CHILLI-AMARANTH INTERCROPPING SYSTEM UNDER FERTIGATION

By

ANITROSA INNAZENT

(2016-11-037)

THESIS

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DECLARATION

I, Anitrosa Innazent (2016-11-037) hereby declare that the thesis entitled **"Chilli-Amaranth intercropping system under fertigation"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that the thesis entitled **"Chilli-Amaranth intercropping system under fertigation"** is a record of research work done independently by **Miss. Anitrosa Innazent** (2016-11-037) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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Introduction

1. INTRODUCTION

India ranks second in vegetable production (next only to China), contributing to 12 percent of world's production. The estimated production of vegetables in Kerala is 8.25 lakh MT as against the requirement of 36.7 lakh MT. However for increasing vegetable production, there is no scope for horizontal expansion of the area. Increasing cropping intensity is one of the possible ways of enhancing agricultural production through better utilization of available but scarce resources. Cropping intensity could be increased by adoption of multiple cropping. The intercropping system which involves raising of more than one crop on the same piece of land more or less simultaneously increases the cropping intensity both in space and time dimensions. So apart from encouraging large scale cultivation of vegetables in general, technology needs to be generated to include vegetables in the intercropping systems.

Importance of intercropping in India was highlighted way back by Aiyer (1949). Intercropping provides an opportunity for efficient use of the plant nutrients from different horizons. Intercropping may also lead to increased production per unit area, per unit time without affecting the production level of main crop to a great extent. Willey (1979) reported that, intercropping can provide substantial yield advantages compared to sole cropping. These advantages are especially important because they are achieved not by means of costly inputs but by the simple expedient of growing crops together. There is advantage of greater stability in yield over different seasons. This is very important for the resource poor farming people. The other form of advantage is the higher production in a given season. A major cause of yield advantages perhaps is attributed to better use of growth resources along with reduced incidence of pests including weeds.

Chilli (*Capsicum annuum* L.) is selected as base crop of the study, which is one of the important spice crops of India and also of the world used as condiment both as green and dry. The chilli cv. Ujwala, the most popular variety was ideal for cultivation in Kerala. The wider spacing of chilli can be effectively utilized for growing intercrops. Amaranth, one of the most preferred vegetable crops and short duration crop used mainly as leafy vegetable was intercropped in between chilli. The duration, critical stages and rooting pattern of amaranth cv. Arun was different from chilli cv. Ujwala.

Productivity of intercropping system can be enhanced by curtailing inter and intra species competition for various resources. This is possible only by selecting compatible crops, by adopting suitable planting geometry and by proper water and nutrient management. Because of its highly localized application and flexibility in scheduling water and fertilizer applications, fertigation has gained widespread popularity as an efficient and economically viable method for water and nutrient management. Research works on fertigation under intercropping situation is very limited. Input information on optimal schedules for micro-irrigation and fertigation and planting geometry for vegetable intercropping needs to be generated.

The present study is proposed against this back drop to assess the bio economic suitability of chilli- amaranthus intercropping system under different nutrient and water regimes.

Review of literature

2. REVIEW OF LITERATURE

Intensive agriculture through sequential and simultaneous raising of crops on the same piece of land in time may be the possible solution for meeting the ever growing need of the world, since extensive agriculture has limited scope. Cropping systems such as intercropping have major role in enhancing the production per unit area. Input information on optimal schedules for micro-irrigation, fertigation and planting geometry for intercropping needs to be generated.

The literature pertaining to yield response of intercropping of chilli and amaranth to different nutrient levels, irrigation levels, and plant geometry are presented in this chapter.

2.1 Crop suitability in intercropping system

The common advantage of intercropping system is to produce maximum yield on given piece of land by efficiently using resources. This depends on complementarity and difference in maturity of component crops.

In intercropping, component crops with different habit (both morphologically and physiologically) would exploit the environment efficiently than monocropping (Donald, 1963). Due to short duration, higher biosuitability and higher returns, vegetables play an important role in intercropping. Natarajan (1992) opined that intercropping with different vegetables would efficiently utilizes the land and resources.

2.1.1 Performance of chilli in intercropping system

Chilli is one of the major vegetable crops which is widely spaced and cultivated throughout the tropics and subtropics. Anitha and Geethakumari (2003) studied the production and economics of chilli- amaranth intercropping system and indicated that it is a viable system for summer fallows of Kerala.

Natarajan (1992) studied the performance of chilli in intercropping with bhindi, onion, coriander, green gram, black gram and cowpea under semidry conditions of Tamil Nadu and indicated that bhindi was found as the best intercrop for chilli recording the highest gross income under normal row system.

Suresha *et al.* (2007) reported that the yield of chilli were affected due to intercropping with radish, carrot, onion, garlic, cluster bean and dolichos bean. Maitra *et al.* (2001) opined that chilli could be intercropped with cotton in coastal alluvial clay loam soils under rainfed conditions.

The yield of chilli was affected when intercropped with tomato, coriander, garlic, onion, carrot, cotton, soybean, greengram, groundnut and stylosanthes (Manjunath *et al.* 2001). Mamun *et al.* (2002) reported that the yield components of chilli would be influenced by different combinations of mustard. Kurubetta *et al.* (2017) revealed that since least competition exists between the component crops, chilli could be intercropped with cotton and onion.

