reported higher grain yield of maize in an intercropping system compared to its sole crop. They also observed that intercropped *Phaseolus vulgaris* gave 30-40 per cent of its sole crop yields. Studies have shown that intercropping of cereals and legumes produce higher grain yields than either sole crop Mpairwe *et al.* (2002).

In an intercropping study under temperate climate condition, when maize at a constant plant population was intercropped with three bean plant populations, Morgado and Willey (2003) showed that competitive effect of intercrop beans on maize yields was high at higher plant populations.

Experiment conducted at Indian Agricultural Research Institute, New Delhi revealed that maize and groundnut accumulated significantly more dry matter when grown in 1:1 row ratio (Aravindkumar *et al.*, 2004). Ghosh *et al.* (2004) also reported that high yield potential, yield recovery and land utilization could be obtained through intercropping of different legumes with maize. Improper row space has very low resource use, because of inadequate use of inputs and lack of appropriate crop management technology.

A field study conducted at Indian Grassland fodder and Agroforestry Research Institute, Dharwad, revealed that intercropping of maize with cowpea recorded higher green and dry fodder yield compared to other cereal-legume intercropping system (Gangaiah, 2004).

2.4 Intercropping system studies

There are several of evaluating the intercropping efficiency (Willey 1979), but land equivalent ration is preferred because it is simple, easy to compute and not affected by market values of crops and inputs. LER for intercropping is the sum of land equivalent ratio of the crops. For intercropping to be a viable production system, it must be more profitable than the sole cropping.

Lima and Lopes (1979), in a plant population and spatial arrangement study on maize-bean intercropping, reported that intercropping was more advantageous than sole cropping and the highest Land Equivalent Ratios-LERs were obtained in the spatial arrangement of one row of maize to two or three rows of beans. Balyan and Seth (1989) reported that maize equivalent yield increased significantly with intercropping of cowpea as compared to the sole maize cropping.

A LER greater than 1.0 has been reported with bean maize intercropping (Saban *et al.*, 2007). LER (Land Equivalent Ratio) values were greater than one in all intercropping systems with different planting ratios, which indicated yield advantage of intercropping over sole cropping of maize. Bean (HF 465) LER increased with increases in bean population (Luiz and Willey, 2008). Vesterager *et al.* (2008) found maize and cowpea intercropping is beneficial on nitrogen poor soils.

Maize-cowpea inter-cropping increases the amount of nitrogen, phosphorus and potassium contents compared to mono crop of maize (Dahmardeh *et al.*, 2010).

Intercropping maize with cowpea showed advantages in land use efficiency expressed as LER, when compared with the optimum density of either sole crop (Dahmardeh *et al.*, 2010). The mean LER values were always greater than 1.0. LER ranging from 2.31 to 1.32 in first year and from 2.57 to 1.07 in second years indicated that there were a 131 to 32% in first year and 157 to 7% at second year greater yield advantage over component sole crops. Therefore, intercropping showed an advantage over sole cropping.

2.5 Soil status

Greater total uptake of nutrients and other growth factors by the component crops in the intercropping is the primary cause of obtaining intercropping advantage (Willey, 1979 and Chowdhury and Rosario, 1994).

Horwith (1984), Reddy *et al.* (1994) and Jensen *et al.* (2003) reported that maize and cowpea are often planted together under intercropping and develop root systems that at the same time explore the same soil for resources.

Fatokun *et al.* (2002) reported that cowpea can fix up to 88 kg N/ha and in an effective cowpea-rhizobium symbiosis, more than 155 kg N/ha is fixed which can supply 80-90% of plants total N requirement.

Maize-legumes intercropping system, besides increasing productivity and profitability also improves soil health, conserves soil moisture and increases total out turn (Padhi and Panigrahi, 2006 and Singh *et al.*, 2008).

Inclusion of cowpea in sole or intercrop systems might make extra soil N, P and K available to the following cereal crops such as maize because annual legumes contribute N though biological N fixation and was prepared suitable condition of soil for P and K available. Like the soils with low fertility in these ecological conditions, enough forage yields with high soil fertility were obtained from 100% maize + 100% cowpea intercrop and harvested in doughty stage (Dahmardeh *et al.*, 2010)

2.6 Economic returns:

Kalra and Gangwar (1980) recorded additional return of Rs. 1251 ha^{-1} when cowpea sown in association with maize. Reddy and Reddi (1981) recorded higher returns of 17 per cent higher when cowpea sown in between two rows of maize as compared to sole planting of maize 90 x 20 cm row spacing.

Ogbuehi and Orzolek (1987) have reported that intercropping where land is scarce would always generate a higher gross monetary return per unit area of land compared to sole cropping. Balyan and Seth (1989) reported that an increase in net returns due to maize + cowpea (fodder) intercrop which was due 10 per cent higher as compared to maize sole crop.

Mandal *et al.* (1990) noted that the total and net return from maize + legume intercrop were higher that sole maize. Salunkhe *et al.* (1990) reported that maximum monetary returns ha^{-1} were obtained in intercropping of sorghum and cowpea as compared to other systems.

Ifenkwe and Odurukwe (1990) and Kumar and Yusuf (1991) observed that the highest LER would not always reflect the highest monetary return to the farmer.

Jayanthi *et al.* (1994) who stated that maize-cowpea 1:1 intercrop gave highest crude protein and resulted in the highest net returns. Pandita *et al.* (1998) obtained higher benefit cost ratio (1.87) under maize-French bean association in 2:1 row ratio over sole maize (1.72). Patel and Rajgopal (2001) reported that the highest monetary returns (Rs.11,781 ha^{-1}) can be obtained when maize + cowpea was sown in planting pattern of 5:2 compared to sole maize.

Padhi (2001) observed that intercropping maize with runner-bean recorded higher net returns (Rs.12667 ha^{-1}) at 2:2 row ratio followed by maize + cowpea (Rs.7800 ha^{-1}) at 1:1 row ratio.

At Jhansi, Sunilkumar *et al.* (2005) reported higher benefit: cost ratio (2.21) under maize-cowpea association in 2:2 row ratio over sole maize (1.78).

Chapter – 3

MATERIALS AND METHODS

A field experiment entitled "Evaluation of black cowpea (*Vinga unguiculata* L.) as intercrop with maize (*Zea mays* L.) in Kashmir valley condition" was conducted at the experimental farm of the Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar during *Kharif* 2012. The details of the materials used, experimental procedures followed and techniques applied have been described in this chapter.

3.1 Experimental site

The investigation was conducted at the experimental farm of Division of Agronomy at main Campus of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar which is situated 16 km away from city center that lies between 34^{o} 0.8′ N latitude and 74^{o} 83′ E longitude at an altitude of 1605 meters above the mean sea level. The field was uniform and levelled having good irrigation and drainage facilities.

3.2 Climate

The climate is temperate and continental type characterized by hot summers and severe winters. The average annual precipitation over past twenty-five years is 786 mm (Division of Agronomy, SKUAST-Kashmir) and more than 80 per cent of precipitation is received from western disturbances. The mean monthly meteorological data collected during the growing season is depicted in Appendix-I and presented in Fig. 3.1.

During crop growth period (8^{th} May-25^{th} September) the maximum temperature ranged 21.57 to 32.78 ^{o}C, while minimum ranged between 8.57 ^{o}C to 18.37 ^{o}C with relative humidity of 71.66 to 93.14% maximum and ranged 41.71 to 72.28% in minimum.

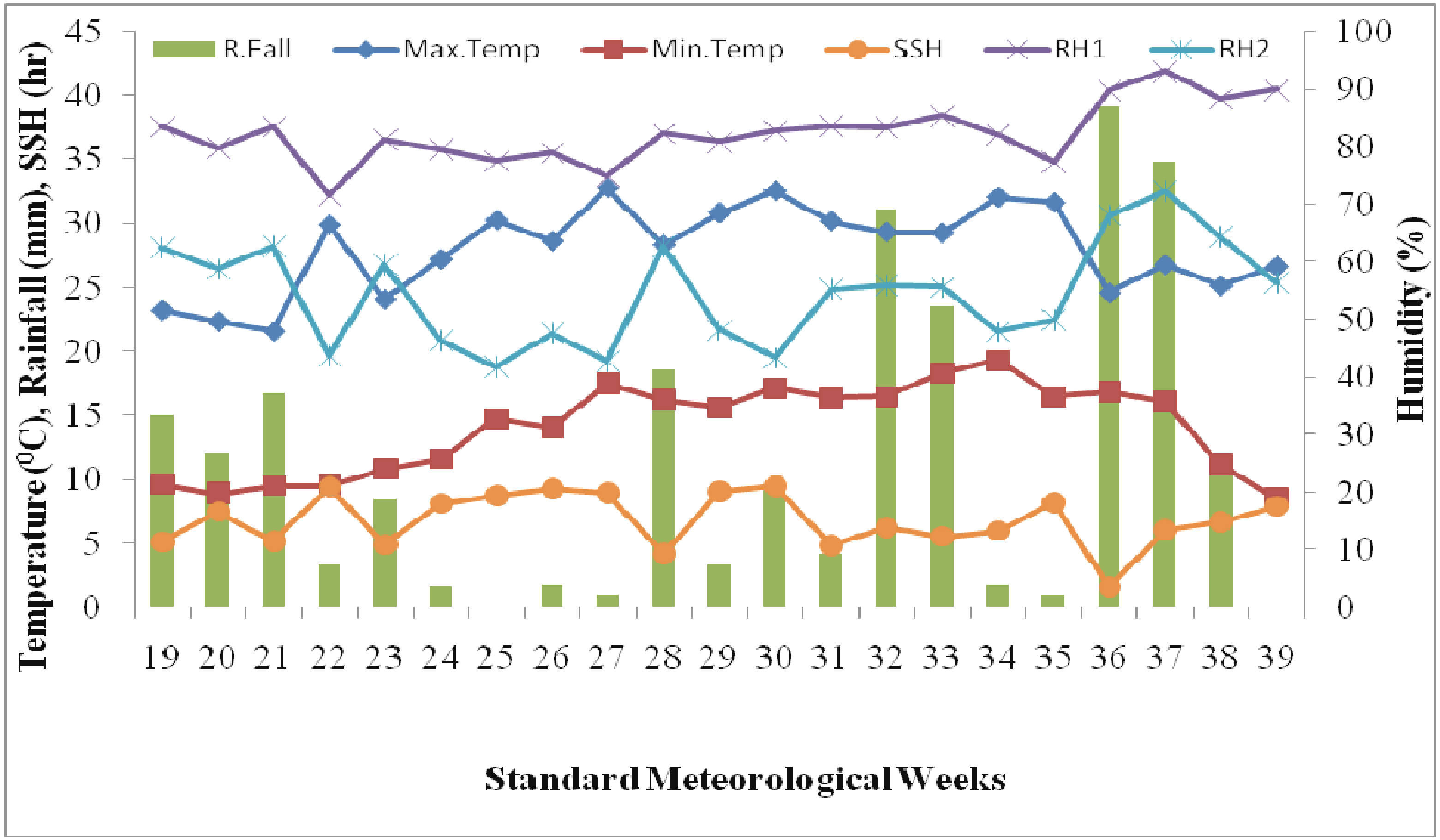


Fig. 3.1 : **Mean weekly weather parameters during the crop growth period 2012**

3.3 Soil characteristics

Prior to the layout of the experiment, soil samples were drawn from 0 to 15 cm depth at five places in the experimental plot at random and a composite sample prepared to determine physico-chemical properties of the soil. The sample was brought to the laboratory, air-dried and crushed to pass through 2.0 mm mesh sieve. The processed sample was subjected to appropriate mechanical and chemical analyses to know its texture as well as initial fertility status. The results, thus, obtained are presented in Table 3.1, which shows that the soil was silty clay loam in texture, neutral in reaction and medium in available organic carbon, nitrogen, phosphorus and potassium.

Table 3.1: Physico-chemical properties of soil of experimental field

Particulars	Initial status	Rating	Methods employed
A) Mechanical composition			
Sand (%)	10.50		International Pipette method (Piper 1966)
Silt (%)	54.20		
Clay (%)	35.30		
Texture class		Silty clay loam	
B) Chemical composition			
Soil pH	6.9	Neutral	1:2.5 soil water suspension using Systronics pH meter (Jackson, 1973)
Electrical conductivity (dSm^{-1})	0.18	Normal	1:25 Soil water suspension with solubridge conductivity meter (Jackson, 1973).
Organic carbon (%)	1.39	Medium	Wet digestion method Walkey and Black’ method (Piper rapid titration method (Piper,1966)
Available nitrogen (kg ha^{-1})	498.62	Medium	Alkali potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	16.21	Medium	Olsen’s method of extraction with 0.5 N, $NaHCO_3$ (Olsen *et al.*, 1954). Using Systronics Spectrophotometer
Available potassium (kg ha^{-1})	127.68	Medium	Flame photometre method Jackson (1967)

3.4 Cropping history of the experimental field

The cropping history of the experimental field was as per Table 3.2.

Table 3.2 : Cropping history of the experimental field

Cropping year	Experimental Field 5	
	Kharif	***Rabi***
2007-08	Maize	Oat
2008-09	Maize	Oat
2009-10	Maize	Oat
2010-11	Maize	Oat
2011-12	Maize	Oat
2012-13	Maize + cowpea (Expt.)	-

3.5 Experimental details

The experiment was laid out with seven methods of maize and cowpea planting in a Randomized Block Design with four replications. The lay out plan of the experimental field is shown in Fig. 3.2. The details of the treatments were as follows:

Treatment details

1. Maize Line sowing (Sole crop) at 60 cm row spacing → T_1
2. Black Cowpea Line sowing (Sole crop) at 30 cm row spacing → T_2
3. Maize Line sowing at 60 cm row spacing + Black Cowpea broadcasted (Farmers' Practice) → T_3
4. Maize + Black Cowpea intercropping (1:1) at 30 cm row spacing → T_4

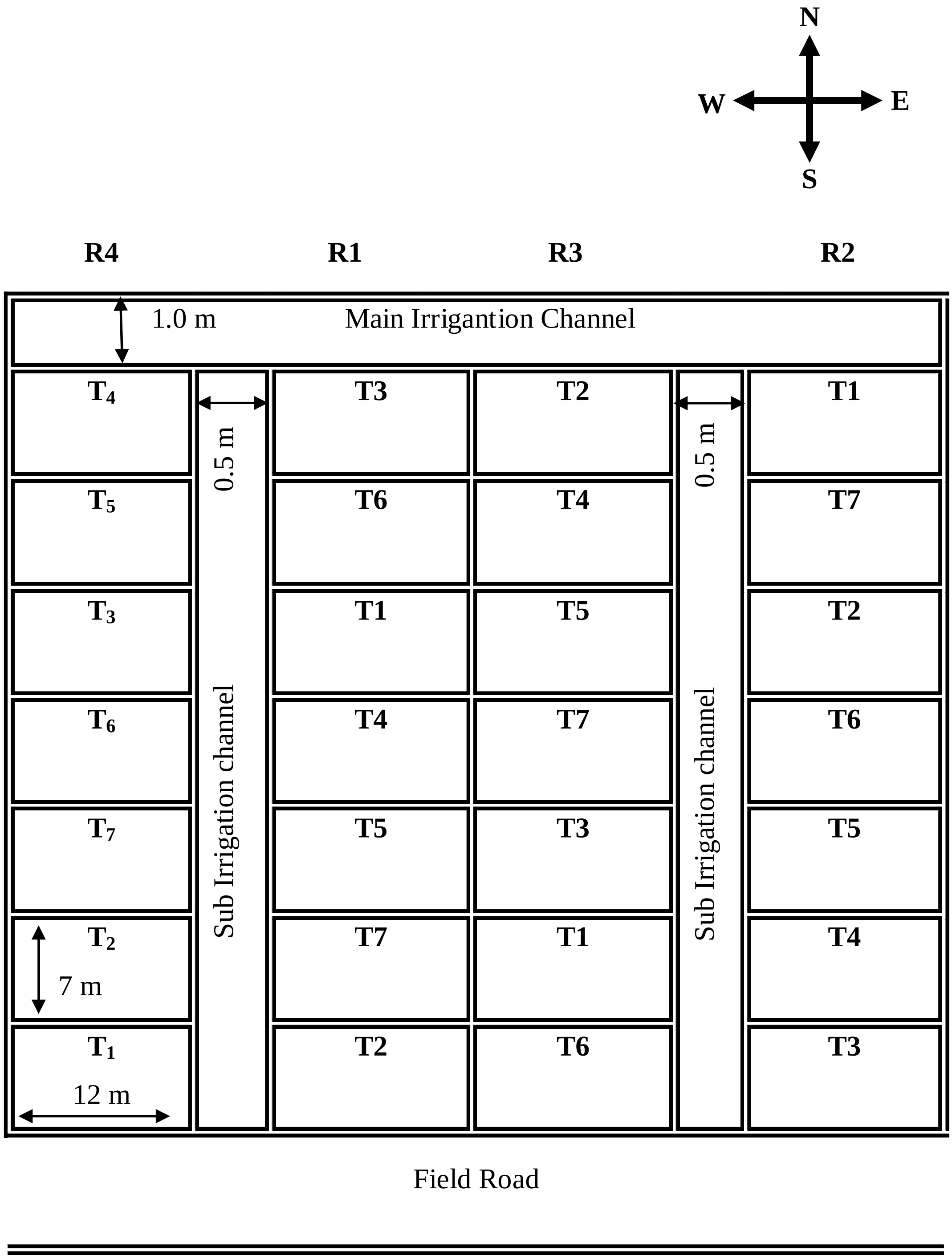


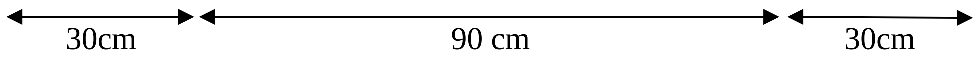
Fig. 3.2 : Lay out of the experimental field

5. Maize + Black Cowpea intercropping (2:1) (Maize as paired row) → T_5

6. Maize + Black Cowpea intercropping (2:2) (Maize as paired row) → T_6

7. Maize + Black Cowpea intercropping (2:3) (Maize as paired row) → T_7

In paired row of maize, two rows were at 30 cm with each other, thus, the distance between two paired rows was 90 cm, and this gap of 90 cm was utilized for black-cowpea in T_5, T_6 and T_7 treatments.



Experimental Details:

Design of experiment	:	Randomized Block Design
No. of replication	:	04
No. of treatment	:	07
Total no. of plots	:	28
Gross plot size	:	$12 \times 7 = 84$ m sq
Net plot size	:	$10 \times 5 = 50$ m sq
Main irrigation channel	:	1.0 m
Sub irrigation channel	:	0.5 m
Width of ridges	:	0.5 m
Season	:	*Kharif* 2012
Plant to plant distance of maize	:	20 cm
Plant to plant distance of cowpea	:	10 cm
Variety- Maize	:	C-6
Variety- Black-Cowpea	:	Shalimar Cowpea-1

3.6 Brief description of the varieties used

3.6.1 Maize : C6

Certified seed of maize variety "C_6" was used in the experiment. This variety was released in 1976 and recommended for areas upto 1850 m amsl. It has vigorous medium tall plants with a height of 175-225 cm and has a tendency to bear two ears per plant. Cobs are long, tapering towards the end with bright orange flint grains. It matures in about 125-130 days in mid-elevations (below 1600 m) and 155-160 days in the valley and 125 to 130 in the mid elevation**.** The variety with bright orange flint grains is resistant to blight and stem borer. Yield potential of this variety is 50-55 q ha^{-1}.

The seed was sown in lines spaced with different row ratios and 20 cm from plant to plant population was maintained through thinning and gap filling.

3.6.2 Black Cowpea: Shalimar cowpea-1

Certified seed of Black cowpea variety "Shalimar cowpea -1" was used in the experiment**.** This variety is recommended for rainfed areas of Kashmir valley and can be grown upto 1600 m amsl. Indeterminate climbing habit, white flower colour in clusters arising from axil, medium maturity of 120-125 days. Seeds are oval shape and black in colour and seed index is 8-9 gram. Average yield is 8-8.5 q ha^{-1}. Seeds contain 26-27% protein.

The seed was sown in lines spaced with different row ratios and 10 cm from plant to plant population was maintained through thinning and gap filling.

3.7 Details of field operations

The schedule of field operations performed during the cropping season was as per Table 3.3.