2.1.2 Performance of amaranth in intercropping system

Amma and Ramdas (1991) documented performance of amaranthus as intercrop under different cropping situations. Intercropping with amaranth not only increases the net return but also provide cultural weed control, fertility and moisture conservation and land use maximization (Awe and Abegunrin, 2009).

Brintha and Seran (2009) reported that the interspaces of radish could be best utilized for growing short duration vegetable like amaranth. Clark and Myers (1993) studied the intercrop performance of pearl millet, amaranth, cowpea, soybean and guar in response to planting pattern and nitrogen fertilization and observed yield reduction in amaranth when grown under narrow strip arrangement with cowpea based strip intercropping system. Thavaprakaash *et al.* (2005) studied the production potential of baby corn intercropping system with amaranthus or green gram under two planting geometry and revealed significance of crop geometry on the nutrient uptake in baby corn.

Anitha and Geethakumari (2001) observed intercropping chilli with amaranth as a potentially beneficial system of crop production. Singh *et al.* (2009) revealed that sugarcane performed better when intercropped with amaranthus than under sole cropping system. Dixit and Misra (1991) also reported suitability of sugarcane-amaranth intercropping system. Obadoni *et al.* (2010) suggested the suitability of amaranth as intercrop with bhindi.

2.2 Effect of planting geometry in intercropping system

For the development of a feasible and economically viable intercropping system, adaptation of planting pattern and choice of suitable compatible crops are needed. Thereby benefit of intercropping system can be efficiently utilised by depending on growth habit, land, solar radiation, water and fertilizer utilization.

Sivaraman and Palaniappan (1996) opined that in intercropping system, paired row planting will accommodate the interspaces of base crop with one or two rows of intercrop. The experiments conducted by Palaniappan *et al.* (1975) all over India indicated that paired row planting of sorghum produced similar yield as normal row planting.

Singandhupe *et al.* (2003) reported that compared to normal row planting, adoption of paired row planting not only saved fifty per cent lateral and emitter cost of drip irrigation system but also kept soil moisture in adequate quantity in both horizontal and vertical direction.

In a study conducted by Brintha and Seran (2009) indicated that most suitable planting system in sandy regosol is 20/50 cm paired row planting of radish intercropped with three rows of vegetable amaranthus in between paired rows of radish. They also suggested that the yield of radish was high in sole crop where the intercrop density is very minimum.

Thind *et al* (2008) suggested that paired row planting in cotton resulted in higher seed cotton yield with saving 25 per cent of irrigation water. Because of dense plant cover, higher water use efficiency is recorded for paired row planting though more water is available to each plant due to low evaporation of water (Allen *et al.*, 1998).

In a study conducted on radish based intercropping system, dry matter accumulation among different planting pattern in intercropping system was not significant, since utilization of sunshine for photosynthesis is uniform among crops (Brintha and Seran, 2009).

Oseni (2010) reported that yield of sorghum was comparatively higher in sole crop system than that in paired or normal row intercropping, presumably due to absence of competition from intercrop (cowpea). They also suggested that the relative crowding coefficient was not significantly different at different planting pattern.

Effect of planting geometry on cobs/plant and cob weight were not significant (Thavaprakaash *et al.*, 2005). They also reported that due to better availability of resources, higher yield attributes of maize was recorded under wider row spacing. Padhi *et al.* (2010) suggested that growing four rows of finger millet as an intercrop between two paired rows of pigeon pea was the most productive system than their sole cropping during rainy season.

Ahmad *et al.* (2007) observed that plant height and number of leaves were higher in sole crop than different planting pattern due to competition free environment under sole crop.

Khan *et al.* (2001) reported that number of bolls per plant and boll weight of cotton under 80 cm spaced single row and 120 cm spaced paired rows were not significant. Crop yields in intercropping system was directly affected by plant geometry (Yang *et al.* 2014). Pawar and Khade (1988) revealed non-significant difference due to planting pattern in sorghum when intercropped with gram.

In a study conducted by Ullah *et al.* (2007), maize based intercropping system LER of 135 cm spaced paired row planting of maize was less than 90 cm spaced normal row planting when intercropped with mungbean. Natarajan (1992) observed that yield of intercrops (onion, bhindi, coriander, green gram, black gram and cowpea) was higher in normal row planting than paired row planting.

Imran *et al.* (2011) reported that growth and yield factors were significantly affected by intercropping and crop geometry. In a study conducted by Kumar *et al.* (2013) higher number of leaves and leaf dry weight were reported with paired row planting than normal row planting in stevia based intercropping system. Kumawat *et al.* (2012) concluded that after the harvest, maximum available soil N, P and K was observed under sole pigeon pea followed by normal row and paired row intercropping system.

2.3 Effect of nutrient management in intercropping system

Below ground resource use inevitably involves a consideration of rooting patterns of the component crops involved in the intercropping system. Component crops may exploit different soil layers, thus in combination they may exploit greater total volume of soil. Recommendation of fertilizer requirement for an intercropping system which contains more than one crop with varying growth habit is influenced by their interactions. Effect of nutrient management on crop growth in intercropping system was reported by many workers.