Table 3.3: Details of the operations

Operation	Date	Remarks
Ploughing	05- 05-2012	Two tilling operations were given
Clod breaking and leveling	06-05-2012	Operations were performed manually
Layout	07-05-2012	Layout was done as per the plan shown in the Fig. 3.2, demarcating the plot by making bunds
Fertilizer application	07-05-2012	NPK and Zn fertilizer were applied as per the packages for maize and cowpea
Seed sowing	08-05-2012	Seeds were sown in rows as per the designated spacings
Insectcide application	08-05-2012	Phorate 10 G was given to the inter field
Herbicide application	23-05-2012	Atrazine 1 kg a.i. ha^{-1} to control the weeds in maize sole
First irrigation	05-6-2012	Each plot was irrigated
Thinning/ gap filling by transplantation	09-06-2012	Plants were transplanted and irrigated with rose-can. Thinning was also done where required
Weeding and hoeing	20-6-2012	The weeding/hoeing was done manually
First top dressing of N	25-6-2012	One-fourth of nitrogen was applied as urea
Second irrigation	03-07-2012	Each plot was irrigated
Second weeding, hoeing and earthling up	10-07-2012	Hoeing and earthling-up was done manually
Second top dressing of N	10-7-2012	Remaining one-fourth of nitrogen was applied as urea
Harvesting of black cowpea	15 -09-2012	Harvesting was done at physiological maturity
Harvesting of maize	25-09-2012	Harvesting was done at physiological maturity

3.7.1 Preparatory tillage

One pre-sowing irrigation was given to the experimental field and thoroughly ploughed once with soil turning plough by tractor. After this, the field was cross harrowed and was then planked with the object to level the field and to obtain the fine tilth. The stubbles of previous crop and weeds were removed from the field. The whole field was divided into four replications; borders, plot path and irrigation channels were made manually as per the layout plan (Fig. 3.2).

3.7.2 Fertilizer application

Fertilizers for maize (120 N, 60 P_2O_5, 30 K_2O and 20 $ZnSO_4$ kg ha^{-1}) and black cowpea (30 N, 60 P_2O_5 and 30 K_2O kg ha^{-1}) were applied according to the plant population of the crops in the intercropping system treatment.

For maize crop, half of the required nitrogen and full doses of phosphorous, potash and $ZnSO_4$ were placed below the seed in opened furrows at sowing time. Remaining nitrogen was top dressed in two equal splits, at first hoeing/weeding corresponding to knee-high stage and second dose corresponding to tasseling stage.

For black-cowpea full dose of nitrogen, phosphorous and potash as per the treatment, placed below the seed in opened furrows at sowing time.

3.7.3 Seed and sowing

Maize (C-6) was intercropped with black cowpea (Shalimar cowpea-1) as per the treatments and the seed were sown @ 20 kg ha^{-1} of maize and @ 40 kg ha^{-1} of black cowpea. Plant-to-plant distance of maize and black-cowpea were maintained at 20 cm and 10 cm, respectively within the rows. The seed of black cowpea was treated with *Rhizobium* culture before sowing.

3.7.4 Hoeing and weeding

Two hoeing and weeding were given, first about 35 days after sowing, and second at 50 days after sowing.

3.7.5 Plant protection measures

Phorate dust (10%) @ 20 kg ha^{-1} was applied at the time of land preparation to protect the crop against cut-worms.

3.7.6 Harvesting and threshing

Harvesting of black cowpea was done manually with the help of sickle when pods of black cowpea matured (when nearly 75%pods had turned brown). The border area was harvested first and removed from experimental plots. Net plot was harvested and sundried and tied up into bundles treatment wise, tagged and taken to the threshing floor. Weight of each plot produce was taken before threshing to record the biological yield. Threshing was done by beating the bundles with sticks. Seeds were separated by winnowing and kept treatment wise in bags.

Maize was harvested after the cobs had turned brownish and grain hardened. The border area was harvested first and removed from experimental plots. Net plot was harvested and sundried and tied up into bundles treatment wise, tagged and taken to the threshing floor. Weight of each plot produce was taken before threshing to record the biological yield. Shelling of the cobs was done and grains were kept in bags treatment wise after weighing.

3.8 Observations recorded

In each plot, five plants each of maize and/ or cowpea were randomly selected from the penultimate rows, tagged and used for recording of various crop characteristics at various stages of growth. The procedure for recording observations regarding growth and development, yield attributes and yield and soil status aspects during the course of investigation are described as under:

3.8.1 Pre-harvest studies on black cowpea

3.8.1.1 Plant stand (only at 30 DAS and at maturity)

Initial and final plant stand were recorded at 30 DAS and at maturity in all the plots from net plot area and calculated on the per m^{-2} basis.

3.8.1.2 Dry matter accumulation at 30 days interval

Five plants of black cowpea were sampled from the row earmarked for sampling. These plants were cut just above the ground surface. The sampled plants cut into the small pieces and sun dried. After drying, the samples were kept into oven and dried at 65^0 C for 24 to 48 hours till the weight was constant. The same samples were weighed and expressed as dry weight in g $plant^{-1}$.

3.8.1.3 Days to different phenological stages

Dates were recorded for different phenological stages of black cowpea and days were calculated from date of sowing.

3.8.1.4 Number of nodules $plant^{-1}$ at flowering stage

Number of nodules of black cowpea crop was counted on the roots of five sampled plants at flowering stage of crop and average number of nodules $plant^{-1}$ was worked out.

The plants were randomly uprooted along with soil with the help of *Khurpi* carefully. Covering the major root mass, uprooted plants were put on sieve and washed in running tap water to remove the soil particles adhered to it. Then the nodules were removed by forceps and blotted dry with the help of ordinary filter paper and counted and mean value was expressed as number of nodules $plant^{-1}$.

3.8.1.5 Fresh weight of nodules $plant^{-1}$ at flowering stage

Nodules from five plants of black cowpea were collected and fresh weight of nodules was recorded and average value reported on $plant^{-1}$ basis in gram.

3.8.2 Post-harvest studies on black cowpea

3.8.2.1 Number of pods $plant^{-1}$

Total number of pods on the five tagged plants were recorded and average number of pods plant^{-1} was calculated by dividing with number of plants and expressed in plant^{-1} basis.

3.8.2.2 Number of seeds pods^{-1}

Number of grains was recorded from 10 representative pods taken from tagged plants. The average value was calculated by dividing with 10 to express the number of seeds pod^{-1}.

3.8.2.3 100-grain weight (g)

A representative sample of 100 grains of black cowpea, irrespective of shape and size, was taken from the grains of five tagged plant and weight was recorded with the help of digital balance and expressed in grams.

3.8.2.4 Biological yield (q ha^{-1})

The black cowpea experimental plots meant for grain purpose were cut at physiological maturity and after sun drying, bundle weight of each net plot was recorded in kg as biological yield and expressed as q ha$^{-1.}$

3.8.2.5 Grain yield (q ha^{-1})

Seeds of black cowpea collected from each treatment weighed after threshing and cleaning and expressed as grain yield in q ha^{-1}.

3.8.2.6 Straw yield (q ha^{-1})

Straw yield was calculated simply by deducting grain yield from the biological yield and expressed in q ha^{-1}.

3.8.2.7 Harvest index (%)

The economic (grain) yield of black cowpea was divided by their biological yield (total produce) and its relationship expressed in percentage. It was calculated by the formula given below.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.8.3 Pre-harvest studies on maize

3.8.3.1 Plant stand (only at 30 DAS and at maturity)

Initial and final plant stand were recorded at 30 DAS and at maturity in all the plots from net plot area and calculated on the m^{-2} basis.

3.8.3.2 Plant height at different phenological stages (cm)

Plant height of randomly selected plants were recorded from ground-level to base of fully opened top leaf at knee-high, tasseling, silking and maturity stages of maize. The mean values were expressed in cm.

3.8.3.3 Dry matter accumulation at 30 days interval

Five plants of maize were sampled from the row earmarked for sampling. These plants were cut just above the ground surface. The sampled plants cut into the small pieces and sun dried. After drying, the samples were kept into oven and dried at 65 ^{o}C for 24 to 48 hours till the weight was constant. The same samples were weighed and expressed as dry weight in g $plant^{-1}$.

3.8.3.4 Days to different phenological stages

Dates were recorded for different phenological stages of maize and days were calculated from date of sowing.

3.8.4 Post-harvest studies on maize

3.8.4.1 No. of cobs $plant^{-1}$

Total numbers of cobs present on five randomly selected maize plants were counted and average calculated for each plant.

3.8.4.2 Grain weight cob^{-1} (g)

Grain of maize collected from randomly selected five cobs as per treatments, weighed after threshing and cleaning. Then the average was worked out and expressed as grain weight cob^{-1} (g).

3.8.4.3 100-seed weight (g)

A representative sample of 100 grains of maize, irrespective of shape and size, was taken from the grains of five tagged plant and its weight was recorded with the help of digital balance and expressed in grams.

3.8.4.4 Biological yield (q ha^{-1})

After harvesting the crop treatment-wise, the produce was sun-dried and kept in bundles. Bundle weight of each net-plot was recorded in kg plot^{-1} and expressed in q ha^{-1}.

3.8.4.5 Grain yield (q ha^{-1})

The produce collected from each plot was weighed after threshing and cleaning. Grain yield was recorded in kg plot^{-1} and then converted to q ha^{-1} at 15 per cent moisture basis.

3.8.4.6 Stover yield (q ha^{-1})

Stover yield was calculated for each treatment by deducing grain yield from biological yield and expressed in q ha^{-1}.

3.8.4.7 Harvest index (%)

The economic (grain) yield of maize was divided by their biological yield (total produce) and its relationship expressed in percentage. It was calculated by the formula given below :

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.9 Maize + Cowpea Intercropping studies

3.9.1 Maize equivalent yield (q ha^{-1})

The economical values of maize and cowpea as being different, the yields of the two were not comparable. As such, yield of cowpea was converted into equivalent yield of maize. A factor was calculated on the basis of relative values of maize @ Rs 8000.00 q^{-1} and cowpea @ Rs. 2500.00 q^{-1} and the grain yield of each pulse from both sole as well as inter- cropped stands was converted into maize equivalent yield. It was then added to yield of each treatment of corresponding maize of both sole and inter-cropped stands. The maize equivalent yield (MEY) was calculated by using the formula:

$$MEY = \frac{Yc}{Pm} \times Pc + Ym$$

Where,

Yc = Yield of black cowpea as intercrop

Ym = Yield of maize (of the same treatment)

Pc = Price of black cowpea

Pm = Price of maize

3.9.2 Land equivalent ratio (LER)

Land equivalent ratio (LER) was worked out as per procedure given below to find out the economics of individual intercropping system.

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where,

Yab = Yield of maize in association with black cowpea

Yba = Yield of black cowpea in association with maize

Yaa = Yield of sole maize

Ybb = Yield of sole black cowpea

If value of LER is > 1, then intercropping is considered to be advantageous, if LER is < 1, then intercropping is disadvantageous and if LER is = 1, then it indicates no profit, no loss from the intercropping.

3.9.3 Area time equivalency ratio (ATER)

It is the ratio of number of hectare-days required in monoculture to the number of hectare-days used in intercropping to produce identical quantities of each of the component crop.

$$ATER = \frac{(L_a \times D_a) + (L_b \times D_b)}{\text{Total duration of intercropping system in days}}$$

Where,

$$L_a = \frac{\text{Grain yield of intercrop maize}}{\text{Grain yield of intercrop maize in full cropping}}$$

D_a = Duration of crop maize

$$L_b = \frac{\text{Grain yield of intercrop black cowpea}}{\text{Grain yield of intercrop black cowpea in full cropping}}$$

D_b = Duration of crop black cowpea

3.9.4 Relative crowding coefficient (RCC)

Relative crowding coefficient (K) which measures the dominance of one species over the other in a mixture (Banik *et al.*, 2006). Relative crowding coefficient (RCC) was calculated as:

$$RCC = K_{maize} \text{ X } K_{cowpea},$$

Where,

K_{maize} = Ymc x Zcm / (Ym-Ymc) x Zmc and

K_{cowpea} = Ycm x Zmc / (Yc-Ycm) x Zcm

Where, Ym = yield of maize

Yc = yield of black cowpea

Ymc = yield of maize as intercrops

Ycm = yield of black cowpea as intercrops

And, Zmc and Zcm were proportions of maize and cowpea in the intercrops, respectively. When the value of K is greater than 1, there is a yield advantage; when K is equal to 1, there is no yield advantage; and, when it is less than 1.00, there is a disadvantage.

3.9.5 Production efficiency (kg day^{-1})

Production efficiency (PE) was worked out as per procedure given below to find out the economics of individual intercropping system.

$$PE = \frac{\text{Equivalent yield (kg)}}{\text{Duration (days)}}$$

3.9.6 Aggressivity (A)

The third index was aggressivity (A) which is often used to determine the competitive relationship between 2 crops used in the mixed cropping (Willey, 1979). The aggressivity was formulated (Dhima *et al.*, 2007) as follows:

Alegume = (Ylm/Yl × Zlm)-(Yml/Ym × Zml), and

Acereal = (Yml/Ym × Zml)-(Ylm/Yl × Zlm)

For cereal example; if Acereal = 0, both crops are equally competitive,

if Acereal is positive, then the cereal species is dominant,

if Acereal is negative, then the cereal is weak.

3.10 Economics studies

3.10.1 Cost of cultivation

Cost of cultivation of the cropping system was calculated on the basis of prevailing local charges for different inputs like labourers, implements, seeds, fertilizers and other chemicals used in cultivation of crops under different treatments (Appendix- XIV and XV).

3.10.2 Gross return

The grain and stover yield of both maize and cowpea was converted into gross return (Rs. ha^{-1}) on the basis of prevailing local market prices of produce.

3.10.3 Net return

The net return of each treatment was calculated by deducting the cost of cultivation from the gross return of individual treatments.

3.10.4 Net return per rupee invested

Net return per rupee invested (benefit: cost ratio) was calculated as follows:

$$\text{Net returns per rupee invested} = \frac{\text{Net Returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.11 Statistical analysis

All the final data obtained during the course of investing were analyzed statically by applying the analysis of variance technique using NE Software package. The Statistical analysis for black cowpea and maize observation was done separately using six treatments in randomized block design (Ansari *et al.,* 2012 and Yadav *et al.,* 2013). The treatment differences were tested by F test of significance on the basis of hypothesis (Cochran and Cox, 1966). The result of the analysis of variance are given in the Appendices- IV to XIII.

3.11.1 Critical difference

The critical difference at five percent level of probability was worked out to compare the treatment in those cases where the F test was significant.

$$S\,Ed = S\,Em \pm \times \sqrt{2}$$

C.D. (P=0.05) = S Ed x t (0.05) at error degree of freedom.

Chapter – 4

EXPERIMENTAL FINDINGS

Results obtained from the experiment to elucidate the effect of planting pattern in black cowpea and maize intercropping system have been reported in this chapter as follows :

4.1 Black cowpea

4.1.1 Pre-harvest studies

4.1.1.1 Plant stand (m^{-2}) (Initial and at maturity)

Perusal of data presented in Table-4.1 revealed that variation in initial (at 30 DAS) and final plant population at maturity of black cowpea due to different planting patterns were significant during course of study.

Significantly higher initial plant population (32.75 m^{-2}) was recorded with sole cropping of black cowpea than that of all the other planting patterns. Among the intercropping systems, intercropping of maize with black cowpea in 2:3 row ratio recorded maximum plant population (23.22 m^{-2}) and was significantly higher than rest of the treatments.

However, minimum initial plant population of black cowpea (9.35 m^{-2}) was recorded with 2:1 row ratio of maize + black cowpea intercropping patterns.

The highest plant population of black cowpea (30.35 m^{-2}) at maturity was recorded with sole black cowpea and it was significantly higher than all other treatments. Among different intercropping systems, 2:3 row ratio of maize + black cowpea recorded highest plant population (20.80 m^{-2}) at maturity of black cowpea, which was significantly higher than rest of the treatments. Similar to initial plant population, 2:1 row ratio of maize + black cowpea intercropping pattern recorded lowest plant population of black cowpea (8.60 m^{-2}) at maturity.

Table 4.1: Effect of various planting patterns on plant population (m^{-2}) of black cowpea

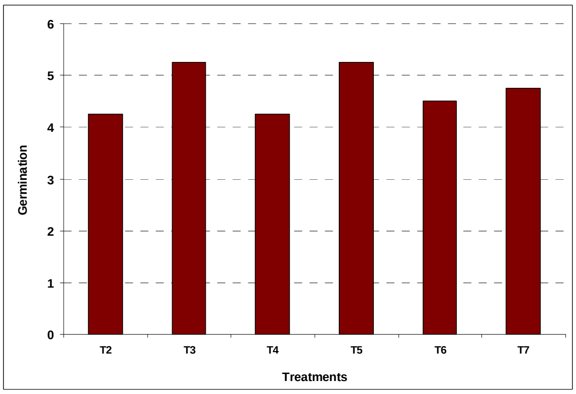
Treatment	Initial (30 DAS)	Maturity
Maize sole	-	-
Black Cowpea sole	32.75	30.35
Maize + Black Cowpea (Broadcast)	15.43	13.75
Maize + Black Cowpea (1:1)	16.30	14.80
Maize + Black Cowpea (2:1)	9.35	8.60
Maize + Black Cowpea (2:2)	16.50	14.90
Maize + Black Cowpea (2:3)	23.22	20.80
S.E(m)±	0.34	0.33
C.D.(P=0.05)	1.02	0.99

4.1.1.2 Days to different phenological stages of black cowpea

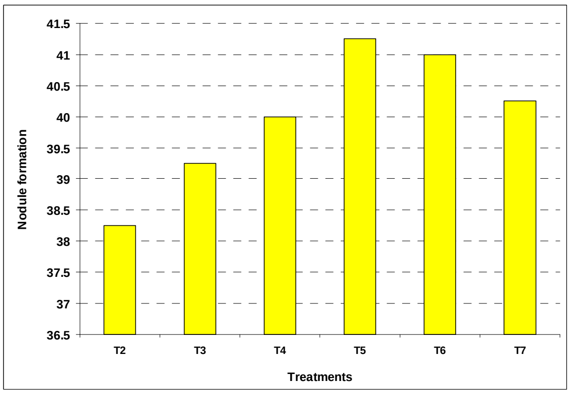
4.1.1.2.1 Days taken to germination

Number of days taken to germination could not be affected significantly due to various plant patterns have been presented in Appendix-II (Fig. 4.1a)

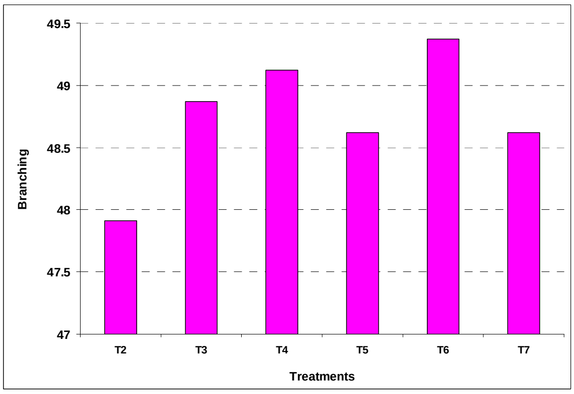
However, lesser number of days taken to germination of black cowpea were recorded under black cowpea sole (4.25 days) as compared to other planting patterns. Though, equal number of days to germination were observed in sole planting of black cowpea and intercropping of maize with black cowpea in 1:1 row ratio. Higher number of days taken to germination of black cowpea were recorded under 2:1 row ratio and broadcasted black cowpea with line sown maize.



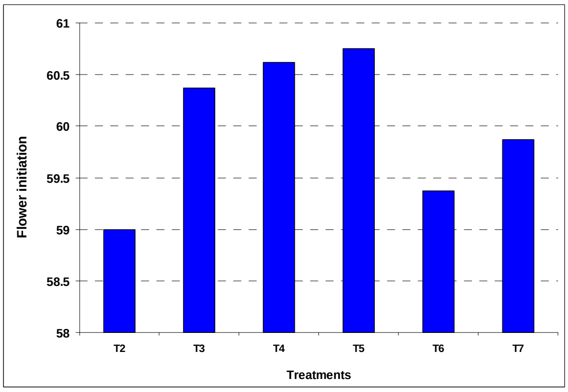
a) Germination



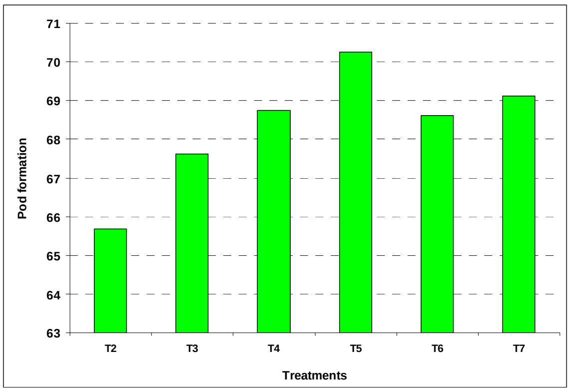
b) Nodule formation



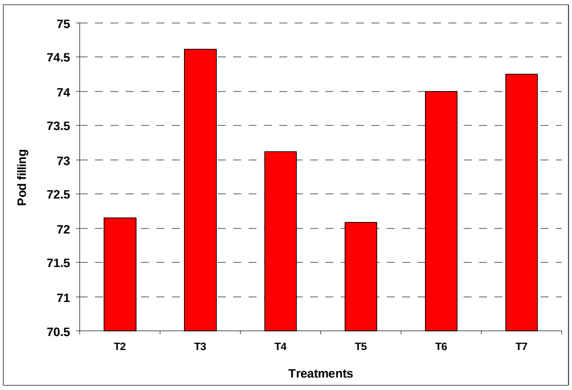
c) Branching



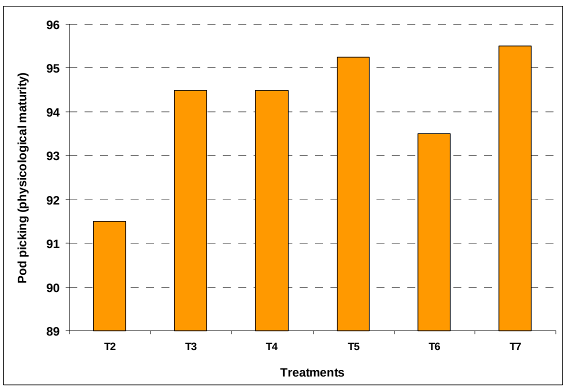
d) Flower initiation



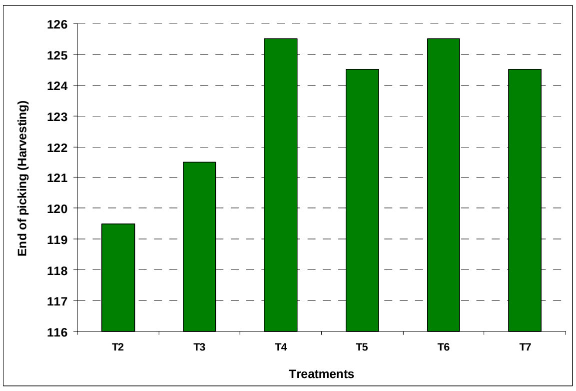
e) Pod formation



f) Pod filling



g) Pod pickling (Physiological maturity)



h) End of picking (Harvesting)

Fig. 4.1 : Effect of various planting patterns on days to different phenological stages of black cowpea

T_1 = Maize sole; T_2 = Black Cowpea sole; T_3 = Maize + Black Cowpea (Broadcast); T_4 = Maize + Black Cowpea (1:1); T_5 = Maize + Black Cowpea (2:1); T_6 = Maize + Black Cowpea (2:2); T_7 = Maize + Black Cowpea (2:3)

4.1.1.2.2 Days taken to start to nodule formation

Number of days taken to start of nodule formation in black cowpea statistically remained unaffected due to different planting patterns and presented in Table-4.2. However, planting of black cowpea as sole crop showed early start of nodule formation and taken 38.25 days to this activity as compared to different intercropping patterns of maize and black cowpea. Higher number of days (41-25) to nodulation were recorded with 2:1 row ratio of maize + black cowpea (Fig. 4.1b).

4.1.1.2.3 Days taken to start of branching

Number of days taken to start of branching of black cowpea could not be affected significantly due to various planting patterns have been presented in Appendix-II (Fig. 4.1c).

However, lesser number of days (47.91) taken to start of branching were recorded under black cowpea sole as compared to other planting patterns during experimentation. Where as, higher number of days (49.37) taken to branching with 2:2 row ratio of maize + black cowpea intercropping pattern.

4.1.1.2.4 Days taken to start of flowering

Data pertaining to days taken to start of flowering of black cowpea as influenced by different intercropping patterns have been presented in Appendix-II (Fig. 4.1d).

Perusal of data revealed that differences in days taken to start of flowering due to different intercropping systems were significant during course of study. However, lesser number (59.00) of days taken to start of flowering was observed under sole cropping of black cowpea and remained at par with 2:2 (59.37) and 2:3 (59.87) row ratio of maize + black cowpea intercropping system as compared to rest of the treatments. Delayed flowering of black cowpea was observed with 2:1 (60.75) row ratio of maize + black cowpea intercropping pattern.

4.1.1.2.5 Days taken to start of pod formation

Number of days required to start of pod formation in black cowpea were significantly influenced by various planting patterns have been presented in Appendix-II (Fig. 4.1e).

Significantly lesser number of days (65.67) taken to start of pod formation was observed under sole cropping of black cowpea. Which found statistically at par to broadcasting of black cowpea in line sown maize (67.62 days) as compared other planting patterns of intercropping of maize with black cowpea. Similar to flowering, the delayed pod formation of black cowpea was observed with 2:1 row ratio of maize + black cowpea intercropping pattern.

4.1.1.2.6 Days taken to start of pod filling

Number of days taken to start of pod filling in black cowpea could not be affected significantly due to various planting patterns during experimentation have been presented in Appendix-II (Fig. 4.1f).

However, lesser number of days (72.15) taken to start of pod filling in black cowpea were recorded under sole cropping of black cowpea as compared to other planting patterns. Among different intercropping systems, the number of days required to start of pod filling were lesser (72.08) in 2:1 row ratio of maize + black cowpea intercropping systems than that of rest of the treatments. Where as higher number of days (74.25) were observed in 2:3 row ratio of maize + black cowpea.

4.1.1.2.7 Days taken to start of pod picking physiological maturity

Number of days taken to physiological maturity or start of pod picking due to different intercropping patterns were found significant and presented in have been presented in Appendix-II (Fig. 4.1g).

Statistically lesser number of days (91.50) taken to physiological maturity or start of pod picking was observed under sole cropping of black cowpea as compared to rest of the treatments. Among different intercropping systems, 2:2 row ratio of intercropping of maize + black cowpea recorded lesser number of days taken (93.50) to physiological maturity or start of pod picking as compared to other intercropping systems. Maximum number of days (95.50) to physiological maturity were observed in 2:3 row ratio of maize + black cowpea intercropping pattern.

4.1.1.2.8 Days taken to end of pod picking or harvesting

Data pertaining to days taken to harvesting or end of pod picking in black cowpea as influenced by different intercropping patterns have been presented in Appendix-II (Fig. 4.1h).

Perusal of data revealed that differences in days taken to end of pod picking due to different treatments were significant during course of study. However significantly lesser number of days taken to end of pod picking were observed under sole cropping of black cowpea (119.5 days) as compared to other planting patterns. Among different planting patterns, 2:2 row ratio of maize + black cowpea recorded lesser number of days taken to end of pod picking (121.50 days) as compared to other planting patterns. Whereas, the number of days taken to maturity (end of pod picking) was maximum (125.50 days) with 2:1 row ratio of maize + black cowpea intercropping and when black cowpea intercropping and when black cowpea broadcasted in line sown maize.

4.1.1.3 Nodule studies

4.1.1.3.1 No. of nodules plant^{-1} at flowering stage

Data pertaining to overage number of nodules plant^{-1} of black cowpea intercropped with maize as influenced by different planting patterns have been presented in Table 4.2 (Fig. 4.2).

The number of nodules plant^{-1}of black cowpea was significantly influenced by different planting patterns during course of study. The maximum number of nodules plant^{-1} (18.27) of black cowpea observed in sole black cowpea, was statistically at par with 2:2 row ratio and significantly higher than all other treatments. Lowest number of nodules plant^{-1} (12.35) of black cowpea was observed in maize + black cowpea (Broadcast).

4.1.1.3.2 Fresh weight of nodules plant^{-1} at flowering stage

Perusal of data revealed that different planting patterns including sole cropping significantly influenced the fresh weight of nodules plant^{-1} at flowering stage of black cowpea during experimentation have been presented in Table 4.2 (Fig. 4.2). Sole cropping of black cowpea accumulated higher amount of fresh weight (0.235 g) of nodules plant^{-1} at flowering stage of the crop. Lowest fresh weight of nodules plant^{-1} (0.159 g) was observed in maize + black cowpea (Broadcast).

Table 4.2: Number and fresh weight (g) of nodules plant^{-1} as influenced by various planting patterns at flowering stage of black cowpea

Treatment	Number	Fresh weight (g)
Maize sole	-	-
Black Cowpea sole	18.27	0.235
Maize + Black Cowpea (Broadcast)	12.35	0.159
Maize + Black Cowpea (1:1)	13.31	0.171
Maize + Black Cowpea (2:1)	14.21	0.183
Maize + Black Cowpea (2:2)	16.24	0.209
Maize + Black Cowpea (2:3)	15.32	0.197
S.E(m)±	0.04	0.0007
C.D.(P=0.05)	0.14	0.00019

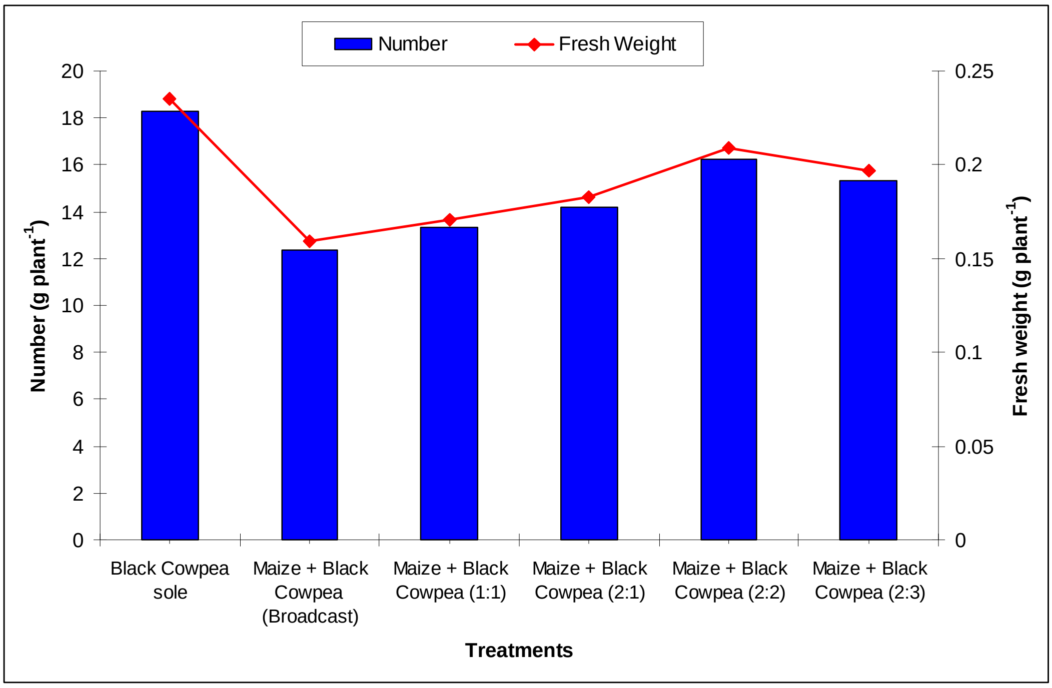


Fig. 4.2 : Number and fresh weight (g) of nodules plant^{-1} as influenced by various planting patterns at flowering stage of black cowpea

4.1.1.4 Dry matter accumulation (g plant^{-1}) at 30 days interval

Perusal of data revealed that various planting pattern including sole cropping significantly influenced the total dry matter accumulation in plant at all the stages of crop growth of black cowpea except 30 days after sowing. Total dry matter accumulation plant^{-1} increased with the advancement of crop age and reached maximum at harvest (120 days) during course of investigation have been presented in Table 4.3 (Fig. 4.3).

Sole cropping of black cowpea accumulated significantly higher dry matter except 30 days after sowing. At 30 DAS, dry matter accumulation of black cowpea could not effected significantly due to various planting patterns.

Significantly highest dry matter accumulation of black cowpea recorded under sole cropping of black cowpea recorded i.e., 2.95, 9.00 and 11.37 g plant^{-1} at 60, 90, and 120, DAS, respectively as compared to rest of the intercropping patterns.

Table 4.3 : Effect of various planting patterns on dry matter accumulation of black cowpea

Treatment	Dry matter accumulation (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	120 DAS (At harvest)
Maize sole	-	-	-	-
Black Cowpea sole	0.28	2.95	9.00	11.37
Maize + Black Cowpea (Broadcast)	0.29	1.85	4.88	7.30
Maize + Black Cowpea (1:1)	0.20	1.75	6.05	9.28
Maize + Black Cowpea (2:1)	0.22	2.33	7.86	10.69
Maize + Black Cowpea (2:2)	0.31	1.97	7.40	10.36
Maize + Black Cowpea (2:3)	0.27	1.76	6.20	9.30
S.E(m)±	0.04	0.18	0.16	0.12
CD at 5 %	NS	0.54	0.50	0.37

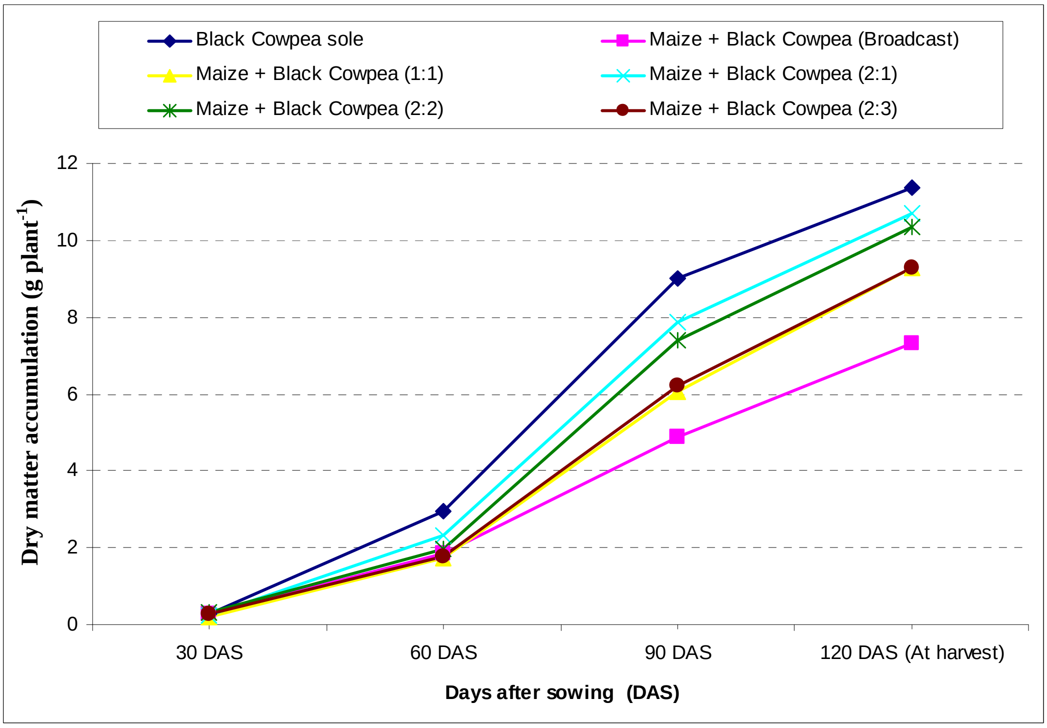


Fig. 4.3 : Effect of various planting patterns on dry matter accumulation (g plant^{-1}) of black cowpea

Among different intercropping patterns 2:1 row ratio of maize + black cowpea intercropping recorded maximum dry matter accumulation remained at par with 2:2 row ratio and was significantly higher than all other intercropping patterns at 60,40, and 120 days after sowing. The lowest dry matter accumulation at maturity was recorded when black cowpea broadcasted in line sown maize.

4.1.2 Post-harvest studies

4.1.2.1 Number of pods plant^{-1}

Number of pods plant^{-1} of black cowpea affected significantly due to various planting patterns of maize + black cowpea intercropping Table-4.4.

However, more number of pods (14.74) per plant of black cowpea was recorded under sole black cowpea as compared to other planting patterns during course of study. Where as, lowest number of pods (11.50) plants^{-1}of black cowpea were recorded with (1:1) row ratio.

4.1.2.2 Number of seeds pod^{-1}

Number of seeds pod^{-1} of black cowpea differed significantly under sole cropping and row ratios during the experimentation Table-4.4.

Table 4.4: Yield attributes of black cowpea as influenced by various planting patterns

Treatment	Pods plant^{-1}	Seeds pod^{-1}	100-grain weight (g)
Maize sole	-	-	-
Black Cowpea sole	14.74	12.00	8.75
Maize + Black Cowpea (Broadcast)	12.12	11.00	7.76
Maize + Black Cowpea (1:1)	11.50	10.25	8.32
Maize + Black Cowpea(2:1)	12.75	10.00	8.47
Maize + Black Cowpea(2:2)	12.50	10.25	8.32
Maize + Black Cowpea(2:3)	12.25	10.00	8.47
S.E(m)±	0.71	0.49	0.04
C.D.(P=0.05)	NS	1.29	0.14

Sole black cowpea had highest number of pods (12.00) which was significantly higher than that of all the planting patterns of maize + black cow pea except broadcasting of black cowpea with maize line sowing. However, the lowest number of grains pod^{-1} of black cowpea was recorded with 2:1 row ratio of maize + black cowpea (10.00), at par with all intercropping patterns of maize + black cowpea.

4.1.2.3 100-grain weight (g)

Data pertaining to the 100-grain weight of black cowpea as influenced by various intercropping patterns are presented in Table-4.4.

Different planting patterns of intercropping had significant differences in 100-grain weight of black cowpea. Significantly higher 100-grain weight (8.75 g) of black cowpea was recorded with sole black cowpea that of all the other planting patterns. Among the intercropping systems, intercropping of black cowpea with maize in 2:1 and 2:3 row ratios recorded equal (8.47 g) 100-grain weight as compared to other planting patterns. Significantly, lowest 100-grain weight of black cowpea (7.76 g) was recorded when black cowpea broadcasted in line sown maize.

4.1.2.4 Grain yield (q ha^{-1})

Data relating to grain yield of black cowpea as influenced by different intercropping patterns and sole cropping are presented in Table-4.5 (Fig. 4.4).

Sole cropping and various intercropping patterns brought significant differences in grain yield of black cowpea. Significantly higher grain yield (9.27 q ha^{-1}) was recorded under sole black cowpea over rest of the treatments during the year of experimentation.

Among different intercropping patterns of maize + black cowpea, 2:2 row ratio recorded significantly higher grain yield (5.50 q ha^{-1}) than that of rest intercropping patterns. Lowest grain yield (3.18 q ha^{-1}) of black cowpea was recorded with 2:1 row ratio of maize + black cowpea.

Table 4.5: Yields and harvest index of black cowpea as influenced by various planting patterns

Treatment	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Maize sole	-	-	-	-
Black Cowpea sole	9.27	18.41	27.69	33.49
Maize + Black Cowpea (Broadcast)	3.35	7.38	10.73	31.22
Maize + Black Cowpea (1:1)	4.13	9.13	13.27	31.33
Maize + Black Cowpea (2:1)	3.18	7.26	11.07	30.47
Maize + Black Cowpea (2:2)	5.50	11.16	16.66	33.12
Maize + Black Cowpea (2:3)	4.36	9.36	13.32	32.05
S.E(m)±	0.06	0.07	0.23	0.37
C.D.(P=0.05)	0.17	0.21	0.69	1.12

4.1.2.5 Stover yield (q ha^{-1})

Data pertaining to effect of planting patters on Stover yield of black cowpea under maize intercropping are presented in Table-4.5 (Fig. 4.4).

Different treatments brought significant differences in stover yield of black cowpea significantly. The highest stover yield (18.41 q ha^{-1}) was recorded under sole black cowpea as compared to rest of the treatments. Among various intercropping patterns, 2:2 row ratio of maize + black cowpea recorded significantly highest stover yield (11.16 q ha^{-1}) than that of all intercropping patterns. The lowest stover yield (7.26 q ha^{-1}) was recorded with 2:1 row ratio of maize + black cowpea intercropping.