Midmore (1993) reported that resource complementarity enhances the uptake of nutrients like P, K and micronutrients and thereby improves better rooting ability and ground cover of crops. Anitha and Geethakumari (2006) reported that to reap maximum biological and economic advantage from chilli based cropping system both, the crops should be supplied with 100 percent of the recommended dose as per POP.

Sharma *et al.* (2010) observed that in pigeon pea- green gram intercropping system application of different levels of fertilizers significantly influenced the plant height, pods/plant and seeds/pod. They also reported that different dose of fertilizers also showed significance on plant height, ear head weight and grain weight of pearl millet in pigeon pea and pearl millet intercropping system.

In a study conducted on wheat based intercropping system by Pandey *et al.* (2016), 100 per cent of the nutrient dose recorded significantly higher rate of NPK uptake than 75 and 50 per cent of the recommended dose.

Fanish *et al.* (2011) revealed that rooting depth of maize was affected by irrigation methods, different intercrops and fertilizer levels. They also reported that better root parameters was obtained with 100 per cent of recommended dose of fertilizer with 50 per cent P and K as water soluble fertilizers and 150 per cent of recommended dose of fertilizer.

Ghosh *et al.* (2006) opined that interaction between nutrient and cropping system in soybean- pigeon pea intercropping system resulted in better soybean equivalent yield than the sole crop of component crops.

Ghosh *et al.* (2009) reported a better nutrient management practice for soybean-sorghum intercropping system by application of 75 per cent of recommended dose of fertilizer along with FYM/poultry manure/phosphocompost during 60–80 DAS. Zhang and Li (2003) revealed that when wheat was intercropped with peanut and fababean, the nitrogen and phosphorus uptake increased. It was also reported that nitrate in soil profile was efficiently utilized by component crops in intercropping system.

Jensen (1996) opined that due toncomplementary use of soil and atmospheric nitrogen by component crops in intercropping system, a better yield advantage was obtained in pea-barley intercropping system. Ofori andStern (1987) reported that intercropping of non-lrgume crops with legumes increased the N fixation and thereby increase of nitrogen use efficiency.

Sawargonkar *et al.* (2008) concluded that maize based intercropping system recorded the highest B:C ratio at 100 per cent of recommended dose of fertilizer than 126 per cent and 75 per cent of recommended dose of fertilizer. Kumawat *et al.* (2012)

recorded highest net return (Rs. 117010 /ha) from normal row planting with 100 per cent of RDF followed by normal row planting with 50 per cent of RDF.

Bhagat *et al.* (2006) revealed that under intercropping system highest net return and B:C ratio was recorded for groundnut- sweet corn intercropping system with 125 per cent of RDF. Awasthi *et al.* (2011) observed chickpea- fennel intercropping system with 100 per cent of RDF efficiently performed well under intercropping system. Singh *et al.* (1993) revealed maximum net return of Rs. 29043/ha when crop grown with 150 kg N ha^{-1} than with 100 kg N ha^{-1}.

Giri *et al.* (2006) concluded that NPK uptake by cotton was significantly higher in sole cotton and blackgram intercropped with cotton and soybean intercropped with cotton. Somashekharappa *et al.* (2010) recorded that integrated application of recommended dose of fertilizer along with pressmud, zinc sulphate and lime enhanced nutrient uptake in chilli- groundnut intercropping system.

Singh and Ahuja (1990) observed higher yield of sorghum and N uptake when it was intercropped with legumes *viz.*, green gram, black gram, cluster bean or soybeans, than sole crop. In cotton based intercropping system, the NPK concentration and uptake by cotton significantly increased with increasing level of fertilizers (Kote *et al.,* 2005).

In a study conducted by Mallanagouda (1991) in chilli based intercropping system, highest nitrogen and phosphorus uptake was observed with chilli + onion combination (49.36 and 6.20 kg/ha, respectively), while potassium uptake was highest in chilli + garlic (30.84 kg/ha) combination. Pasalawar *et al.* (2004) revealed that cotton intercropped with soybean added nitrogen to soil to a significant level.

Yildrim and Guvenc (2005) noticed that cauliflower based intercropping system did not significantly vary from sole crop in case of uptake of nitrogen, phosphorus, potassium, calcium, magnesium and iron content. Anitha and Geethakumari (2001) reported nutrient uptake of chilli with french bean as intercrop was significantly superior (38.7, 13.1, 23.1 kg NPK/ha) than that of chilli with amaranthus as intercrop (20.8, 7.1, 10.7 kg NPK/ha) and pure crop (26.9, 9.5 and 18.20 kg NPK/ha) of chilli. More *et al.* (2005) observed that application of single superphosphate to green manures and their in situ incorporation in chilli + cotton cropping system resulted in significantly higher uptake of nutrients by chilli.

2.4 Effect of water management in intercropping system

Though the technology for water management is the same for sole and intercropping, additional water use by different crops in intercropping system need to be addressed. Scheduling of irrigation and water application may have to be done carefully under intercropping systems, if use of component is sensitive to excess water while the other crop need frequent irrigation. Research information as water management of intercropping system is rather limited and the available information is presented below.