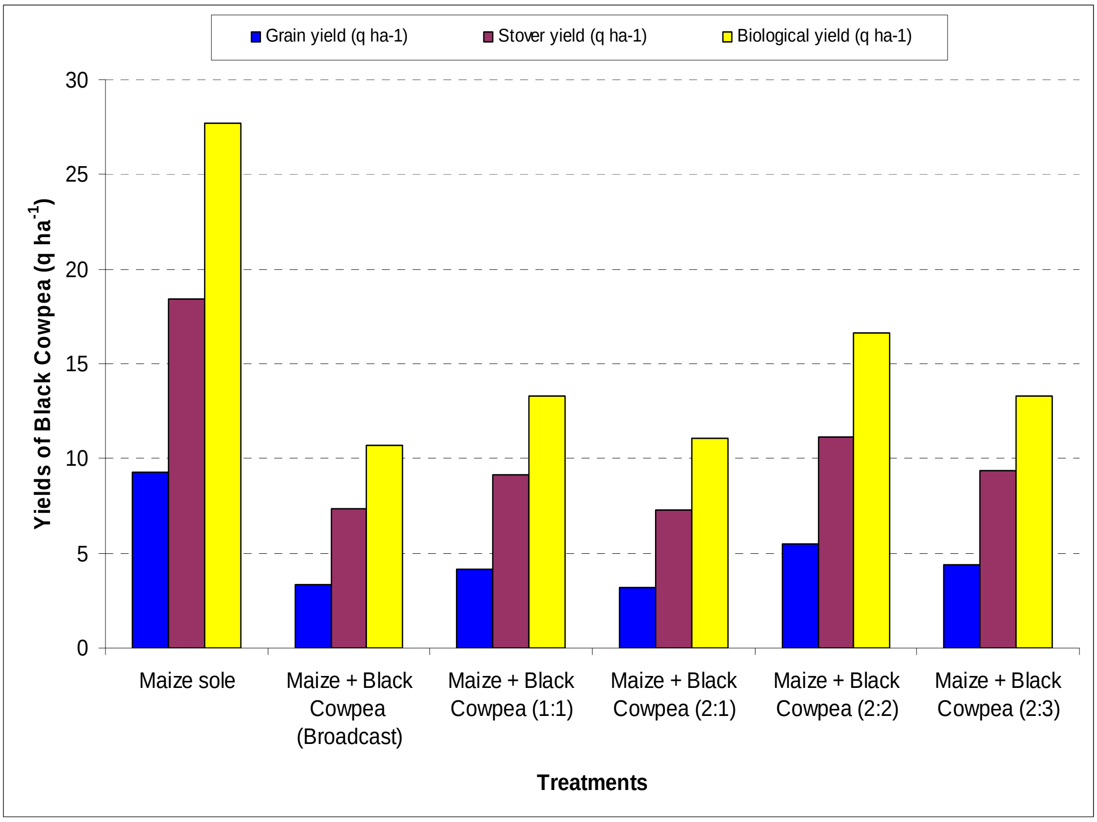


Fig. 4.4 : Yields of black cowpea as influenced by various planting patterns

4.1.2.6 Biological yield (q ha^{-1})

Data representing the effect of intercropping systems of maize + black cowpea on the biological yield of black cowpea are presented in Table-4.5 (Fig. 4.4).

Significant differences were recorded by the various treatments of intercropping patterns and sole cropping during course of study.

Sole black cowpea recorded significantly higher biological yield (27.69 q ha^{-1}) than all the other intercropping patterns. Among the intercropping patterns, 2:2 row ratio of maize + black cowpea recorded the significantly higher biological yield (16.66 q ha^{-1}) than all other intercropping treatments. However, the lowest biological yield (10.73 q ha^{-1}) was recorded when black cowpea broadcasted in line sown maize.

4.1.2.7 Harvest index (%)

Perusal of data revealed that different intercropping patterns significantly influenced the harvest index of chickpea during experimentation (Table-4.5).

The highest harvest index (33.49%) was recorded under sole black cowpea. However, sole black cowpea was statistically at par with its harvest index in intercropping patterns of 2:2 row ratio (33.12%) than rest of the intercropping patterns. Among the intercropping patterns, followed by 2:2 row ratio, 2:3 row ratio of maize + black cowpea recorded higher harvest index (32.05%) which was statistically at par with 1:1 row ratio of maize + black cowpea (31.33%) and when black cowpea broadcasted in line sown maize (31.22%). However, the lowest harvest index of 30.47 per cent was recorded by 2:1 row ratio of maize + black cowpea intercropping patterns.

4.2 Maize

4.2.1 Pre-harvest studies

4.2.1.1 Plant population (m^{-2}) (initial and at maturity)

Data on plant population revealed that different planting patterns of maize + black cowpea intercropping along with sole maize did not differed significantly at 30 DAS (initial) and maturity stage during the study year (Table 4.6).

Table 4.6 : Effect of various planting patterns on plant population (m^{-2}) of maize

Treatment	Initial (30 DAS)	Maturity
Maize sole	7.98	7.58
Black Cowpea sole	-	-
Maize + Black Cowpea (Broadcast)	7.68	7.28
Maize + Black Cowpea (1:1)	7.86	7.45
Maize + Black Cowpea (2:1)	7.80	7.40
Maize + Black Cowpea (2:2)	7.75	7.33
Maize + Black Cowpea (2:3)	7.83	7.38
S.E(m)±	0.19	0.12
C.D.(P=0.05)	NS	NS

Both initial and final plant population under sole cropping of maize were higher than all intercropping treatments. Among intercropping patterns, maximum plant population both initial as well as maturity were recorded with 1:1 row ratio of maize + black cowpea intercropping pattern which was found at par with the rest of the intercropping treatments. The lowest plant population both initial as well as maturity were recorded in the treatment in which black cowpea broadcasted in line sown maize.

4.2.1.2 Days taken to different phenological stages of maize

4.2.1.2.1 Days taken to germination

Data pertaining to days taken germination to in maize as influenced by different intercropping patterns have been presented in Appendix-III (Fig. 4.5a).

Perusal of data revealed that lesser number days taken to germination was observed under sole cropping of maize and other intercropping treatments except 2:3 row ratio of maize + black cowpea intercropping systems.

4.2.1.2.2 Days taken to emergence

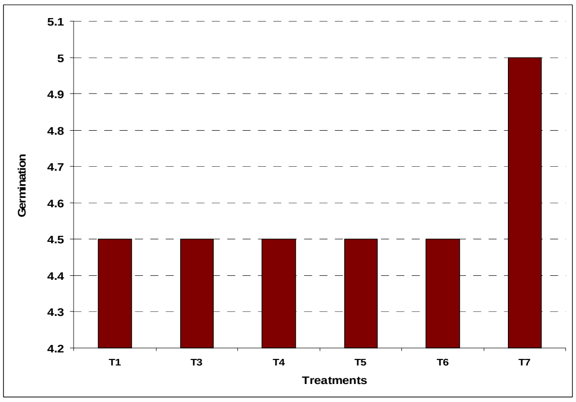
Number of days required to emergence in maize was not significantly influenced by different planting patterns during course of study presented in Appendix-III.

However, maize under 1:1 row ratio of maize + black cowpea pattern emerged earlier than other planting patterns followed by maize sole and 2:1 row ratio of maize + black cowpea intercropping pattern.

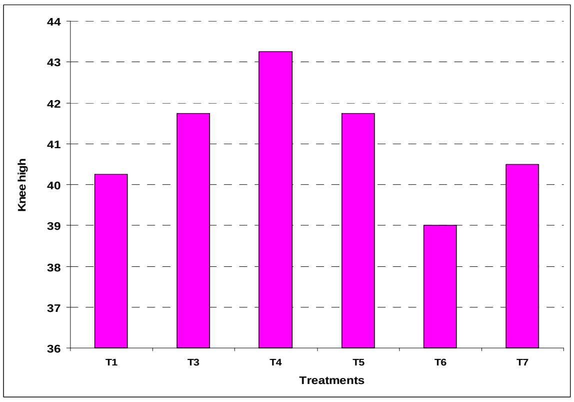
4.2.1.2.3 Days taken to start of knee high

Number of days to start of knee high as be affected significantly due to various planting patterns of maize + black cowpea during course of study have presented in Appendix-III (Fig. 4.5b).

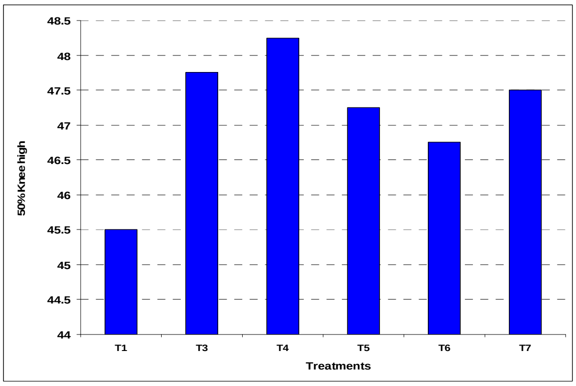
However, lesser number of days taken to start of knee high was recorded under maize sole (40.25) and 2:2 row ratio of maize + black cowpea pattern as compared to other planting patterns. Though, the highest number of days (43.25 days) required to start of knee high stage was with 1:1 row ratio of maize + black cowpea patterns.



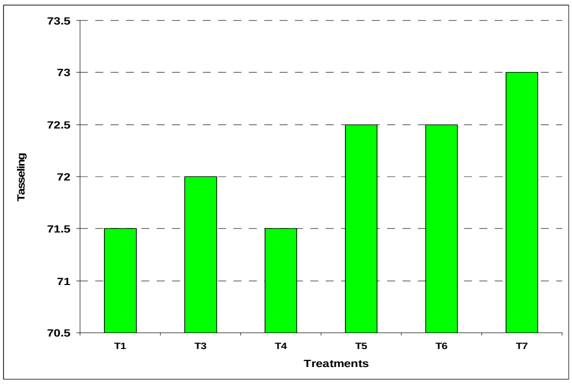
a) Germination



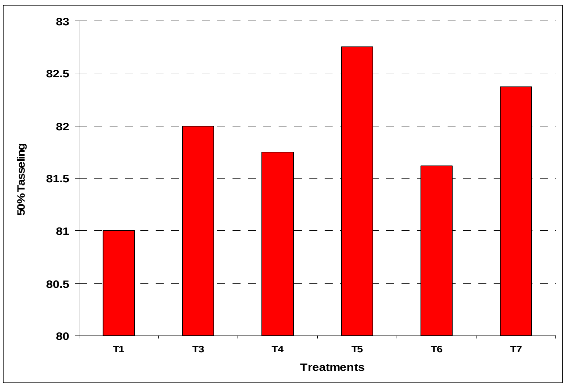
b) Knee high



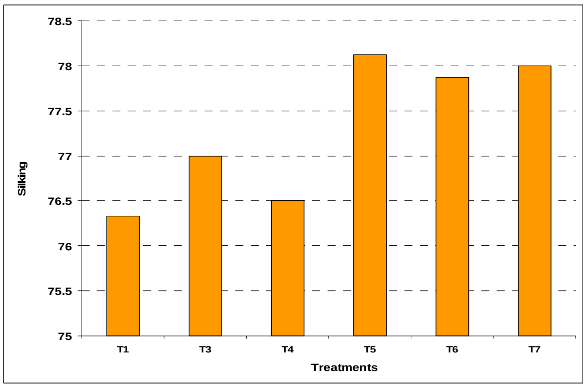
c) 50% knee high



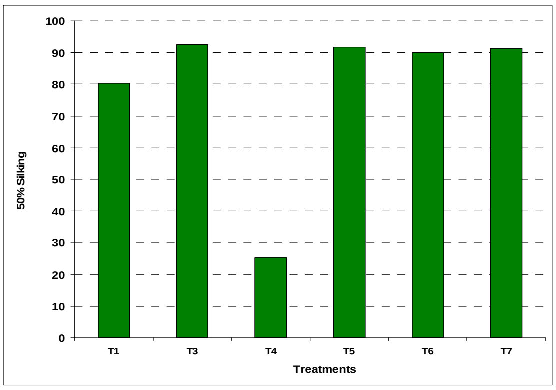
d) Tasseling



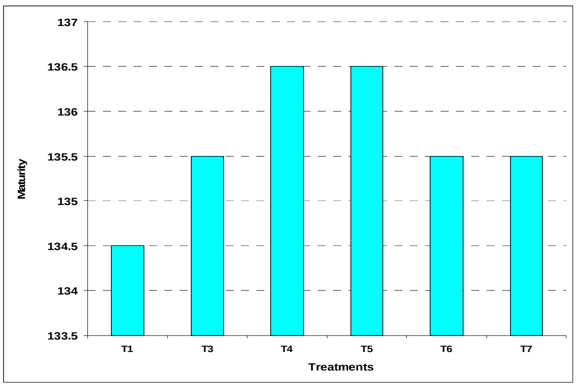
e) 50% tasseling



f) Silking



g) 50% silking



h) Maturity

Fig. 4.5 : Effect of various planting patterns on days to different phenological stages of maize

T_1 = Maize sole; T_2 = Black Cowpea sole; T_3 = Maize + Black Cowpea (Broadcast); T_4 = Maize + Black Cowpea (1:1); T_5 = Maize + Black Cowpea (2:1); T_6 = Maize + Black Cowpea (2:2); T_7 = Maize + Black Cowpea (2:3)

4.2.1.2.4 Days taken to 50% knee high

Data pertaining to 50% knee high maize in as influenced by different intercropping patterns have been presented in Appendix-III (Fig. 4.5c).

However, lesser number of days taken to 50% knee high was observed under sole cropping of maize as compared to other planting patterns.Where as, 1:1 row ratio of maize + black cowpea patterns taken maximum number of days to reach 50% knee high stage of maize.

4.2.1.2.5 Days taken to start of tasseling

Number of days required to start of tasseling in maize as influenced by different planting patterns of maize + black cowpea during the study year have been presented in Appendix-III (Fig. 4.5d). However, sole cropping of maize and 1:1 row ratio of maize + black cowpea intercropping pattern taken lesser number of days to start tasseling of maize. The row ratio 2:3 of maize + black cowpea intercropping was found to have delayed start of tasseling of maize.

4.2.1.2.6 Days taken to 50% tasseling

Data pertaining to 50% tasseling in maize as influenced by different intercropping patterns have been presented in Appendix-III (Fig. 4.5e).

However, lesser number of days taken to 50% tasseling of maize was observed under sole cropping of maize as compared to rest of the treatments. Row ratio 2:3 of maize + black cowpea intercropping recorded maximum number of days taken to 50% tasseling of maize.

4.2.1.2.7 Days taken to start of silking

Number of days taken to start of silking as affected significantly by due to various planting patterns during the year of study have been presented in Appendix-III (Fig. 4.5f).

However, lesser number of days (76.33) taken to start of silking was recorded under sole cropping of maize as compared to other planting patterns.

Where as, maximum number of days (78.12) taken to start of silking were recorded with 2:1 row ratio of maize + black cowpea intercropping patterns.

4.2.1.2.8 Days taken to 50 % of silking

Data pertaining to days taken to 50% silking in maize as influenced by various intercropping patterns have been presented in Appendix-III (Fig. 4.5g).

However, lesser number of days (80.25) taken to 50% silking of maize under sole cropping of maize as compared to rest of the treatments. Maximum number of days (90.50) taken to 50% silking of maize was recorded in the treatment when black cowpea broadcast in line sown maize.

4.2.1.2.9 Days taken to maturity

Number of days taken to maturity as affected by various planting patterns maize + black cowpea intercropping system and have presented in Appendix-III (Fig. 4.5h).

However, lesser number of days (134.50) were required to achieve maturity under sole cropping of maize as compared to rest of the treatments. Where as, maturity was delayed in intercropping treatments of maize + black cowpea. Maximum number of days (136.5) were recorded to achieve maturity under the treatments having row ratio 1:1 and 2:1 of maize + black cowpea intercropping pattern during the experimentation.

4.2.1.3 Plant height at different phenological stages

Data pertaining to plant height of maize as influenced by different treatments are presented in Table 4.7 (Fig. 4.6).

Plant height of maize increased with advancement of crop age and reached to its maximum at maturity. The variations in plant height due to different planting patterns were significant at all the growth stages of the crop. The rate of increment in plant height was higher during the period between, knee high to tasseling stage of the maize.

At knee high stage, maximum plant height of maize (55.64 cm) was recorded in 1:1 row ratio of maize + black cowpea intercropping pattern which was statistically at par with 2:1, sole cropping and 2:3 row ratio of maize + black cowpea intercropping patterns and significantly higher than that 2:2 row ratio and when black cowpea broadcasted in line sown maize which recorded lowest (50.56 cm) plant height.

Table 4.7: Plant height (cm) of maize at various phenological stages of crop as influenced by various planting patterns

Treatment	Knee high	Tasseling	Silking	Maturity
Maize sole	53.95	220.50	227.25	229.55
Black Cowpea sole	-	-	-	-
Maize + Black Cowpea (Broadcast)	50.56	206.00	224.02	227.12
Maize + Black Cowpea (1:1)	55.64	191.25	222.60	225.75
Maize + Black Cowpea (2:1)	54.67	220.50	227.50	229.36
Maize + Black Cowpea (2:2)	51.76	224.25	227.95	229.69
Maize + Black Cowpea (2:3)	53.05	223.25	227.22	229.38
S.E(m)±	1.04	8.17	1.10	0.91
C.D.(P=0.05)	3.15	24.65	3.34	2.76

At tasseling stage, among various treatments, 2:2 row ratio of maize + black cowpea recorded maximum plant height of maize (224.25 cm), being at par with all row ratios of maize + black cowpea intercropping patterns except 1:1 row ratio. However, 1:1 row ratio of maize + black cowpea intercropping pattern recorded lowest plant height of maize (191.25 cm) among different planting patterns during year of experimentation.

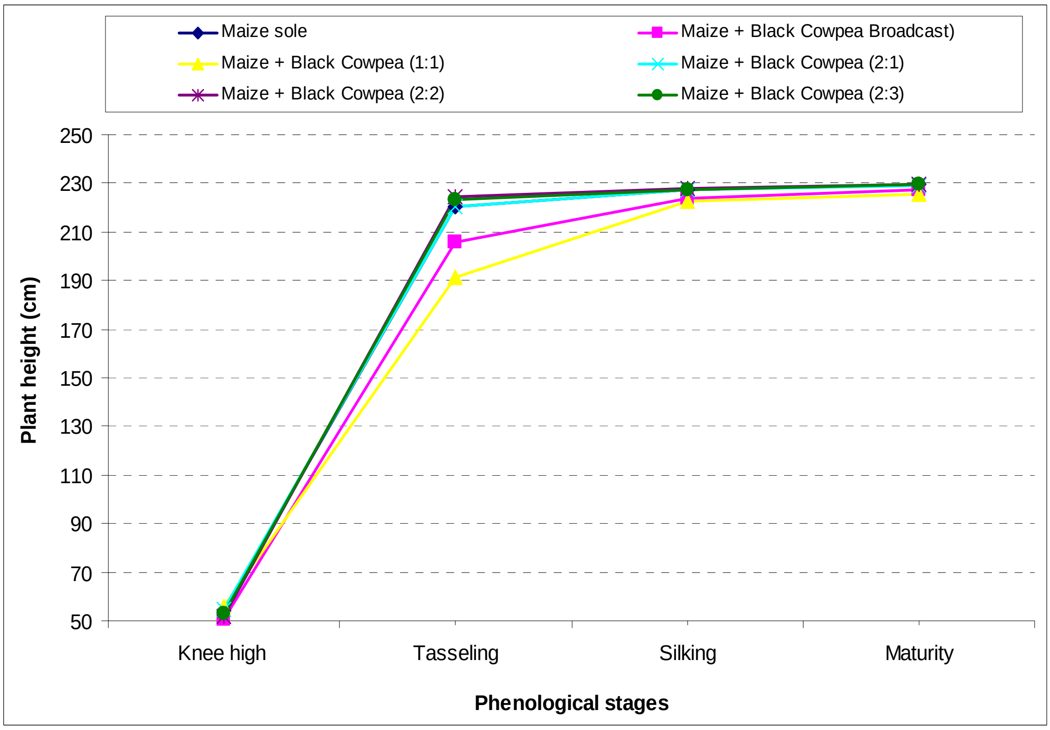


Fig. 4.6 : Plant height (cm) of maize at various phenological stages of crop as influenced by various planting patterns

At silking stage of maize, significantly highest plant height (227.95. cm) was recorded with 2:2 row ratio of maize + black cowpea intercropping pattern, at par with 2:1, 2:2 row ratio of maize + black cowpea and sole cropping of maize. the lowest plant height (222.60 cm) of maize was recorded with 1:1 row ratio of maize + black intercropping pattern.

At maturity of maize, different planting patterns influenced the plant height significantly. However, significantly maximum plant height of maize (229.69 cm) was recorded with 2:2 row ratio of maize + black cowpea intercropping pattern were at par with others. Whereas, the lowest plant height (225.75 cm) was recorded with of maize + black cowpea broadcasting intercropping patterns.

4.2.1.4 Total dry matter accumulation

Perusal of data revealed that planting patterns including sole cropping significantly influenced the total dry matter accumulation in maize plant at all the stages of crop growth when recorded at 30 days intervals during the course of study Table 4.8 (Fig. 4.7). Total dry matter accumulation (g) plant^{-1} increased with the advancement of crop age and reached maximum at maturity.

Table 4.8 : Effect of various planting patterns on dry matter accumulation of maize

Treatment	Dry matter accumulation (g plant^{-1})			
	30DAS	60 DAS	90 DAS	120 DAS
Maize sole	1.56	32.96	245.00	271.50
Black Cowpea sole	-	-	-	-
Maize + Black Cowpea (Broadcast)	0.64	21.19	192.25	235.75
Maize + Black Cowpea (1:1)	0.67	22.35	183.50	218.25
Maize + Black Cowpea (2:1)	1.42	27.84	217.50	255.00
Maize + Black Cowpea (2:2)	0.70	23.92	208.25	248.00
Maize + Black Cowpea (2:3)	0.61	17.33	173.85	213.75
S.E(m)±	0.08	1.45	4.44	5.36
CD at 5 %	0.24	4.38	13.39	16.16

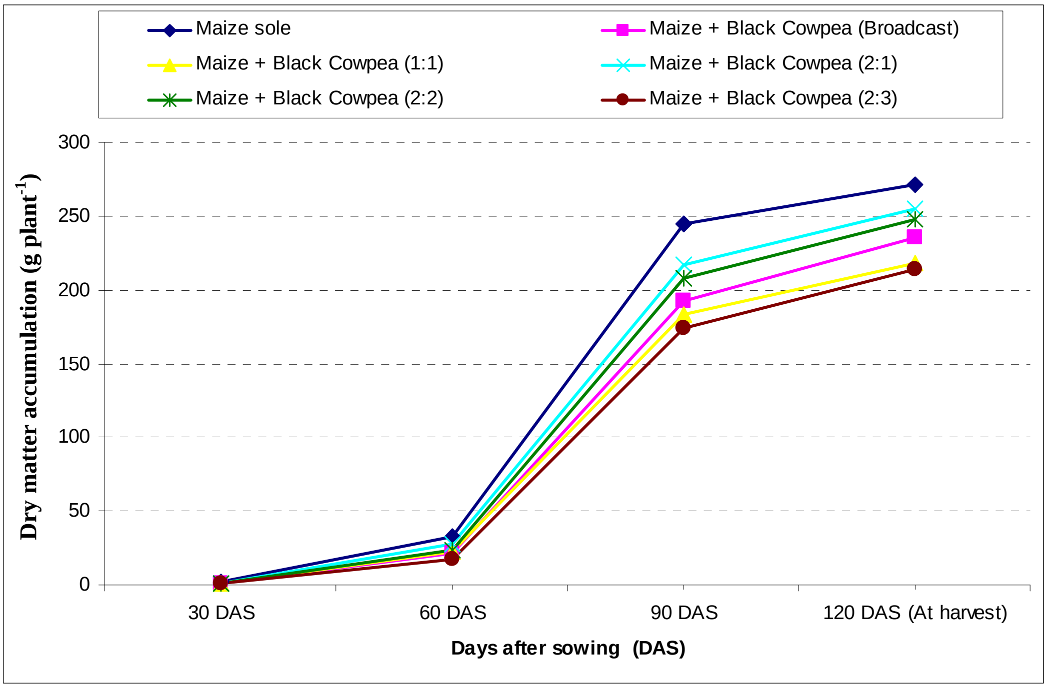


Fig. 4.7: Effect of various planting patterns on dry matter accumulation (g plant^{-1}) of maize

Sole cropping of maize accumulated maximum amount of dry matter plant^{-1} at all the stages of crop growth. At 30 days after sowing, being at par with sole cropping of maize, 2:1 row ratio of maize + black cowpea accumulated higher amount of dry matter (1.42 g plant^{-1}) as compared to rest of the treatments.

Among different intercropping patterns of maize + black cowpea, 2:1 row ratio of maize + black cowpea accumulated higher dry matter (1.42, 27.84, 217.50 and 255.00 g plant^{-1}) at par with 2:2 row ratio over rest of the treatments at 60, 90 and 120 days after sowing. Whereas, 2:3 row ratio of maize + black cowpea intercropping system accumulated lowest dry matter (0.61, 17.33, 173.85 and 213.75 g plant^{-1}) at 30, 60, 90 and 120 days after sowing stages.

4.2.2 Post-harvest studies

4.2.2.1 Number of cobs plant^{-1}

Cobs number did not found differed significantly under sole cropping and row ratios during course of experimentation Table 4.9.

Sole maize had highest number of cobs plant^{-1} (1.08) over rest of the treatments of intercropping. Among various intercropping patterns of maize + black cowpea, 2:3, 2:1 and 1:1 row ratios recorded equal number of cobs plant^{-1} (1.05) .The lowest (1.00) number of cob plant^{-1} was recorded with 2:2 row ratio of maize + black cowpea intercropping pattern.

4.2.2.2 Grain weight cob^{-1} (g)

Perusal of data revealed that various planting patterns including sole cropping significantly influenced the grain weight per cob of maize at harvest stage of maize crop (Table 4.9).

Sole cropping of maize accumulated maximum amount of grain weight cob^{-1} (46.28 g) over various intercropping patterns. Among different intercropping patterns, 2:1 row ratio of maize + black cowpea accumulated higher amount of grain weight cob^{-1} (45.15 g) at par with 2:2 (44.89 g) and 1:1 (44.49 g) row ratios over rest of the patterns. The lowest grain weight cob^{-1} (43.32 g) was accumulated with the treatment when black cowpea broadcasted in line sown maize.

Table 4.9 : Yield attributes of maize as influenced by various planting patterns

Treatment	Cobs plant^{-1}	Grain wt. cob^{-1}	100-grain weight (g)
Maize sole	1.08	46.28	22.38
Black Cowpea sole	-	-	-
Maize + Black Cowpea (Broadcast)	1.03	43.32	21.44
Maize + Black Cowpea (1:1)	1.05	44.49	21.96
Maize + Black Cowpea(2:1)	1.05	45.15	22.28
Maize + Black Cowpea(2:2)	1.00	44.89	22.29
Maize + Black Cowpea(2:3)	1.05	43.83	21.98
S.E(m)±	0.27	0.31	0.16
C.D.(P=0.05)	NS	0.96	0.47

4.2.2.3 100-grain weight (g)

Data presenting the effect of different planting patterns on 100-grain weight show that various planting patterns brought significant differences in 100-grain weight of maize during experimentation Table.4.9.

However, sole cropping of maize recorded maximum 100-grain weight (22.38 g) over rest of the intercropping patterns of maize + black cowpea patterns. Among different intercropping patterns, 2:2 row ratio recorded higher (22.29 g) 100-grain weight were at par with 1:1, 2:1 and 2:3 row ratio, comparable to 2:1 row ratio (22.28 g). The lowest (21.44 g) 100-grain weight of maize was recorded in the treatment when black cowpea was broadcasted in line sown maize.

4.2.2.4 Grain yield (q ha^{-1})

Data pertaining to effect of planting patterns on grain yield of maize under black cowpea intercropping are presented in Table-4.10 (Fig. 4.8).

Perusal of data revealed that different planting patterns brought significant differences in grain yield of maize during experimentation. The highest grain yield (50.62 q ha^{-1}) was recorded under sole cropping of maize. However, sole maize yield was statistically at par with its yield in intercropping patterns of 2:1 (49.20 q ha^{-1}), 2:2 (48.60 q ha^{-1}) and 1:1 (47.66 q ha^{-1}) row ratios of maize + black cowpea and significantly higher than rest of the intercropping patterns. Among the intercropping patterns, 2:1 row ratio registered the highest grain yield which was at par with rest of the intercropping patterns. The lowest grain yield (43.47 q ha^{-1}) of maize was recorded when black cowpea broadcasted in line sown maize treatment.

Table 4.10 : Yield and harvest index of maize as influenced by various planting patterns

Treatment	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Maize sole	50.62	189.90	240.53	21.02
Black Cowpea sole	-	-	-	-
Maize + Black Cowpea (Broadcast)	43.47	187.33	230.83	18.83
Maize + Black Cowpea (1:1)	47.03	185.88	232.91	20.18
Maize + Black Cowpea(2:1)	49.20	189.29	238.49	20.61
Maize + Black Cowpea(2:2)	48.60	188.69	237.29	20.46
Maize + Black Cowpea(2:3)	46.17	187.33	233.50	19.95
S.E(m)±	1.32	0.84	1.44	0.47
C.D.(P=0.05)	3.98	2.54	4.36	NS

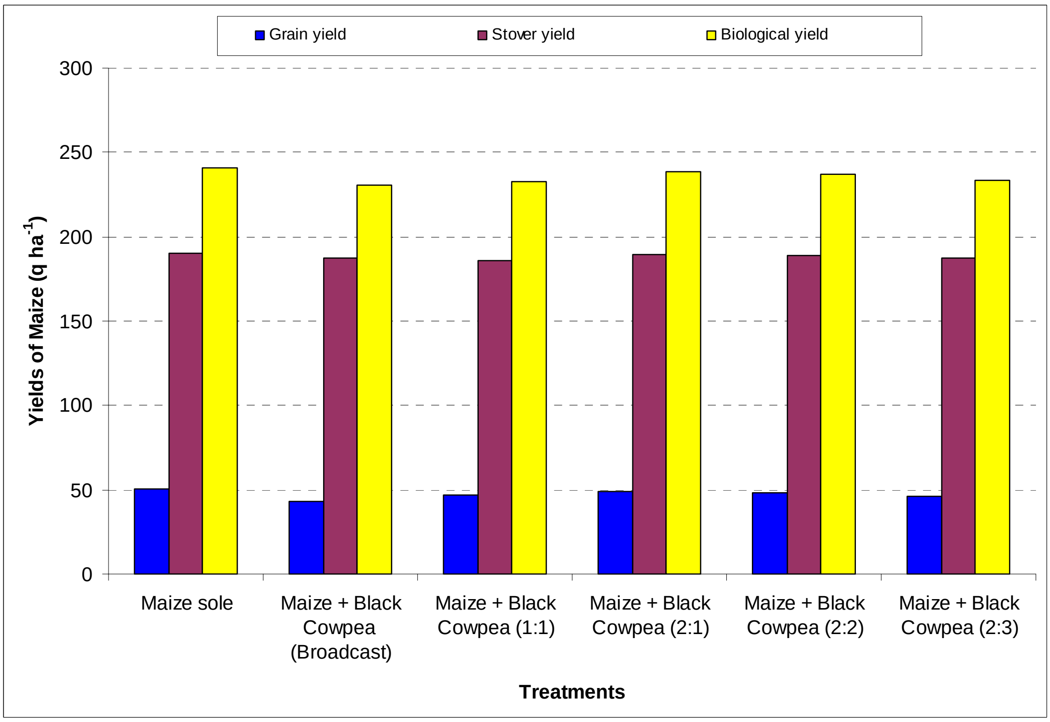


Fig. 4.8 : Yields of maize as influenced by various planting patterns

4.2.2.5 Stove yield (q ha^{-1})

Stover yield of maize under sole cropping and intercropping patterns during the year of experimentation are presented in Table-4.10 (Fig. 4.8).

Data revealed that sole cropping of maize registered significantly higher stover yield (189.90 q ha^{-1}) at par with 2:1 and 2:2 row ratios of maize + black cowpea intercropping patterns. Among different intercropping patterns, 2:1 row ratio recorded higher stover yield of maize (189.29 q ha^{-1}) which was statistically equal to 2:2, 2:3 row ratios of maize + black cowpea and when black cowpea broadcasted in line sown maize. The lowest stover yield (185.88 q ha^{-1}) was recorded with 1:1 row ratio of maize + black cowpea intercropping pattern during year of study.

4.2.2.6 Biological yield (q ha^{-1})

Data representing the effect of intercropping patterns of maize + black cowpea on the biological yield of maize are presented in Table-4.10 (Fig. 4.8). Significant differences were recorded by the various treatments of intercropping and sole cropping during course of study.

The highest biological yield of maize (240.53 q ha^{-1}) was recorded under sole cropping of maize, which was statistically at par with 2:1 and 2:2 row ratios of maize + black cowpea intercropping patterns as compared to rest of the treatments. The lowest biological yield of maize (230.83 q ha^{-1}) was recorded in the treatment when black cowpea broadcasted in line sown maize.

4.2.27 Harvest index (%)

Data representing the effect of intercropping patterns of maize + black cowpea on the harvest index of maize are presented did not differ significantly during course of investigation presented in Table-4.10.

However, highest harvest index (21.02%) of maize was recorded under sole cropping of maize where as the minimum (18.83) was recorded when black cowpea in the treatments when black cowpea broadcasted in line sown maize.

4.3 Maize + black cowpea intercropping indices

4.3.1 Maize equivalent yield (q ha^{-1})

Data pertaining to maize equivalent yield (MEY) as influenced by different planting patterns have been presented in Table 4.11 (Fig. 4.9a). Data revealed that the variations in maize equivalent yield due to different treatments were significant during year of experimentation.

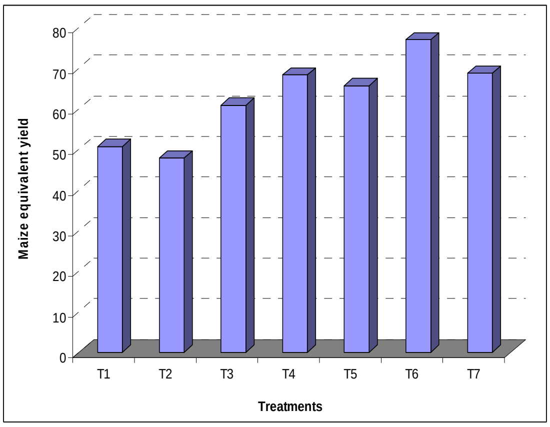
Maize equivalent yield recorded in all the intercropping patterns was significantly higher than sole cropping of maize and black cowpea. Sole black cowpea gave lowest maize equivalent yield (47.85q ha^{-1}). Where as, intercropping pattern of 2:2 row ratio recorded significantly highest maize equivalent yield (76.99 q ha^{-1}) than rest of the intercropping and sole cropping of maize and black cowpea. Next to 2:2 row ratio of maize + black cowpea intercropping pattern, 2:3 row ratio recorded higher maize equivalent yield (68.69 qha^{-1}) which was at par with 1:1 (68.35 qha^{-1}) and 2:1 (65.63 q ha^{-1}) row ratio of maize + black cowpea intercropping patterns over rest of the treatments.

4.3.2 Land equivalent ratio (LER)

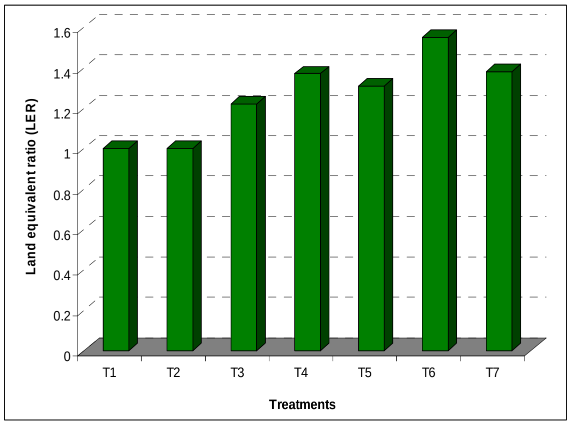
Data pertaining to land equivalent ratio revealed that different planting patterns brought differences in land equivalent ratio during course of study (Table 4.11; Fig. 4.9b) Compared with sole cropping of maize and black cowpea, all the intercropping patterns of maize + black cowpea resulted in land equivalent ration greater than one. among different patterns, 2:2 row ratio of maize + black cow pea intercropping recorded maximum land equivalent ratio (1.55) followed by 2:3 row ratio (1.38). Thus, data revealed that different intercropping patterns recorded 22 to 55 per cent more land use efficiency during experimentation.

Table 4.11: Effect of various planting patterns on different intercropping indices

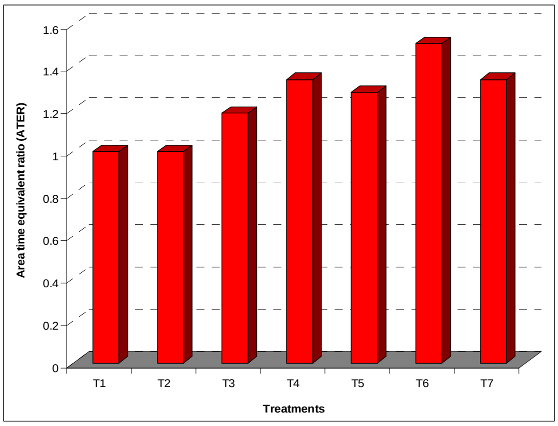
Treatment	Maize equivalent yield	Land equivalent ratio (LER)	Area time equivalent ratio (ATER)	Relative crowding coefficient (RCC)			Production efficiency (PE)	Aggressivity (A)	
				Maize	Black cowpea	Total		Maize	Black cowpea
Maize sole	50.62	1.0	1.0	-	-	-	37.50	-	-
Black Cowpea sole	47.85	1.0	1.0	-	-	-	39.87	-	-
Maize + Black Cowpea (Broadcast)	60.76	1.22	1.18	3.04	1.13	4.17	44.68	0.14	-0.14
Maize + Black Cowpea (1:1)	68.35	1.37	1.34	6.55	1.61	8.16	49.89	0.04	-0.04
Maize + Black Cowpea (2:1)	65.63	1.31	1.28	17.32	1.04	18.36	47.89	0.29	-0.29
Maize + Black Cowpea (2:2)	76.99	1.55	1.51	6.98	5.03	12.01	56.61	-1.09	1.09
Maize + Black Cowpea (2:3)	68.69	1.38	1.34	7.68	1.20	8.88	50.50	0.28	-0.28
S.E(m)±	1.29	-	-	-	-	-	-	-	-
C.D. (P=0.05)	3.83	-	-	-	-	-	-	-	-



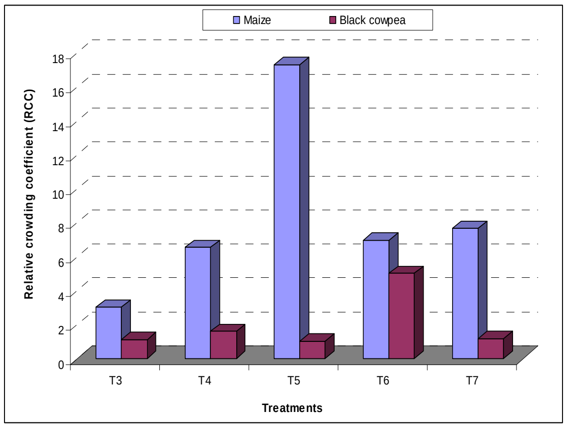
a) Maize equivalent yield



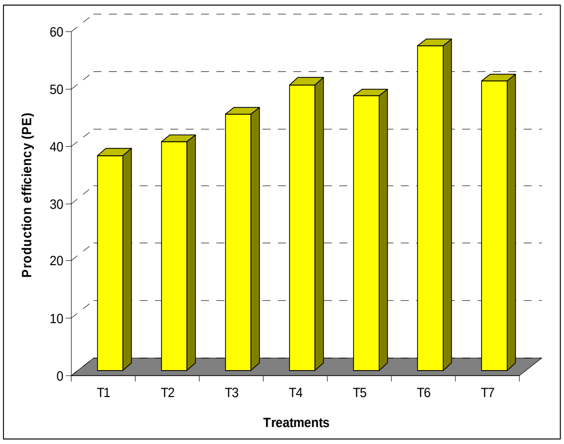
b) Land equivalent ratio



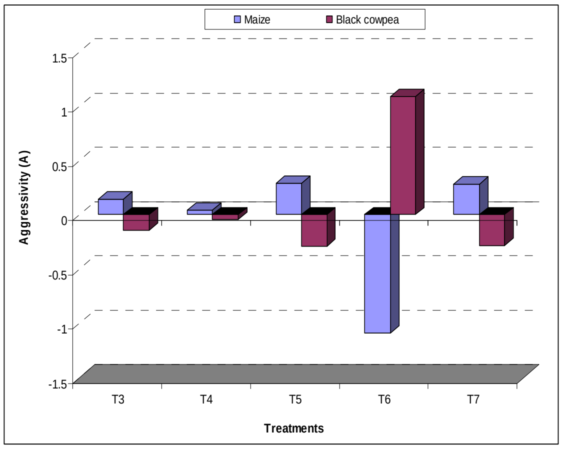
c) Area time equivalent ratio



d) Relative crowding coefficient



e) Production efficiency



f) Aggressivity

Fig. 4.9 : Effect of various planting patterns on different intercropping indices

T_1 = Maize sole; T_2 = Black Cowpea Sole; T_3 = Maize + Black Cowpea (Broadcast);
T_4 = Maize + Black Cowpea (1:1); T_5 = Maize + Black Cowpea (2:1); T_6 = Maize + Black Cowpea (2:2);
T_7 = Maize + Black Cowpea (2:3)

4.3.3 Area time equivalent ration (ATER)

Data pertaining to area time equivalent ratio (ATER) as influenced by, different planting patterns are presented in Table 4.11 (Fig. 4.9c). Area time equivalent ratio of various planting patterns was greater the 1.0 in all intercropping patterns as compared to sole cropping of maize and black cowpea. Among different intercropping patterns, 2:2 row ratio of maize + black cowpea recorded highest (1.51) area time equivalent ratio as compared to rest of treatments. Next to 2:2 row ratio, 1:1 and 2:3 row ratio of maize + black cowpea recorded higher (1.34) ATER as compared to rest of treatments.