Morris and Garrity (1993) observed that water uptake by intercrops is 7 per cent higher than by sole crop. Water use efficiency in wheat- spring maize intercropping (21.72 kg ha^{-1} mm^{-1}) was 23 per cent lower than sole maize crop and 4 per cent greater than sole crop of wheat (Gao *et al.*, 2009). In the study of maize- peas intercropping system, Mao *et al.* (2012) revealed maximum yield and WUE with a cropping system of 4 rows of maize with 4 rows of peas than system with 2 rows of maize and 4 rows of peas.

Hulugalle and Lal (1986) recorded that WUE in intercropping system is better than pure crop under limited water conditions. In the study of maize based intercropping system, maize- pea intercrop recorded higher WUE than sole maize (Kanton and Dennette, 2004). Singh *et al.* (2007) reported that nutrient uptake in maize- potato intercropping system increases with higher level of irrigation. Ahlawat and Gangaiah (2010) revealed intercropping of chick pea with linseed at 0.4 IW/CPE produced higher yield.

Increase in IW/CPE ratio significantly influenced plant height, leaf area index and yield attributes except number of cobs per plant of maize based intercropping

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system (Bharati *et al.* 2007). Degefa *et al.* (2016) reported 75 per cent ET of irrigation depth and 12 days of irrigation intervals is a better practice of water management in sugarcane- soyabean intercropping system during water shortage.

Sani *et al.* (2015) studied effect of irrigation levels on corn- soybean intercropping system and concluded that highest yield was obtained with pure crop of soyabean and irrigation levels had no significant effect on yield of soybean in intercropping. He also observed no significance on interaction between irrigation levels and cropping pattern in soybean- corn intercropping system

Hulugalle and Lal (1986) revealed senescence of soybean leaves in late March accompanied by an increase in water uptake by the chilli intercrop. The leaf water potential of the intercropped chilli was generally greater than that of the corresponding monocrops. Gab-Alla *et al.* (1986) observed simultaneous planting of maize and soybean in maize + soybean intercropping system resulted in maximum water use efficiency (WUE).

Higher water use and water use efficiency was observed in intercropping of soybean with sorghum and pigeon pea than sole crop (Prasad *et al.,* 1997). Ramulu and Gautam (1999) observed higher rainfall use efficiency with pearl millet + pigeonpea (2:1) intercropping system followed by pearl millet + groundnut (1:2) system compared to sole pearl millet. High nutrient and water uptake in intercropping system was attributed to differential duration and rooting pattern which enabled component crops to exploit different soil layers.

Fertigation improved fertilizer use efficiency of applied fertilizer through the drip system by placing it in the active plant root zone. Fertigation is profitable practice among farmers for obtaining higher yield and quality of vegetables with low doses of fertilizer and irrigation levels (Hartz and Hochmuth, 1996).

Singandhupe *et al.* (2003) indicated that application of ten equal splits of nitrogen at 8-days interval by fertigation saved 20- 40 per cent of nitrogen than furrow irrigation with two equal splits of nitrogen. He also reported that nutrient use efficiency was increased by frequent application of nitrogen as urea in drip irrigation though its adsorption as ammonium ions on soil clay minerals took longer period followed by a gradual formation of nitrate nitrogen.

Miller *et al.* (1976) observed that, higher value of fertilizer use efficiency and nutrient use efficiency at lowest level of fertilizer dose through fertigation. An experiment conducted to study the effect of different fertigation levels and intercrops in intensive maize based cropping system revealed that in maize and radish intercropping system, drip irrigation with 100 percent recommended dose of fertilizer recorded the highest gross income (Anitta and Muthukrishnan, 2011).

Adoption of fertigation resulted higher yield potential (thrice) by saving 45 to 50 per cent of water and productivity increased by 40 per cent. Sivanappan and Ranghaswami (2005) revealed better yield when fertilizer was applied through drip irrigation and 30 per cent of fertilizer could be saved. Fanish *et al* (2011) studied drip fertigated maize based intercropping system produced higher grain yield at 150 per cent of recommended dose of fertilizer.

2.5 Bio suitability of intercropping system

2.5.1 Biosuitability of chilli under intercropping

Kurubetta *et al.* (2017) reported that the intercropping treatments significantly differed for equivalent yield of dry chilli, when chilli was intercropped with onion and cotton. Mamun *et al.* (2002) observed that yield of chilli would be decreased by increasing the population of mustard. Ahmed et al. (2016) revealed that higher equivalent yield was produced when one row of maize was intercropped with three rows of chilli than sole crop.

Farhad *et al.* (2014) indicated that maximum complementary use of different growth resources in chilli - garlic intercropping system with the highest LER value. Natarajan (1992) revealed that yield of chilli got drastically reduced in intercropping system than sole crop. Higher equivalent yield and LER was recorded for intercropping soybean with chilli-cotton mixed cropping system than sole crop (Kagi, 1994).

Anitha and Geethakumari (2006) reported significantly higher chilli yield (4550 kg/ha), land equivalent ratio (2.74), land equivalent coefficient (1.53) and chilli equivalent yield (10421 kg/ha) were recorded with chilli + amaranthus intercropping.

DeCosta and Perera (1998) reported that greater radiation interception, lower weed growth, and different maturation period of chilli and dwarf bean were responsible for greater LER of intercrops. Tarafder *et al.* (2003) revealed that the highest chilli equivalent yield (2732 kg ha^{-1}) and land equivalent ratio (1.34) was obtained from 20 per cent of onion population intercropped with chilli.