4.3.4 Relative crowding coefficient (RCC)

Data pertaining to relative crowding coefficient (RCC) of maize, black cowpea and total as influence by various planting patterns have been presented in Table 4.11 (Fig. 4.9d).

Relative crowding coefficients for maize and black cowpea were greater than 1.0 in all the intercropping patterns during course of study. Relative crowding coefficient for maize was highest (17.32) under 2:1 row ratio and lowest (3.04) under the treatment where black cowpea broadcasted in line sown maize. Relative crowding coefficient for black cowpea was highest (5.03) under 2:2 row ration and lowest (1.13) under the treatment where black cowpea broadcasted in line sown maize. In totality, highest (18.36) relative crowding coefficient of the different intercropping patterns of maize+ black cowpea was under 2:1 row ratio and minimum (4.17) was recorded under the treatment where black cowpea broadcasted in line sown maize.

4.3.5 Production efficiency (PE)

Perusal of data stated the different planting patterns brought differences in production efficiency of the various intercropping systems. Production efficiency of different intercropping patterns was found higher than sole cropping of maize and black cowpea (Table 4.11; Fig. 4.9e). Among various intercropping patterns, 2:2 row ratio of maize + black cowpea recorded maximum (56.61) production efficiency of the system.

4.3.6 Aggressivity (A)

Data pertaining to aggressivity of maize and black cowpea have been presented in Table 4.11 (Fig. 4.9f). It is revealed from the data that maize crop showed its dominance over black cowpea in all the intercropping patterns of maize + black cowpea except 2:2 row ratio of maize + black cowpea. Whereas, dominance of black cowpea over maize was found only under 2:2 row ratio of maize + black cowpea among rest of the intercropping patterns.

4.4 Physico-chemical properties of soil (after harvest of maize and black cowpea)

Differences in physico-chemical properties of soil after harvest of maize and black cowpea due to different intercropping patterns were presented in Table 4.12.

Soil pH in sole maize cropping recorded higher values (7.00) than that of any of the inter cropping patterns after harvest of maize of and black cowpea and initial values before experimentation. The treatments having black cowpea in the system resulted in equal or slightly reduction in soil reaction.

Organic carbon (%) of soil after harvest of maize and black cowpea showed that a slight increase was found in different cropping patterns having black cowpea in the system as compared to initial values of organic carbon (%) except 2:1 row ratio of maize + black cowpea pattern. A slight decrease in soil organic carbon (%) was found in maize sole cropping treatment.

Available nitrogen content (kg ha^{-1}) in soil after harvest of maize and black cowpea showed that highest (531.00 kg ha^{-1}) and minimum (360.62 kg ha^{-1}) were recorded with sole black cowpea and sole maize, respectively. Among different intercropping patterns, 2:3 and 2:2 row ratios of maize + black cowpea were found to add available nitrogen over initial values as compared to rest of treatments.

Table 4.12: Effect of various planting patterns on physico-chemical properties of soil after harvest of the maize and black cowpea

Treatment	Soil pH	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Maize sole	7.00	1.35	360.62	14.00	121.00
Black Cowpea sole	6.80	1.46	531.00	15.50	125.00
Maize + Black Cowpea (Broadcast)	6.90	1.40	454.71	14.33	122.05
Maize + Black Cowpea (1:1)	6.80	1.41	489.21	14.75	123.00
Maize + Black Cowpea (2:1)	6.48	1.38	485.45	14.00	121.75
Maize + Black Cowpea (2:2)	6.90	1.40	500.00	14.85	122.85
Maize + Black Cowpea (2:3)	6.85	1.45	510.00	15.00	124.25
Initial value	6.9	1.39	498.62	16.21	127.68

Available phosphorous (kg ha^{-1}) of soil after harvest of maize and black cowpea was found reduced slightly in different intercropping patterns as compared to initial available phosphorous (16.21 kg ha^{-1}). Highest available phosphorous (15.50 kg ha$^{-1)}$ was recorded with sole cropping of black cowpea. Lowest available phosphorous (14.00 kg ha^{-1}) was recorded with sole cropping of maize and 2:1 row ratio of maize + black cowpea intercropping system

Available potassium (kg ha^{-1}) of soil after harvest of maize and black cowpea was found slightly reduced in different intercropping patterns as compared to initial available potassium (127.68 kg ha^{-1}). The highest (125.00 kg ha^{-1}) and minimum (121.00 kg ha^{-1}) were found with sole black cowpea and sole maize cropping, respectively.

4.5 Economical studies of maize and black cowpea intercropping

The data pertaining to economical analysis of treatments given to maize and black cowpea intercropping system are presented in Table 4.13 (Fig. 4.10).

4.5.1 Cost of cultivation

Cost of cultivation of different treatments applied to maize + black cowpea intercropping system was worked out by summation of cost of cultivation of component crops. Among the various planting patterns, highest cost of cultivation (Rs. 50530.50 ha^{-1}) was involved in 2:3 row ratio of maize + black cowpea intercropping patterns which was followed by (Rs. 43432.50 ha^{-1}) for 2:2 row ratio of maize +black cowpea. The lowest cost of cultivation of (Rs. 35688.00 ha^{-1}) was calculated for sole cropping of black cowpea (Table 4.13; Fig. 4.10a).

4.5.2 Gross return

Gross return for the different planting patterns was obtained by addition of returns obtained from all the commercials part of both the crop of the crop of the system Table 4.13 (Fig. 4.10b).

The maximum gross return (Rs. 140085.90 ha^{-1}) was observed in 2:2 row ratio of maize + black cowpea intercropping system which was followed by 2:3 row ratio (Rs. 127049.80 ha^{-1}). The lowest gross return (Rs. 74160.00 ha^{-1}) was noted by sole cropping of black cowpea.

4.5.3 Net return

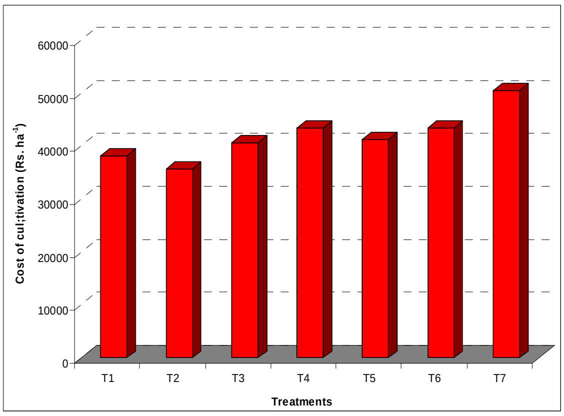
Net return of the various intercropping systems was workout to evaluate the profitability of the treatments for maize + black cowpea intercrops as a whole Table 4.13 (Fig. 4.10c). Maximum net return of (Rs. 96653.40 ha^{-1}) was recorded in 2:2 row ratio of maize + black cowpea the lowest net return (Rs. 38472.00 ha^{-1}).

4.5.4 Benefit: cost ratio

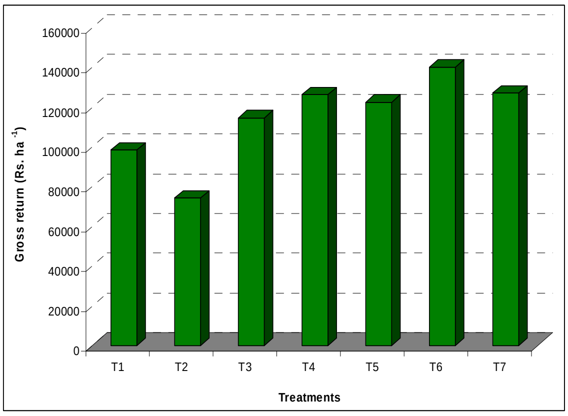
Maximum benefit: cost ratio 2.23 was recorded with 2:2 row ratio of maize + black cowpea pattern. Whereas, sole black cowpea gave lowest (1.08) benefit cost ratio during the course of investigation (Table 4.13; Fig. 4.10d).

Table 4.13: Economics of maize and black cowpea intercropping system as influenced by various planting patterns

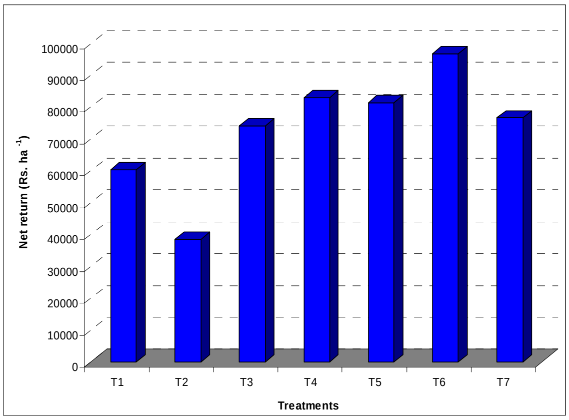
Treatment	Cost of cultivation (Rs ha^{-1})	Return from maize (Rs. ha^{-1})			Return from grains of black cowpea (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs ha^{-1})	Benefit: cost ratio
		Grain	Stover	Total				
Maize sole	38145.00	77500.00	20889.00	98389.00	0.00	98389.00	60244.00	1.58
Black Cowpea sole	35688.00	0.00	0.00	0.00	74160.00	74160.00	38472.00	1.08
Maize + Black Cowpea (Broadcast)	40557.50	67270.00	20606.30	87876.30	26800.00	114676.30	74118.80	1.83
Maize + Black Cowpea (1:1)	43432.50	72896.50	20446.80	93343.30	33040.00	126383.30	82950.80	1.91
Maize + Black Cowpea (2:1)	41221.75	76260.00	20821.90	97081.90	25440.00	122521.90	81300.15	1.97
Maize + Black Cowpea (2:2)	43432.50	75330.00	20755.90	96085.90	44000.00	140085.90	96653.40	2.23
Maize + Black Cowpea (2:3)	50530.50	71563.50	20606.30	92169.80	34880.00	127049.80	76519.30	1.51



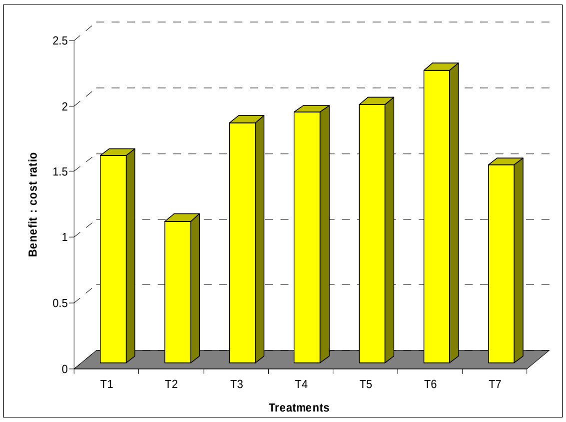
a) Cost of cultivation (Rs. ha^{-1})



b) Gross return (Rs. ha^{-1})



c) Net return (Rs. ha^{-1})



b) Benefit : cost ratio

Fig. 4.10 : Economics of maize and black cowpea intercropping system as influenced by various planting patterns

T_1 = Maize sole; T_2 = Black Cowpea Sole; T_3 = Maize + Black Cowpea (Broadcast);
T_4 = Maize + Black Cowpea (1:1); T_5 = Maize + Black Cowpea (2:1); T_6 = Maize + Black Cowpea (2:2);
T_7 = Maize + Black Cowpea (2:3)

Chapter - 5

DISCUSSION

The experimental findings described in the previous chapter provide a detailed account of the effects of planting patterns on growth, yield components and yields, physico-chemical properties of soil and economics of both maize and black cowpea crops. In this chapter, attempts have been made to discuss the significant experimental findings observed during the course of investigation and to offer possible explanations and evidences wherever necessary, with a view to find out the cause and effect relationship among different treatments with respect to the various attributes studied and sort out the information of practices values.

5.1 Crop response to planting patterns

Yield of crop is a complex function of growth and metabolic process taking place in plant body which is modified by microclimate and cultural practices. In an intercropping system, not only the aboitic factors but also the associated intercrops growing side by side affect the performance of main crop. Variations due to treatments on growth, yield and yield contributes of sole as well as intercrop are discussed below.

5.2 Effect of planting patterns on black cowpea

A perusal of yield response exhibited by different planting patterns in the present study revealed that grain yield of black cowpea was significantly influenced by different planting patterns during course of experimentation. Table 4.5 and Fig. 6 revealed that black cowpea grain yield was significantly higher in sole cropping as compared to all other planting patterns. Superiority of sole cropping over intercropping patterns might be attributed to higher plant population under sole cropping of black cowpea, absence of intraspace competition and limited disturbance of habitat. The lower yield under intercropping systems mighty be due to the shading effects imposed by maize crop which did not allow to penetrate solar radiation upto a minimum level for the normal photosynthetic activity of black cowpea and also reduction in plant density. These results confirm the findings of Sunail *et al.*(2005)and Ghosh *et al.* (2004) in studies of intercropping of with legumes..

Further examination of Table 4.6 and Fig.6 indicated that similar to grain yield, stover and biological yields were also higher with sole cropping of black cowpea, which was mainly attributed to higher plant population at maturity. Whereas highest values of harvest index (33.49%) recorded under sole cropping of black cowpea, was at par with 2:2 row ratio of maize + black cowpea intercropping pattern (33:12%) as compared to rest of the treatments. This increase in harvest index of black cowpea was perhaps due to efficient translocation of photosynthates from source to sink.

Sole stand of black cowpea recorded better yield attributes viz., number of pods plant $^{-1}$, number of seeds pod $^{-1}$ and 100-grain weight as compared to intercropping systems. This might be due to the fact that maize deep root system and vigorous plant growth, offered more competition both below and above ground for growth resources whereas better root growth in sole black cowpea facilitated more area for nodule formation resulting higher yield attributes. Similar results were reported by Padhi (2001) and Patel and Rajagopal (2001).

Total dry matter production is the function of crop growth rate over the entire growth period. It is directly related to grain yield. The ability of a plant to produce dry matter depends upon the size, efficiency and duration of photosynthetic apparatus. The total dry matter production in a plant often indicates its potentiality for yield but its mobilization towards the grain development is an important factor for realization in economic yield. The data presented in Table 4.4 and Fig. 5 clearly illustrated the fact that sole cropping of black cowpea accumulated maximum dry matter at all the stages of crop growth except 30 days after sowing as compared to all other planting patterns. The less dry matter accumulation per plant in intercropping systems was due to suppressing ability of maize on black cowpea. Similar results were reported by Javanmard *et al.* (2009).

Number of nodules plant $^{-1}$ and fresh weight (g) of nodules plant^{-1} were significantly influenced by different planting patterns. Sole cropping of black cowpea nodulated better than intercropping patterns (Fig.4). The number of nodules plant^{-1} and fresh weight of nodule plant $^{-1}$ both were maximum with sole cropping of black cowpea, at par with 2:1 row ratio of maize + black cowpea. Different intercropping patterns, irrespective of row ratio also performed good nodulation. This may be due to the fact that maize plants depleted soil nitrogen rapidly to meet their requirement for growth. Soil nitrogen stress thus, possibly created increased nodulation and nodule growth. Another possible reason may be due to the fact that black cowpea was treated with *Rhizobium* culture before sowing in the experimentation. Results confirmed the findings of Kushwaha and De (1987).

Days to different phenological stages of black cowpea were lesser in sole cropping (Fig.3). Days taken to germination, start of nodulation, start of branching, start of flowering, start of pod formation and start of filling pod picking and physiological maturity were lesser with sole cropping of black cowpea as compared to rest of the intercropping treatments. This might be due to efficient utilization of moisture, nutrients, solar energy, uniform similar habitat etc. coupled with absence of interspace competition and shading effect of maize. Similar results were also reported by Hussain *et al.* (2003)

5.3 Effect of planting patterns on maize

In the present study, grain yield of maize was significantly influence by different planting patterns during course of investigation, sole cropping of maize produced maximum grain yield being significantly equal to 2:1, 2:2 and 1:1 row ratio of maize + black cowpea intercropping patterns over rest of the planting patterns (Fig.10). This was mainly due to higher plant population at maturity under these treatments along with less mortality percentage, higher yield attributes viz., number of cob plant^{-1} grain weight cob^{-1} and 100 grain weight, widening of maize by paired row method showed increase in grain yield. Similar results were reported by Shah *et al.* (1991).

Further examination of Table 4.10 and Fig. 10 indicated that similar to grain yield, biological and stover yields were also higher with sole cropping of maize, which was mainly attributed to higher plant population at maturity. Whereas, the values of harvest index were unaffected by various planting patterns of maize + black cowpea intercropping. Similar results were reported by Padhi (2001).

Sole stand of maize recorded better yield attributes viz., number of cobs plant^{-1}, grain weight cob^{-1} and 100-grain weight (g) as compared to various intercropping systems during investigation (Table 4.9). This might be due to lesser competition for nutrients, light and space. Similar results were reported by Padhi (2001).

Sole cropping of maize accumulated greater amount of dry matter plant^{-1} at all the stages of crop growth (Fig. 9). Being statistically equal to sole cropping of maize only at 30 days after sown, 2:1 row ratio of maize + black cowpea intercropping recorded maximum dry matter accumulation plant^{-1} at all the stages of crop growth among various intercropping patterns of maize + black cowpea. This might be due to beneficial effect of legumes in terms of nitrogen, leading to better growth and development of maize. Similar results were reported by Hugar and Palled (2008).

Intercropping patterns has greater as well as equal maize plant height as compared to sole cropping of maize. Row ratio 2:2 of maize + black cowpea recorded greater plant height of maize comparable to other intercropping patterns at tasseling, silking and maturity stages except knee high stage (Fig. 8). This may be due to the beneficial effect of legumes in terms of nitrogen, leading to better growth in terms of plant height of maize. These results confirmed the finding of Hugar and Palled (2008).

Days to different phenological stages of maize were lesser in sole cropping (Fig.7). Days taken to germination, emergence, start of knee high, start of tasseling, start of skilling and maturity were minimum with sole cropping of maize as compared to rest of the inter cropping patterns. This might be due to efficient utilization of moisture, nutrients solar energy etc coupled with absence of interspace competition. Similar results were also reported by Hussain *et al.* (2003).

5.4 Effect of planting patterns on inter cropping indices

The highest total productivity in terms of maize equivalent yield (MEY) was recorded with 2:2 row ratio of maize + black cowpea intercropping pattern than rest of the intercropping and sole cropping of maize and black cowpea. This may be attributed to additional advantage of intercrop yield and also higher economic value of intercrop (Table 4.11 and Fig.11). The findings confirmed by Thakur *et al.* (2000) stated that intercropping is one of the ways to increase the productivity $unit^{-1}$ area of land under supply of limited resources.

All the intercropping patterns resulted in land equivalent ratio (LER) more than one. Among different intercropping patterns, 2:2 row ratio of maize + black cowpea recorded highest LER as compared to rest of the treatments. Similar results were also noted by Saban *et al.* (2007) and Dahmardeh *et al.* (2010).

Area time equivalent ratio (ATER) of various planting patterns were greater than 1.0 in different intercropping patterns of maize + black cowpea as compared to sole cropping of maize and black cowpea highest (ATER) was recorded under 2:2 row ratio of maize + black cow pea intercropping patterns. This may be attributed to additional advantage of intercrops yield in a unit time of duration was noted by Egbe *et al.* (2010).

Relative crowding coefficients (RCC) for maize and black cowpea were greater than 1.0 in all the intercropping patterns. RCC in totality was highest under 2:1 row ratio of maize + black cowpea intercropping pattern. This was mainly due to the widening of paired rows of maize which gave sufficient space for spread of black cowpea was noted by Tamkin (2012).

Production efficiency (PE) of various planting patterns was greater in different intercropping patterns of maize+ black cowpea as compared to sole cropping of maize and black cowpea. Highest production efficiency was recorded with 2:2 row ratio of maize + black cowpea intercropping pattern than rest of the planting patterns. This may be attributed to additional advantage of intercrop yield and higher economic value of intercropping of maize with legume at 2:2 row ratio realized the maximum production efficiency (Padhi, 2001).

Competitive relationship between maize and black cowpea was expressed as aggressivity. Positivity in aggressivity showed dominance of one crop to second one and vice versa in case of negative values. Row ratio of 2:2 of maize + black cowpea showed dominance of black cowpea over maize crop. This may be due to the fact black cowpea efficiently utilized nutrients, light space, moisture etc coupled with less intraspace and shading effect of maize. Similar results have been reported by Shah *et al.* (1991).

5.5 Effect of planting patterns on physico-chemical properties of soil after harvest

Various planting patterns showed that systems having black cowpea resulted in equal or slight decrease in soil reaction (Table 4.12). However, soil organic carbon (%) was found slightly reduced in maize sole cropping, whereas, planting patterns having black cowpea resulted in good organic carbon (%) after harvest of crops. This may be due to the fact that legumes accumulated greater amounts of microbial carbon in the soil than cereals. Similar results were noted by Walker *et al.* (2003). Intercropping of cereal and legume crops helps to maintain and improve soil fertility. Legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be extracted from the nodules into soil and be used by other plants growing nearby (Andrew, 1975).