2.5.2 Biosuitability of amaranth under intercropping

Clark and Myers (1993) studied that LER of amaranth and pearl millet grown in alternate rows with cowpea were not significantly different from their monocrops. Singh *et al.* (2009) observed that higher yield advantage (LER 1.92) was realized with sugarcane- amaranth intercropping system. Brintha and Seran (2009) observed that LER of radish- amaranth intercropping system exceeds unity which indicated yield advantage.

Krishnankutty (1983) studied on effect of amaranthus when intercropped with coconut garden and indicated that the yield of amaranth was drastically reduced. Reduction in yield due to intercropping was reported in radish and amaranth by Brintha and Seran (2009).

2. 6 Economics of intercropping system

Somashekharappa *et al.* (2010) reported that combined application of RDF, pressmud (10 t/ha), zinc sulfate (10 kg/ha) and lime (400 kg/ha) to chilli + groundnut intercropping system recorded higher gross returns (Rs. 61267/ha), net returns (Rs. 40142/ha) and B:C ratio (2.90) as compared to other treatments.

Study conducted by Shivaprasad (2008) indicated chilli + garlic intercropping accounted for significantly higher gross returns (Rs. 63000/ha), net returns (Rs. 42550/ha) and B:C ratio (3.08) compared to sole chilli and intercropping of chilli + coriander which were at par with each other. Kadalli *et al.* (1989) studied companion cropping of onion with chilli and frenchbean and indicated that chilli + onion followed by french bean gave 192 per cent higher income over growing chilli alone. Highest average chilli equivalent yield (2732 kg/ha), land equivalent ratio (1.34) and net returns (Rs. 46395/ha) were obtained from 20 per cent onion population intercropped with chilli indicating the practice of intercropping of chilli at different onion population was more profitable than the conventional monoculture of chilli (Tarafder *et al.*, 2003).

Economic analysis done by Suresha *et al.* (2007) for chilli based cropping system revealed that highest gross returns (Rs. 108766/ha), net returns (Rs. 59261/ha) and B:C ratio (1.75) were recorded with chilli + garlic intercropping compared to sole chilli.

2.6.1 Economic suitability of chilli under intercropping

Anitha and Geethakumari, (2006) reported that to reap maximum economic advantage from chilli based cropping systems both, the crops should be supplied with 100 percent of the recommended dose as per POP. Tarafder *et al.* (2003) found that additional income was fetched from intercropping chilli at different onion population.

Mamun (2002) studied the economics of chilli – mustard intercropping system and indicated that an additional net income of Rs.1937 per ha was obtained from intercropping system than sole crop. Suresha *et al.* (2007) noted that the highest gross returns and net returns was realized by intercropping garlic with chilli followed by cluster bean with chilli. The above studies revealed the suitability of chilli under intercropping.

Effect of planting geometry on economics of intercropping system is furnished below. Natarajan (1992) reported that gross return of chilli with bhindi under paired row planting was lower than normal row planting. Singh *et al.* (2009) reported that paired row planting of amaranth in autumn sugarcane with 150 per cent of recommended dose of fertilizer resulted in higher profitability and productivity. This system obtained a return of Rs. 78,135 /ha and B:C ratio of 3.14. Ramamoorthy *et al.* (2004) revealed that in case of intercropping between pigeon pea and finger millet, 2:4 row ratio produced higher net returns.

2.6.2 Economic suitability of amaranth under intercropping

Brintha and Seran (2009) reported that radish with amaranth occupies a greater land use and thereby provided higher net returns than sole crop. Obadoni *et al.* (2010) reported that the monetary advantage of amaranth-okra intercropping system was on par with pure crop of amaranth. Singh *et al.* (2009) studied on sugarcane- amaranth intercropping system and indicated that this fetched higher net return (Rs. 78135/ha) and B:C ratio of 3.14.

Materials & Methods

3. MATERIALS AND METHODS

A field study on "Chilli- Amaranth intercropping system under fertigation" was carried out during January 2017 to July 2017 at Water Management Research Unit, Vellanikkara, Thrissur. The details of materials used and methodology adopted for the study are briefly described in this chapter.

3.1 GENERAL DETAILS

3.1.1 Location

The experiment was conducted at Water Management Research Unit, Vellanikkara, Thrissur, Kerala. The field is located geographically at 13° 32'N latitude and 76° 26'E longitude, at an altitude of 40.3 m above mean sea level.

3.1.2 Season

The experiment was conducted during the period of January to July of 2017. Seedlings were transplanted during January.

3.1.3 Crop and variety

Chilli variety, Ujwala the most popular variety with long pods, dark green in colour, high degree of pungency was used for this study. Ujwala is a bacterial wilt resistant variety developed by Kerala Agricultural University. It is capable of producing yield over 8 t/ha.

Amaranth variety, Arun a high yielding variety, maroon red leaves, photoinsensitive, suitable for multicut was used for the experiment. It is capable of producing a yield of over 15 t/ha.

3.1.4 Soil characters

The soil texture was sandy loam. The initial data on physical and chemical analysis of the soils of experimental site are presented in Table 1.

Table 1. Physico –chemical characteristics of soil

Particulars	Value	Method used
a. Physical properties		
Bulk density (g/cm^3)	1.1 - 1.2	Core method (Piper, 1966)
Water holding capacity (%)	56.4	Core sampler method (Piper, 1966)
Mechanical composition		
Sand (%)	52.0	Robinson's International pipette method (Piper, 1966)
Silt (%)	23.5	
Clay (%)	24.5	
b. Chemical composition		
pH	5.38	Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1958)
Electrical Conductivity ($dS\ m^{-1}$)	0.145	Soil water suspension of 1:2.5 and read in EC meter (Jackson, 1958)
Organic carbon (%)	1.677	Walkley and Black method (Walkley and Black, 1934)
Available N (kg/ha)	214.2	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg/ha)	30.56	Ascorbic acid reduced molybdophosphoric blue colour method (Bray and Kurtz, 1945)
Available K_2O (kg/ha)	215.24	Neutral normal ammonium acetate extract using Flame photometer (Jackson, 1958)

3.1.5 Climate and weather conditions

The experimental site experiences a typical tropical humid climate. The mean weakly averages of important meteorological parameters were recorded (Fig.1). The maximum temperature during cropping period was 38°C and the minimum temperature was 20.9°C. The average RH during the crop growth period was 69.8%. A total rainfall of 1302.6 mm was received over 31 rainy days.

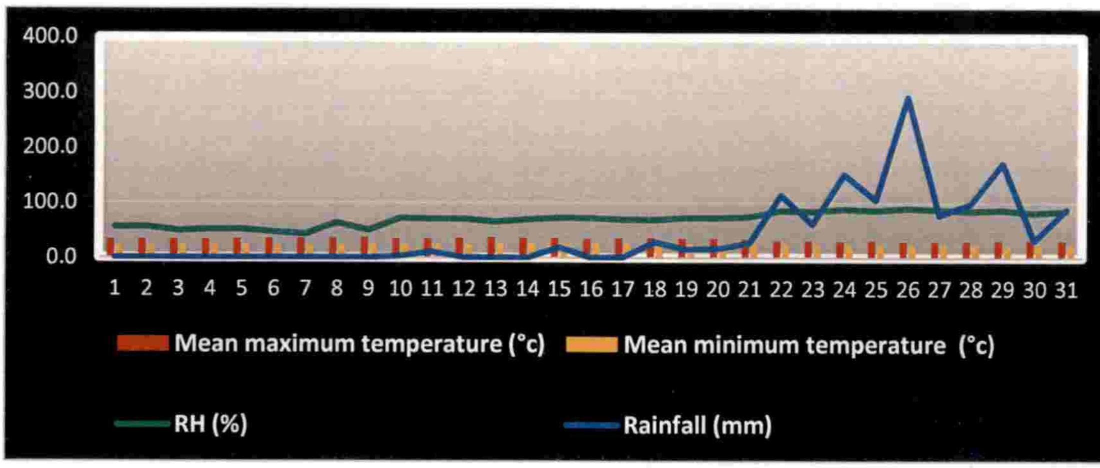


Fig. 1 Mean weekly weather data of atmospheric temperature, RH and rainfall during crop period

3.1.6 Cropping history of the experimental site

The experimental area was under the cultivation of vegetables during the previous years.

3.2 EXPERIMENTAL DETAILS

3.2.1 Design and layout

The study was conducted during January to July of 2017. The experiment was laid out in Randomized Block Design (RBD) with 3 replications. The plot size was 3.6 m x 3.6 m with chilli and amaranth grown under intercropping system. The layout plan of experiment is given in Fig. 2.

3.2.2 Treatments

Table 2. Details of the treatments in the experiment

Treatments	
T_1	Normal row – NL100 – IL 100
T_2	Normal row – NL 75 – IL 100
T_3	Normal row – NL 50 – IL 100
T_4	Normal row – NL 100 – IL 75
T_5	Normal row – NL 75 – IL 75
T_6	Normal row – NL 50 – IL 75
T_7	Paired row – NL 100 – IL 100
T_8	Paired row – NL 75 – IL 100
T_9	Paired row – NL 50 – IL 100
T_{10}	Paired row – NL 100 – IL 75
T_{11}	Paired row – NL 75 – IL 75
T_{12}	Paired row – NL 50 – IL 75
T_{13}	Chilli crop alone under fertigation
T_{14}	Amaranth crop under fertigation

The treatment consisted of 2 planting geometry, 3 nutrient levels, 2 irrigation levels and 2 controls. The treatment details are given below: (Table 2)

Base crop - Chilli

Intercrop - Amaranth

Planting geometry (2)

1. Normal row planting
2. Paired row planting

Nutrient levels (3)

1. NL 100 - 100% NPK for both crops as fertigation
2. NL 75 - 75% NPK for both crops as fertigation
3. NL 50 - 50% NPK for both crops as fertigation

Irrigation levels (2)

1. IL 100 - 100% Epan
2. IL 75 - 75% Epan

Absolute controls

1. Chilli crop alone under fertigation
2. Amaranth crop alone under fertigation

Treatment combinations - $2 \times 3 \times 2 + 2 = 14$

3,2.3 Cultural practices

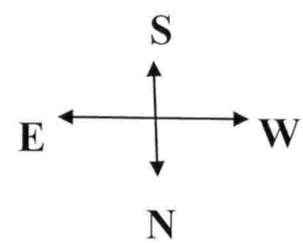
Nursery

Chilli and amaranth seedlings were raised in potrays and seed beds respectively. Chilli seedlings were transplanted at one month growth stage and amaranth seedlings at 25 days after sowing.