Similar to organic carbon, intercropping patterns having black cowpea in the system showed that black cowpea fixed atmospheric nitrogen, which may be extracted from nodules into the soil whereas sole cropping of maize yield showed slight reduction in available nitrogen (kg ha^{-1}) in soil after harvest of crops. Available phosphorus and potassium content (kg ha^{-1}) were slightly reduced in all planting patterns in soil after harvest of crops as compared to initial values. This may be due to the fact that inclusion of black cowpea in the system might make extra soil N because annual legume contribute N through biological N-fixation (Padhi and Panigrahi, 2006 and Dahmardeh *et al.* 2010.

5.6 Effect of planting patterns on economics

Economics of various planting patterns revealed that highest gross and net returns as well as benefit: cost ratio followed a trend quite similar to LER, which were recorded with 2:2 row ratio of maize + black cowpea intercropping system (Table 4.13 and Fig. 12). This may be due to the fact that working out gross and net returns, the by-product yield being as important component was also taken into account as a result this character gave better assessment of the system. Here, it may be pointed out that higher gross return was the resultant of more total produce of the system. Similar results were noted by Padhi (2001) and Sunailkumar *et al.* (2005).

Chapter – 6

SUMMARY AND CONCLUSION

A field experiment was conducted during the *Kharif* season of 2012 at Experimental Farm of Division of Agronomy at main campus of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar to study the "Evaluation of black cowpea (*Vigna unguiculata* L.) as intercrop with maize (*Zea mays*. L) under Kashmir valley condition". The experiment consisted of seven cropping patterns viz., sole maize, sole black cowpea, maize(line sown) + black cowpea (broadcasted) and intercropping patterns of 1:1, 2:1, 2:2 and 2:3 row ratio of maize and black cowpea. All the seven treatments were replicated four times in a Randomized black design. The salient points of the investigation are summarized in this chapter.

6.1 Effect of planting patterns on black cowpea

- Sole cropping of black cowpea crops recorded higher plant population (at initial stage and at maturity) as compared to intercropping patterns.
- Days taken to different phonological stages of black cowpea (germination, nodulation, branching, flowering, pod formation, pod filling, pod picking and maturity) were lesser with sole cropping of black cowpea as compared to various intercropping patterns.
- Number of nodules plant $^{-1}$ and fresh weight (g) plant $^{-1}$ of black cowpea were recorded significantly higher in sole cropping of black cowpea at par with 2:2 row ratio of maize + black cowpea intercropping pattern over rest of the patterns.
- Dry matter accumulation plant^{-1} of black cowpea was significantly influenced by different planting patterns from 60 DAS onwards to 120 DAS (maturity). Sole cropping of black cowpea accumulated

significantly higher amount of dry matter plant^{-1} at all the stages except 30 days after sowing.

- Yield attributes of black cowpea viz., number of pods plant^{-1}, number of seeds pod^{-1} and 100-grain weight (g) were significantly affected by various planting patterns. Sole cropping of black cowpea registered highest number of pods plant^{-1}, number of seed pod^{-1} and 100-grain weight (g) as compared to intercropping patterns.
- Grain, stover and biological yields of black cowpea were significantly varied by various planting patterns. Maximum yields were recorded under sole cropping as compared to intercropping patterns. Among different intercropping patterns, 2:2 row ratio of maize + black cowpea recorded maximum grain, stover and biological yield of black cowpea.
- Similar to yields, harvest index (%) of black cowpea recorded under sole cropping was also significantly highest and statistically equal to 2:2 row ratio of maize + black cowpea intercropping patterns.

6.2 Effect of planting patterns on maize

- Sole cropping of maize recorded higher plant population (at initial stage and at maturity) as compared to intercropping patterns of maize + black cowpea.
- Days taken to various phenological stages of maize germination, emergence, knee high tasseling, silking and maturity were lesser with sole cropping of maize as compared to different intercropping patterns.
- Plant height of maize crop significantly differed due to intercropping systems at all the stages of crop growth. However, taller plants for the crop were observed under intercropping systems as compared to sole cropping.

- Dry matter accumulation plant^{-1} of maize was significantly affected by various planting patterns at all the stages of crop growth. In maize, highest dry matter accumulation was recorded under sole cropping of maize at all the stages.

- Yield attributes of maize were significantly affected by different intercropping patterns except number of cobs plant^{-1}. Sole maize registered highest grain weight (g) cob^{-1} and 100-grain weight (g) as compared to intercropping patterns. Number of cobs plant^{-1} remained unaffected during the year of experimentation.

- Grain, stover and biological yields of maize significantly varied due to different treatments. Maximum yields were recorded under sole cropping of maize followed by 2:1 and 2:2 row ratios of maize and black cowpea intercropping patterns.

- Harvest index (%) of maize was not affected by various planting patterns of maize + black cowpea. However, highest harvest index of maize was recorded under sole cropping of maize as compared to intercropping patterns.

6.3 Effect of planting patterns on intercropping indices

- The maximum maize equivalent yield, land equivalent ratio (LER) and production efficiency (PE) were greater in intercropping patterns of maize and black cowpea as compared to sole cropping of these crops. Highest maize equivalent yield, LER and PE was recorded under 2:2 row ratio of maize + black cowpea intercropping patterns as compared to rest at the planting patterns.

- Area time equivalent (ATER) of various planting patterns recorded highest under 2:2 row ratio of maize + black cowpea intercropping.

- Relative crowding coefficient (RCC) was highest with 2:1 row ratio of maize + black cowpea intercropping pattern. Dominance of crops in terms of aggressivity reflected that under 2;2 row ratio of maize + black cowpea intercropping patterns, black cowpea was found dominant over maize crop and recorded highest value.

6.4 Effect of planting patterns on soil physico- chemical properties

- Different intercropping patterns showed variable response on soil reaction, organic carbon (%), available nitrogen, phosphorus and potassium (kg ha^{-1}) in soil after harvest of maize and black cowpea. Planting patterns having black cowpea in the system resulted in maintaining soil reaction, organic carbon (%) and available nitrogen. Whereas, available phosphorus and potassium both were slightly reduced in all planting patterns.

6.5 Effect of planting patterns on economics

- Highest means gross and net returns and benefit: cost ratio were recorded in 2:2 row ratio of maize + black cowpea intercropping patterns over rest of the planting patterns.

CONCLUSION

In the light of the result summarized above, it can be concluded that intercropping of maize with black cowpea in 2:2 row ratio had highest maize equivalent yield, LER, ATER, production efficiency, aggressivity of black cowpea, gross return, net return and benefit: cost ratio, which were higher than other planting patterns. Hence, 2:2 row ratio of maize and black cowpea can be recommended for intercropping.

LITERATURE CITED

Agboola, A.A. and Fayeni, A.A. 1972. Fixation and excretion of nitrogen by tropical legumes. *Agronomy Journal* **64** : 409-412.

Aiyer, A.K. 1949. Mixed cropping in India. *Indian L. Agric. Sci*. **19**:439-543.

Alderch, S.R., Scott, W.O. and Leng, E.R. 1975. Modern crop production 2nd ed Champaign IL,USA, A and L Publications.

Ali, M. and Gupta, S. 2012. Carrying capacity of Indian agriculture : pulse crop. *Current Science* **102**(6) : 25.

Andrew, D. J. and Kassam A.H. 1975. The importance of multiple cropping in increasing world food supplies. **In** : Multiple cropping (Eds. Papendic, R. I. Sanchez, P.A. And Triplet, G.B.) Am. Soc. Agron. Sp. Pub. No. 27 Madison, Wis., p.10

Ansari, M.A., Rana, K.S., Rana, D.S., Ashok Kumar and Hariom, 2012. Effect of anti-transpirant and nutrient management on pearlmillet (*Pennisetum glaucum*)- pigeonpea (*Cajanus cajan*) intercropping system under rainfed conditions. *Indian Journal of Agronomy* **57**(4): 343-348.

Arvindkumar, Singh, S.N. and Gajendra Giri, 2004. Influence of planting ratio and fertilizer application on dry matter production LAI and nutrient content and uptake by maize and groundnut in intercropping. *Annals of Agricultural Research* **25**(2) : 283-288.

Balyan, J.S and Seth, Jagdish. 1989. Effect of cropping systems on maize production and their residual effect on succeeding wheat. *Indian Journal of Agronomy* **27**(1):57-60.

Banik, P., Midya, A., Sarkar, B.K., Gose, S.S. 2006. Wheat and chickpea intercropping system in an additive series experiment: advantages and weed smothering. *Eur. J. Agro*. **24** : 325-332.

Bhunia, R.S., Raja, K.S. and Mandal, B.B. 1991. Growth in intercrops of maize-peanut and mung beans. *Environment and Ecology* **9**(1):59-65.

*Cardoso, M.J., Freire Filho, F.R., Ribeiro, V.Q., Frota, A.B., Melo, F.B. 1993. Densidade de plantas no consórcio milho x caupi sob irrigação. *Pesquisa Agropecuária Brasileira* **28** : .93-99.

Chabi-Olaye, A., Nolte, C., Schulthess, F. and Borgemeister, C. 2002. "Effect of maize, cassava, cowpea and soybean intercropping on the population dynamics of stem borers and their natural enemies in the humid forest zones of Cameroon". A paper presented at the *2002 ESA Annual Meeting and Exhibition*.

Choudhary, V.K., Kumar, P. Suresh and Bajwati, R. 2012. Production potential, soil moisture and temperature as influenced by maize-legume intercropping. *International Journal of Sciences and Nature* **3**(1):41-46.

Chowdhury, M.K. and E.L. Rosario, 1994. Comparsion of nitrogen, phosphorus and potassium utilization efficiency in maize mungbean intercropping. *J. Agri. Sci. Comb.* **122** : 193-199.

Dahmardeh, M., Ghanbari, A., Syasar, B. and Ramroudi, M. 2009. Effect of intercropping maize with cowpea on green forage yield and quality evaluation. *Asian Journal of Plant Science* **8**(3):235-239.

Dahmardeh, M., Ghanbari, A., Syasar, B. and Ramroudi, M. 2010. The role of intercropping maize (*Zea mays* L.) and Cowpea (*Vigna unguiculata* L.) on yield and soil chemical properties. *African Journal of Agricultural Research* **5**(8):631-636.

Dapaah, H.K., Asafu-Agyei, J.N., Ennin, S.A. and Yamoah, C. 2003. Yield stability of cassava, maize, soybean and cowpea intercrops. *J. Agric. Sci*. **140** : 73-82.

Das, S.K. and Mathur, B.P. 1980. Relative performance of different *Kharif* legumes, as pure and intercrops in maize and their residual effect on wheat. *Indian Journal of Agronomy* **25**(4): 743-745.

Dhima, K.U., Lithourgidis, A.A., Vasilakoqlou, I.B., Dordas, C.A. 2007. Competation indicies of common vetch and creals intercropping in two seeding ratio. *Field Crops Research* **100** : 249-258

Dhingra, K.K., Dhillon, D.S. and Sharma, K. 1991. Performance of maize and mungbean intercropping in different planting patterns and orientations. *Indian J. of Agronomy* **36**(2): 207-212.

Donald, C.M. 1963 competition among crop and pasture plants. *Advances in Agronomy* **15**: 1-18.

Doswell, C.D, Paliwal, R.L. and Centrell, R.P. 1996. Maize in the 3rd world. Boulder, CO, USA Westview Press.

Duke, J.A 1983. Handbook of legumes of world economic importance. Plenum Press, New York.

Eaglesham, A.R. J., Ayanaba, A., Rama, V.R. and Eskew, D.L. 1992. Mineral N effect on cowpea and soyabean crops in a Nigeria soil : Amounts of nitrogen fixed and accrual to the soil. *Plant and Soil* **68** : 183-186.

Economic Survey (J&K Govt.). 2012-13. Economic survey of Jammu and Kashmir. pp.12.

Economic Survey 2012-13. Directorate of Economics and Statistics, Department of Agriculture and Cooperation New Delhi. pp 14-19.

Egbe, O.M., Alibo, S.E. and Nwueze, I. 2010. Evaluation of some extra-early-maturity cowpea varieties for intercropping with maize in Southern Guinea Savanna of Nigera. *Agric. Biol. J.N. Am.* **1**(5): 845-858.

FAOSTAT, 2010. http://r4dreview.org/2010/09/conserving-cowpea-using-gis-tools.

Fatoken, C.A., Tarawali, S.S., Singh, B.B., Korimawa, P.M. and Tamo, M. 2002. Challenges and opportunities for enhancing sustainable cowpea production. **In** : *Proceedings of the world cowpea conference III*, held at the International Institute of Tropical Agriculture (IITA),Ibadan, Nigeria, 4-8, September, 2000, IITA, Ibadan, Nigeria, pp. 214-220.

Galinant. W.C. 1988. The orign of corn. **In** : *Corn and corn improvement* (Eds. G.F. Sprague and J.W. Dudly). 3rd ed., pp 1-3. Madison, W.I. U.S.A. American Society of Agronomy.

Gangaiah, B. 2004. Fodder production potential of pure and intercropped cereal and legume forages under rainfed conditions. *Annals of Agricultural Research* **25**(2): 229-232.

Garrity, D.P., Akinnifesi, F.K., Ajayi, O.C., Weldesemayat, S.G., Mowo, J.G., Kalinganire, A., Larwanou, M. and Bayala, J. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. *Food Security* **2** : 197-214.

Ghanbari, A., Dahmardeh, M., Siahsar, B.A. and Ramroudi, M. 2010. Effect of maize (*Zea mays* L.) - cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in and environment. *Journal of Food Agr. Environ*. **8**:102-108.

Ghosh, P.K. 2004. Growth and yield competition and economics of groundnut/ cereal fodder intercropping system in the semi-arid tropics of India. *Field Crop Research* **88**(2-3): 227-237.

Hastrman, O.B., Russele, M.P. and Heichel, G.H. 1987. Nitrogen utilization fomr fertilizer and legume residues in legume-corn rotations. *Agron. J*. 79 : 726-731.

Horwith, B. 1984. A role for intercropping in modern agriculture. *Biosic*. **35** : 286-291.

Hugar, H.Y. and Palled, Y.B. 2008. Effect of intercropping vegetables on maize and associated weeds in maize-vegetable intercropping systems. *Karnataka J. Agric. Sci.* **21**(2): 159-161.

Hussain, N., Shamsi, I.H., Khan, S., Akbar, H. and Shah, A.W. 2003.Effect of legume intercrops and Nitrogen levels on the yield of performance of maize. *Asian J. of Plant Sciences* **2**(2) : 242-246.

Ifenkwe, O.P. and Odurukwe, S.O. 1990. Patato/mize intercropping in the jos plateau of Nigeria. *Fld.Crop Res.* **25** :75-82.

Jackson, M.L. 1967. Soil chemical analysis. Prentice Hall. Inc. England, Cliffs, N.J.

Jackson, M.L. 1973. Soil chemical analysis-Prentice Hall of India Prvite Limited, New Delhi.

Javanmard, A., Dabbagh, Mohammadi-Nasab A., Javanshir, A., Moghaddam, M. and Janmohammadi, H. 2009. Forage yield and quality in intercropping of maize with different legumes as double-cropped. *Journal of Food, Agriculture and Environment* **7**(1):163-166.

Jayanthi, C., Chinnusamy, C., Veerabadran, V. and Rangasamy, P. 1994. Production potential of compatible fodder cereal-legume mixtures in the North-Western Zone of Tamil Nadu. *Madras Agri. J*. **81**(8): 420-422.

Jensen, J.R., Bernhard, R.H., Hansen, S., Donagh, J., Moberg, J.P., Nielson, N.E. and Nordbo, E. 2003. Productivity in maize based cropping, systems under various soil-water-nutrient management strategies in semiarid, alfisol environment in East Africa-Agric. *Water Management* **59** : 217-237.

Jeranyama, P., Hesterman, O.B., Waddington S.R. and Harwood, R.R. 2000. Relay intercropping of Sunhemp and cowpea into a smallholder maize system in Zimbabwe. *Agronomy Journal* **92**: 239-244.

Jose, S., Gillerspie, A.R., Seifert, J.R., Mengel, D.B. and Pope. 2000. Defining competition n vectors in temperate alley cropping system in the mid Western USA.3.Competition for nitrogen and litter decomposition dynamics. *Agroforestry Systems* **48** : 61-77.

Kalra, G.S. and Gangwar, B. 1980. Economics of intercropping of different legumes with maize at different levels of N under rainfed conditions. *Indian J. Agronomy* **25**: 181-185.

Khan, A.G., Nadeem, M. A., Ali, A. and Bhatti, M.B. 1987. Comparative effiency of different varieties of cowpea for production and nutritive value under ranifed.

Kimaro, A.A., Timmer, V.R., Chamshama, S.A.O., Ngaga, Y.N. and Kimaro, D.A. 2009. Competition between maize and pigeon pea in semi-arid Tanzania: Effect on yields and nutrition of crops. *Agric. Ecosys. Environ.* **134**: 115-125.

Kumar, V. and Yusuf, Y. 1991. Effects of row arrangements and component density of mixture on cotton-millet, cotton-groundnut and cotton-maize. *Niger. Agric. J.* **16** : 43-53.

Kumwenda, J.D.T., Waddington, S.R., Snapp,S.S., Jones, R.B. and Blackie, M.J., 1997. Soil fertility management in Southern Africa. **In** : *Afrier, CO, ca's emerging maize revolution* (Eds. Byerlee D. and Eicher, C.K.), pp 157-172.

Kushwaha, B.L. and De, R. 1987. Studied of resource use and yield of mustard and chickpea grown in intercropping systems. *J Agric. Sci., Camb*. 108:487-495.

Langat, M., Mukwana, E. and Woomer, P.L. 2000 "MBILI update: Testing an innovative cropping arrangement." Sustainable Agricultural Centre for Research and Development in Africa (SACRED AFRICA), Bungoma, Kenya.

Li, L., Sun, J.H., Zhang, F.S., Li, X.L., Yang, S.C. and Rengel, Z. 2006. Wheat/maize or wheat/soybean strip intercropping I. Yield advantage and inter-specific interactions on nutrients. *Field Crops Research* **71**: 123-137.

Lima, A.F. and Lopes, L.H.O. 1979. Plant population and spatial arrangement study on the intercropping of maize and beans (*Phaseolus vulgaris* L.) in Northeast Brazil. **In** : *International Workshop On Intercropping,* Patancheru Proceedings. Patancheru : ICRISAT, 1981, pp. 41-45.

Lithourgidis, A.S., Vasilakoglou, I.B., Dhima, K.V., Dordas, C.A. and Yiakoulaki, M.D. 2006. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crops Research* **99** : 106-113.

Luiz, B.M. and Willey, R.W. 2008. Optimum plant population for maize-bean intercropping system in the Brazilian semi-arid region. *Scientific Agriculture* **65**: 474-480.

Madgo, and Willey, 2008. Optimum Plant Population for Maize-Bean Intercropping System. **In** : *The Brazilian Semi-Arid Region1embrapa* Ed. Semi-Árido, C.P.), 23-56301-970, Brasil.

Mandal, B.K., Dhara, M.C., Mandal, B.B., Das, S.K. and Nandy, R. 1990. Rice, mungbean, soybean, peanut, ricebean and blackgram yields under different intercropping systems. *Agronomy J.* **82**: 1063-1066.

Maurice, *et al*. 2010. Altering the time of intercropping cowpea (*Vigna unguiculata* (L.) Walp) relative to maize (*Zea mays* L.): a food production strategy to increase crop yield attributes in Adamaea-Cameroon. *World Journal of Agriculture Sciences* **6**(5): 473-479.

Morgado, L.B. and Willey, R.W. 2003. Effect of plant population and nitrogen fertilizer on yield and efficiency of maize-bean intercropping. *Pesquisa Agropecuária Brasileira* **38** : 1257-1264.

Mpairwe, D.R., Sabiiti, E.N., Ummuna, N.N., Tegegne, A. and Osuji, P. 2002. Effect of intercropping cereal crops with forage legumes and source of nutrients on cereal grain yield and fodder dry matter yields. *Afr. Crop Sci. J.* **10**: 81-97.

Muoneke, A. 2007. Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savannah agroecosystem. *African Journal of Agricultural Research* **2**(12) : 667-677.

Myaka, F.A. 1995. Effect of time of planting pattern of different cowpea cultivars on yield of intercropped cowpea and maize in tropical sub-humid environment. *Tropical Science* **25** : 274-479.

Nair, K.P.P., Patel, U.K., Singh, R.P. and Kaushik, M.K. 1979. Evaluation of legume intercropping in conservation of fertilizer nitrogen in maize culture. *J. Agric. Sci. Cambridge* **93** : 189-194.