Land preparation

Land was ploughed thoroughly twice to produce fine tilth of soil. The clods were broken and stubbles were removed. The land was then subdivided into 42 plots of 3.6 m × 3.6 m separated with channels of 50 cm width. FYM at the rate of 2.5 kg/m^2 and lime at the rate of 103 g/m^2 were applied and incorporated. After one week, transplanting was done.

R_1T_{14}	R_2T_{14}	R_3T_{14}
R_1T_{13}	R_2T_{13}	R_3T_{13}
R_1T_7	R_2T_7	R_3T_7
R_1T_1	R_2T_1	R_3T_1
R_1T_8	R_2T_8	R_3T_8
R_1T_2	R_2T_2	R_3T_2
R_1T_9	R_2T_9	R_3T_9
R_1T_3	R_2T_3	R_3T_3
R_1T_{12}	R_2T_{12}	R_3T_{12}
R_1T_6	R_2T_6	R_3T_6
R_1T_{11}	R_2T_{11}	R_3T_{11}
R_1T_5	R_2T_5	R_3T_5
R_1T_{10}	R_2T_{10}	R_3T_{10}
R_1T_4	R_2T_4	R_3T_4



Layout of experimental field

Method of transplanting and sowing

The details of planting geometry is furnished in Table 3.

Table 3. Planting geometry and spacing

Crop	Spacing
Chilli Normal row (Pure and Intercrop)	45 cm × 45 cm
Chilli Paired row (Intercrop)	30/60 cm × 30 cm
Amaranth (Pure and Intercrop)	30 cm × 20 cm

Normal row - One row of intercrop (amaranth) was planted in between two rows of chilli.

Paired row - Two rows of chilli were planted in pairs. In between two adjacent pair rows of chilli two rows of intercrop (amaranth) was planted

Manures and fertilizers

Manures and fertilizers were applied as per the package of practices recommendations- (crops 2016 of KAU). Well rotten FYM was applied at a rate of 25 t/ha. According to the treatment schedules, different doses of N, P and K were applied. Based on soil test values, fertilizer doses were calculated. Recommended doses of fertilizer and schedule of fertigation are given in Table 4 and 5 respectively. Fertigation was applied for chilli and amaranth at weekly intervals for 10 and 5 times respectively.

Table 4. Fertilizer recommendation of chilli and amaranth

Crop	Recommendation (kg ha^{-1})		
	N	P_2O_5	K_2O
Chilli	75	40	25
Amaranth	100	50	50

Table 5. Schedule of fertilizer application

Weeks	Schedule of fertigation (% of recommendation)	
	Chilli	Amaranth
Week II	5	10
Week III	5	20
Week IV	10	30
Week V	10	30
Week VI	15	10
Week VII	15	
Week VIII	15	
Week IX	15	
Week X	5	
Week XI	5	
Total	100	100

Irrigation

Drip irrigation was given as per treatment, *ie*, at 100 per cent of Epan and at 75 per cent of Epan. Drip lines were laid out in sandy loam soil at a spacing of 45 cm between drip lines and 40 cm between emitters. Here the average Epan was taken as 6mm. The volume of water applied in litres was calculated using the formula:

Volume (l) = Pan evaporation [Epan (mm)] × Area (m^2)

The time of operation of drip irrigation system to deliver the required volume of water per plot was computed based on the formula,

Time of application (hr) = Volume of water (l) / Discharge rate of emitter (lph)

Weeding

Hand weeding was done to keep the plots weed free. Four hand weedings were done at 20 days interval.

Plant protection

Spiromesifen (Oberon 22.9% SC) @ 96g *a.i* /ha, Imidacloprid (Confidor 17.8 SL) @ 30g *a.i* /ha and Dimethoate (Rogor 30 EC) @ 200g *a.i* /ha were applied against mite and thrips attack. To control damping off of chilli, Copper hydroxide (Kocide 77 WP) @ 385g *a.i* /ha and Copper oxychloride (Fytolan 50 WP) @ 500g *a.i* /ha were applied.

Harvesting of chilli

Chilli green fruits were picked as and when they mature at an interval of 15 days. The first harvest was taken 75 days after transplanting. And six more pickings were done and in the last picking all the green fruits were picked to complete the harvesting.

Harvesting of amaranth

First harvest was done 30 days after transplanting. Three more harvests were taken at an interval of 15 days.

3.3 Observations recorded

Observations on growth characters, yield components and yield were recorded.

3.3.1 Biometric observations

Chilli

Plant height

The height of plant was measured from the base of the plant to the growing tip at 30 days interval. The average value of five plants were taken from each plot and expressed as cm.

Number of leaves per plant

Total number of leaves produced was recorded from five observation plants at 30 days interval. The average was taken.

Number of branches per plant

Number of primary and secondary branches of five plants at 30 days interval was recorded and the average was taken.