Ofori, F. and Stern, W. R. (1987) Cereal-Legume intercropping systems. *Advances in Agronomy* **41** : 41-90.

Ofori, F. and Stern, W.R. 1986. Maize-cowpea intercrop system: effect of nitrogen fertilizer on productivity and efficiency. *Field Crops Research* **14** : 247-261.

Ogbuehi, C.R.A. and Orzolek, M.D. 1987. Intercropping carrot and sweet corn in a multiple cropping system. *Sci. Hort*. **31**:17-24.

Oljaca, S., Cvetkovic, R., Kovacevic, D., Vasic, G. and Momirovic, N., 2000, Effect of plant arrangement pattern and irrigation on efficiency of maize and bean intercropping system. *The Journal of Agricultural Sciences* **135** : 261-270.

Olsen, S.R, Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorous in soil by extraction with sodium bicarbonate- U.S. Deptt., Agricultural Circulation 939, p. 19.

Olufermi, O., Pitan, R. and Odebiyi, J.A. 2001. The effects of intercropping with maize on the level of infestation and damage of pod-sucking bugs in the cowpea. *Crop Protection* **20** : 367-372.

Padhi, A.K. 2001. Effect of vegetable intercropping on productivity, economics and energetics of maize (*Zea mays* L.). *Indian Journal of Agronomy* **46**: 204-210.

Padhi, A.K. and Panigrahi, R.K. 2006. Effect of intercrop and crop geometry on productivity, economics, energetic and soil fertility status of maize (*Zea mays*) - based intercropping system. *Indian J. Agron.* **51**(3): 174-177.

Pandita, A.K., Shah, M.H. and Bali Amarjit, S. 1998. Row ratio of maize (*Zea mays*)-legume intercropping in temperate Valley conditions. *Indian J. of Agricultural Sciences* **68**(10) : 633- 635.

Patel, J.R. and Rajagopal, S. 2001. Production potential of forage maize *(Zea mays)* with legumes under intercropping system. *Indian J. Agronomy* **46**(2): 211-215.

Pereirafitho, I.A., Oliveira, A.C., De, Cruz, J.C. and Oliveria, A.C. 2000. Maize and common bean intercropping system with double and single maize rows, *Pesquisa Agropernaria Brasilira* **35**: 5.

Piper, C. S. 1966. Soil and Plant Analysis. Academic Press, New York.

Rana, R.S., Bhupinder Singh, Negi, S.C. and Singh, B. 2001. Management of maize-legume intercropping under mid-hill subhumid conditions. *Indian Journal of Agricultural Research* **35** : 100-103.

Rao, M.R. and Mathuva, M.N. 2000. Legumes for improving maize yields and income in semi-arid Kenya. *Agrioc Ecosys Environ* **78** : 123-137.

Reddy, J. and Reddi, M.R. 1981. Studies on intercropping maize under varied row spacing, *Indian J. of Agronomy* **26**(3):360-362.

Reddy, K.C., Visser, P.L., Klaij, M.C. and Renard, C. 1994. The effects of sole and traditional intercropping of millet and cowpea on soil and crop productivity. *Exp. Agric*. **30** : 83-88.

Reddy, M.S., Floyd, C.M. and Willey, R.W. 1980. Groundnut in intercropping systems. **In** : *Proceedings of International Workshop on Groundnut*, India, 13-17, October, pp.133-142.

Saban, Y., Mehmt, A. and Mustafa, E. 2007. Identification of Advantages of Maize-Legume Intercropping over Solitary Cropping through Competition Indices in the East Mediterranean Region. *Turk. J. Agric*. **32**: 111- 119.

Salunkhe, C.D., Patil, E.N. and Patil, D.F. 1990. Intercropping of important legumes in *kharif* sorghum. *Journal of Maharashtra Agricultural Universities*, **15** : 182-184.

Scarle, P.G.E., Cumudon, Y., Seeden, D.C. and Nanco, R.A. 1981. Effect of maize and legume intercropping systems and fertilizer N on crop yields and residual N. *Field Crop Research* **4**: 133-145.

Shah, M.H., Koul, P.K., Khanday, B.A. and Kschoo, D. 1991. Production potential and monetary advantage index of maize intercropped with different grain legume. *Indian J. Agron*. **36**(1) :23-28

Shumba, E.M., Dhiwayo, H.H. and Mukoko, O.Z. 1990. The potential of maize-cowpea intercropping in low rainfall areas of Zimbabwe. *Zimbabwe J. of Agric. Res*. 28 : 33-38.

Silwana, T.T. and Lucas, E.O. 2000.The effect of planting combinations and weeding on yield of component crop of maize/ beans and maize/pumpkin intercrops. *J. Agric Sci*. **138**,193-200.

Singh, B.B. 2002. Recent genetic studies in cowpea. **In** : *Challenges and opportunities for enhancing sustainable cowpea production* (Eds. Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M. and Tamò, M.). *Proceedings of the World Cowpea Conference III*, held at the International Institute of Tropical Agriculture IITA), Ibadan, Nigeria, 4-8 September 2000. pp 3-13.

Singh, D.P., Rana, N.S. and Singh, R.P. 2000. Growth and yield of winter maize as influenced by intercrops and nitrogen application. *Indian Journal of Agronomy* **45**(3): 515-519.

Singh, U., Saad, A.A. and Singh, S.R. 2008. Production potential, biological feasibility and economic viability of maize (*Zea mays*)-based intercropping system under rainfed conditions. *Indian J. Agric. Sci.* **78**(12) : 1023-1027.

Subbarao, G.V., Renard, C.R., Payne, W.A. and Bationo, A.B. 2000. "Long-term effects of tillage, phosphorus fertilization and crop rotation on pearl millet/ cowpea productivity in West Africa. *Exploratory Agriculture* **36** : 243-264.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soil. *Current Science* **31**: 96.

Sullivan, P. 2003. "Intercropping principles and production practices". *Agronomy Systems Guide*, University of Arkansas, Fayetteville, 16 p.

Sullivan, P. 2003. Intercrop principles practices (Agronomy system guide) ATTRA-National Sustanable Agriculture Information Service-pp 1-12.www.atara.org/attar-pub/intercrop. Html.

Sunilkumar, Rawat, C.R. and Melkania, N.P. 2005, Forage production potential and economics of maize and cowpea intercropping under rainfed conditions. *Indian Journal of Agronomy* **50**(3): 184-186.

Tamkin, F.O. 2012. Advantage of maize-cowpea intercropping over sole cropping through competition indicies. *J. Agric and Biodiversity Research* **1**(4):53-59.

Thakur, N.S., Pannse, S.K. and Sharma, R. S. 2000. Production potential of gram (*Cicer arietinum*) based intercropping systems under rainfed conditions. *Indian J. of Agronomy* **45**(3):534-539.

Tomer, P. S. 1976 Recommended agronomic practices for rasing forage crops. **In** : *Forage evaluation quality and processing technique for increasing animal productivity* (Eds. K. Pradhan and S.S . Khirwar). Dept. of Anim. Nutrition, College of Anim. Sci., Haryana Agric. University, Hissar, India, pp 26-37.

Tripathi, R.K., Pradhan, L. and Rath, B.S. 1997. Performance of maize (*Zea mays*) and cowpea (*Vigna ungiculata*) forage intercropping system in summer. *Indian Journal of Agronomy* **42**(1):38-41.

Tsubo, M., Mukhala, E., Ogindo, H.O. and Walker, S. 2003. Productivity of maize- bean intercropping in a semi-arid of South Africa. *Water SA* **29** : 381-388.

Tsubo, M., Walker, S. and Ogindo, H.O. 2005. A simulation model of cereal-legume intercropping systems for semi-arid regions II. Model application. *Field Crop Res* **93**: 23-33.

Vesterager, J.M., Nielsen, N.E. and Hogn-Jensen, N. 2008. Effect of cropping history and phosphorus source on yield and nitrogen fixation in sole and intercropped cowpea-maize systems. *Nutrient Cycling Agroecosystems* **80**:61-73.

Vyas, A.K. and Rai, R.K. 1993. Effect of planting patterns and phosphorous levels on phosphorous uptake and yield of mustard and chickpea under rainfed condition. *Annals Agric. Research* **12**(4):378-382.

Walker, T.S., Bais, H.P., Grotewold, E. and Vivanco, J.M. 2003. Root exudation and rhizosphere biology. *Plant Physiology* **132** : 44-51.

Watiki, J.M., Fukai, S., Banda, J.A. and Keating B.A., 1993. Radiation interception and growth of maize-cowpea intercrop as affected by plant density and cowpea cultivar. *Field Crop Res*. **35** : 123-133.

Willey, R.W. 1975. The use of shade in coffee, cocoa and tea. *Hort. Abst* .**45**: 791-798.

Willey, R.W. 1979. Intercropping its importance and research needs. Partl. Competition and yield advantage. *Field Crops Abst*. **32** : 1-10.

Witcombe, J.R., Billore, M., Singhal, H.C., Patel, N.B., Tikka, S.B.S, Saini, D.P., Sharma, L.K., Sharma, R., Yadav, S.K. and Pyadavendra, J. 2008. Improving the food security of low-resource farmers : Introducing horse gram into maize-based cropping systems. *Expl. Agric*. **44**: 339-345.

Yadav, P.K., Vishram Ram., Anil Pratap Singh Dohere and Ram Ruch 2013. Effect of row ratio and phosphorus fertilizer in chickpea (*Cicer arietinum*) and mustard (*Brassica juncea*) intercropping system. *Indian journal of Agronomy* **58**(2): 198-202.

Yunusa, I.A.M. 1989. Effect of planting density and plant arrangement pattern on growth and yield of maize (*Zea mays*. L.) and soyabean (*Glysine max*. L Merr.) grown in mixture. *J. of Agri. Sci*. (Camb.) **112** : 1-8.

***Original not seen**

APPENDIX-I

Mean weekly meteorological parameters during the crop growth period of (*Kharif*, 2012)

SWM*	Temperature (^oC)		Rainfall (mm)	Relative humidity (%)		Sunshine (hrs)
	Max.	Min.		Mix.	Min.	
19	23.2	9.61	15	83.57	62.42	5.14
20	22.4	8.92	12	79.85	58.71	7.51
21	21.6	9.51	16.8	83.57	62.57	5.2
22	29.9	9.58	3.4	71.66	43.66	9.46
23	24.1	10.82	8.4	81.28	59.57	4.92
24	27.2	11.6	1.6	79.57	46.28	8.17
25	30.3	14.78	0	77.57	41.71	8.77
26	28.6	14.07	1.8	79	47.57	9.27
27	32.8	17.52	1	75	42.71	9
28	28.4	16.21	18.6	82.42	62.57	4.21
29	30.9	15.64	3.4	80.85	48.14	9.08
30	32.6	17.14	9.2	82.85	43.28	9.54
31	30.2	16.35	4.2	83.71	55.14	4.87
32	29.4	16.47	31.2	83.42	55.85	6.25
33	29.3	18.37	23.6	85.42	55.57	5.54
34	32.1	19.3	1.8	82.28	47.85	5.97
35	31.6	16.47	1	77.42	49.85	8.2
36	24.6	16.85	39.2	89.85	68	1.57
37	26.8	16.12	34.8	93.14	72.28	6.05
38	25.1	11.11	11.4	88.42	64.28	6.67
39	26.6	8.57	0	90	56.42	7.94

*SWM = Standard Meteorological Weeks

*Max. = Maximum

*Min. = Minimum

APPENDIX-II

Effect of various planting patterns on days to different phenological stages of black cowpea

Treatment	Days to different phenological stages of black cowpea							
	Germination	Nodule formation	Branching	Flowering initiation	Pod formation	Pod filling	Pod picking (Physi-ological Maturity)	End of pod picking (harvesting)
Maize sole	-	-	-	-	-	-	-	-
Black Cowpea sole	4.25	38.25	47.91	59.00	65.67	72.15	91.50	119.50
Maize + Black Cowpea (Broadcast)	5.25	39.25	48.87	60.37	67.62	74.62	94.50	121.50
Maize + Black Cowpea (1:1)	4.25	40.00	49.12	60.62	68.75	73.12	94.50	125.50
Maize + Black Cowpea (2:1)	5.25	41.25	48.62	60.75	70.25	72.08	95.25	124.50
Maize + Black Cowpea (2:2)	4.50	41.00	49.37	59.37	68.62	74.00	93.50	125.50
Maize + Black Cowpea (2:3)	4.75	40.25	48.62	59.87	69.12	74.25	95.50	124.50

Appendix-III

Effect of various planting patterns on days to different phenological stages of maize

Treatment	Days to different phenological stages of maize								
	Germi-nation	Emergence	Knee high	50% knee high	Tasseling	50 % Tasseling	Silking	50 % Silking	Maturity
Maize sole	4.50	8.50	40.25	45.50	71.50	81.00	76.33	80.25	134.50
Black Cowpea sole	-	-	-	-	-	-	-	-	-
Maize + Black Cowpea (Broadcast)	4.50	8.75	41.75	47.75	72.00	82.00	77.00	92.50	135.50
Maize + Black Cowpea (1:1)	4.50	8.25	43.25	48.25	71.50	81.75	76.50	92.25	136.50
Maize + Black Cowpea (2:1)	4.50	8.50	41.75	47.25	72.50	82.75	78.12	91.75	136.50
Maize + Black Cowpea (2:2)	4.50	9.00	39.00	46.75	72.50	81.62	77.87	90.00	135.50
Maize + Black Cowpea(2:3)	5.00	9.00	40.50	47.50	73.00	82.37	78.00	91.25	135.50

Appendix -IV

Analysis of variance for plant population (m^{-2}) of black cowpea

Source of Variation	Degree of freedom	Mean sum of square	
		Black cowpea plant population (m^{-2}) at 30 DAS	Black cowpea plant population (m^{-2}) at maturity
Replication	3	13.482	9.998
Treatment	5	261.058	226.236
Error	15	0.461	0.434
Total	23		

Appendix -V

Analysis of variance for number of nodules per plant and nodule fresh weight (g $plant^{-1}$) at flowering stage

Source of Variation	Degree of freedom	Mean sum of square	
		Number of nodules per plant at flowering stage	Nodule fresh weight (g $plant^{-1}$) at flowering stage
Replication	3	0.00008	0.0000006
Treatment	5	0.0151	0.0000003
Error	15	0.00002	0.0000006
Total	23		

Appendix -VI

Analysis of variance for dry matter accumulation (g $plant^{-1}$) of black cowpea at 30 days intervals

Source of Variation	Degree of freedom	Mean sum of square			
		At 30 DAS	At 60 DAS	At 90 DAS	At 120 (Harvest)
Replication	3	0.009	0.181	0.261	0.007
Treatment	5	0.021	0.870	8.701	8.235
Error	15	0.008	0.132	0.113	0.016
Total	23				

Appendix –VII

Analysis of variance for yield attributes of black cowpea

Source of Variation	Degree of freedom	Mean sum of square		
		Number of pods $plant^{-1}$	Number of seeds pod^{-1}	100 grain weight (g)
Replication	3	0.954	0.166	0.010
Treatment	5	4.960	2.466	0.433
Error	15	2.038	0.733	0.009
Total	23			

Appendix -VIII

Analysis of variance for yield and harvest index of black cowpea

Source of Variation	Degree of freedom	Mean sum of square			
		Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Replication	3	0.041	0.083	0.098	0.343
Treatment	5	20.525	69.077	160.338	5.473
Error	15	0.127	0.019	0.211	0.555
Total	23				

Appendix -IX

Analysis of variance for plant population (m^{-2}) of maize

Source of Variation	Degree of freedom	Mean sum of square	
		Maize plant population (m^{-2}) at 30 DAS	Maize plant population (m^{-2}) at maturity
Replication	3	3.807	5.261
Treatment	5	0.042	0.044
Error	15	0.146	0.057
Total	23		

Appendix -X

Analysis of variance for plant height (cm) at different phenological stages of maize

Source of Variation	Degree of freedom	Mean sum of square			
		Knee high	Tasseling	Silking	Maturity
Replication	3	17.721	828.944	51.666	10.194
Treatment	5	14.164	684.950	17.500	10.725
Error	15	4.371	267.561	4.808	3.369
Total	23				

Appendix -XI

Analysis of variance for dry matter accumulation (g plant^{-1}) of maize at 30 days intervals

Source of Variation	Degree of freedom	Mean sum of square			
		At 30 DAS	At 60 DAS	At 90 DAS	At 120 (Harvest)
Replication	3	0.107	26.132	5.562	150.041
Treatment	5	0.758	119.821	2677.150	1968.473
Error	15	0.027	8.484	79.058	115.008
Total	23				

Appendix -XII

Analysis of variance for yield attributes of maize

Source of Variation	Degree of freedom	Mean sum of square		
		Number of cobs plant^{-1}	Grain wt. cob^{-1}	100-grain weight (g)
Replication	3	0.004	0.108	0.138
Treatment	5	0.003	4.344	0.485
Error	15	0.003	0.406	0.096
Total	23			

Appendix -XIII

Analysis of variance for yield and harvest index of maize

Source of Variation	Degree of freedom	Mean sum of square			
		Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Replication	3	13.629	2.694	27.041	1.296
Treatment	5	25.619	8.900	55.900	2.281
Error	15	6.995	2.856	8.4000	0.903
Total	23				

APPENDIX-XIV

Cost of cultivation details (Maize)

S. No.	Operations	Units used	Rate (Rs.)	Cost (Rs.)
1.	Field preparation			
	Tractorization			4000
2.	Fertilizers and Manure			
	a) FYM	10 ha^{-1}	600.00 t^{-1}	6000
	b) Urea	120 kg	5.86 kg^{-1}	703.00
	c) DAP	60 kg	20.90 kg^{-1}	1254.00
	d) MOP	30 kg	5.35 kg^{-1}	160.00
	e) Zn	20 kg	67 kg^{-1}	1340.00
	f) Fertilizer application	2 mandays	125 $manday^{-1}$	250
3.	Sowing operation			
	a) Sowing	30 mandays	125 $manday^{-1}$	3750
	b) Seed	20 kg ha^{-1}	25 kg^{-1}	500
4.	Insecticides			
	a) Phorate	20 kg ha^{-1}	75 kg	1500
	b) Phorate application	1 manday	125 $manday^{-1}$	125
5.	Irrigation (2 times)	4 $manday^{-1}$ Irrigation	125 $manday^{-1}$	1000
6.	Hoeing, weeding, thinning, earthing up	60 manday	125 $manday^{-1}$	7500
7.	Watch and ward	15 manday	125 $manday^{-1}$	1875
8.	Cob picking and harvesting	44 manday	125 $manday^{-1}$	5500
9.	Draying	3 manday	125 $manday^{-1}$	375
10.	Shelling and winnowing	10 manday	125 $manday^{-1}$	1250
	Total			37082

APPENDIX-XV

Cost of cultivation details (Black Cowpea)

S. No.	**Operations**	**Units used**	**Rate (Rs.)**	**Cost (Rs.)**
1.	Field preparation			
	Tractorization			4000
2.	Fertilizers and Manure			
	a) FYM	10 ha^{-1}	600.00 t^{-1}	6000
	b) Urea	30 kg	5.86 kg^{-1}	175
	c) DAP	60 kg	20.90 kg^{-1}	1254
	d) MOP	30 kg	5.35 kg^{-1}	160
	f) Fertilizer application	1 mandays	125 $manday^{-1}$	125
3.	Sowing operation			
	a) Sowing	40 mandays	125 $manday^{-1}$	5,000
	b) Seed	40 kg ha^{-1}	80 Kg^{-1}	3200
4.	Insecticides			
	a) Phorate	20 kg ha^{-1}	75 Kg	1500
	b) Phorate application	1 manday	125 $manday^{-1}$	125
5.	Irrigation (2 times)	4 $manday^{-1}$ Irrigation	125 $manday^{-1}$	1000
6.	Hoeing, weeding, thinning.	60 manday	125 $manday^{-1}$	7500
7.	Watch and ward	15 manday	125 $manday^{-1}$	1875
8.	Pod picking and harvesting	44 manday	125 $manday^{-1}$	5500
9.	Drying	3 manday	125 $manday^{-1}$	375
11.	Shelling and winnowing	10 manday	125 $manday^{-1}$	1250
	Total			39,039

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar Campus Srinagar – 190 025

CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Gulzar Ahmad Wani, Professor (Retired), Division of Agronomy, SKUAST-Kashmir, Shalimar during Viva-Voce examination held on 05th of March, 2014 have been incorporated in the manuscript entitled **"Evaluation of Black Cowpea (*Vigna unguiculata* L.) as Intercropped with Maize (*Zea mays* L.) under Kashmir Valley Condition"** submitted by **Ms. Ramesa Jan (Regd. No. 2011-A-871-M).**

(Dr. Amal Saxena)
Chairman
Advisory Committee