Leaf area per plant

Length and breadth of 10 leaves were taken from each plot and leaf area per plant was calculated by factor method:

Leaf area per plant = length × breadth × factor (factor- 0.7) × Total number of leaves

Dry matter production

Five plants were selected randomly from the plot, uprooted at harvest and air dried. Later the samples were dried in hot air oven to a constant weight at 70- 75 ° C and the total dry weight was recorded.

Days to first flowering

Date on which plants flowered first were taken from each treatment.

Number of fruits per plant

From each picking, the number of chilli fruits harvested from the five observation plants were noted. The total fruits harvested from all pickings was calculated and average of five plants was taken as the number of fruits per plant.

Fruit weight

The chilli fruits at each picking were mixed. From the pooled sample hundred fruits were drawn randomly and its weight was recorded and expressed in grams.

Yield per hectare

The fresh chilli fruit yield obtained from the each plot was recorded at different pickings. The total chilli fruit yield per plot was calculated by adding the yield of fresh chillies obtained at each picking. On the basis on yield per plot, yield per hectare was computed and expressed in kg/ha.

Amaranth

Plant height

From each plot five plants were tagged randomly. The height was recorded from ground level to the growing tip of the plant on 30th day.

Number of leaves per plant

The number of total leaves per tagged plant was recorded on 30 DAT. The average was taken from five tagged plants and furnished.

Leaf area per plant

Length and breadth of 10 leaves were taken from each plot and leaf area per plant was calculated by factor method:

Leaf area per plant = length × breadth × factor (factor- 0.63) × total number of leaves

Leaf- shoot ratio

The fresh weight of shoot and leaves of five plants were taken at the time of harvest separately and leaf – shoot ratio was worked out.

Dry matter production

Five plants were selected randomly from the plot, uprooted at harvest and air dried. Later the samples were dried in hot air oven to a constant weight at 70- 75 ° C and the total dry weight was recorded.

Yield per hectare

The yield obtained from the each plot was recorded at different cuts. The total yield per plot was calculated by adding the yield obtained at each harvest. On the basis of yield per plot, yield per hectare was computed and expressed in kg/ha.

3.3.2 Plant analysis

For plant analysis, plant samples were collected at 30 DAS, 60 DAS, 90 DAS and at final harvest. To achieve constant weights plant samples were dried in the oven at 80 ± 5°C. Then the samples were ground to pass through a 0.5 mm mesh sieve in a

Willey mill. Samples of 0.5 g were weighed out and N, P and K content were analyzed by standard procedures.

Uptake of nitrogen

Total nitrogen content of plant was determined by Microkjeldal digestion and distillation method (Jackson, 1958) and values are expressed as percentage. Then these values were multiplied with total dry weight matter production (kg/ha) to obtain the uptake of nitrogen. The uptake of nitrogen were expressed in kg/ha.

Uptake of phosphorus

Plant samples were digested in diacid mixture. The P content was estimated by Vanado molybdophosphoric yellow colour method (Bray and Kurtz, 1945) and intensity of colour was read using Spectrophotometer at 430 nm. Uptake of phosphorus was calculated by multiplying the P content with the total dry matter production (kg/ha) and expressed in kg/ha.

Uptake of potassium

Total potassium content in diacid digest was estimated using Flame photometer (Jackson, 1958). Potassium content was multiplied with total dry matter production (kg/ha) to give the uptake of potassium in kg/ha.

3.3.3 Soil analysis

The pH, organic carbon and the content of major nutrients of soil before and after experiment were determined using the standard procedure (Table 1). Soil samples were collected, dried, powdered and passed through 0.5 mm sieve, for analyzing the organic carbon content. Samples passed through 2 mm sieve used for analyzing major nutrients viz., available N, available P and available K using standard procedures. The soil pH was analyzed with a soil: water suspension of 1:2.5.

3.3.4 Biosuitability parameters of intercropping system

Land Equivalent Ratio (LER)

LER was worked out for the mixture plots by using the formula suggested by Willey and Osiru (1972).

$$LER = [Yab \div (Yaa \times Zab)] + [Yba \div (Ybb \times Zba)]$$

Yaa and Ybb are the sole crop yield and Yab and Yba are the individual crop yields in intercropping system. Zab and Zba are the proportion of land area occupied in intercropping when compared to sole crop for species a and b respectively.

a - Chilli, b- Amaranth

Land Equivalent Coefficient (LEC)

LEC is the product of LER of intercropped components. LEC for intercropping system was calculated by using the formula proposed by Adetiloye *et al.* (1983).

$$LEC = LER\ of\ base\ crop \times LER\ of\ intercrop$$

Area Time Equivalent Ratio (ATER)

ATER was worked out by using the formula put forward by Hiebsch (1978).

$$ATER = [(RYa \times ta) + (RYb \times ts)] \div T$$

RY = relative yield of species a and b

t = duration (days) for species a and b

T = duration (days) of the intercropping system

Crop Equivalent Yield (CEY)

Verma and Modgal (1983) proposed the formula for the calculation of CEY in intercropping system and expressed in kg/ha.

$$CEY = \sum_{i=1}^{n} (Yiei)$$

Y = the economic yield of 1 to n number of crops (kg/ha)

e = the crop equivalent factor, which can be calculated as Pc/Pa, where Pc is the price of a unit weight of concerned crop and Pa is the price of unit weight of chilli

i = 1 to n number of crops

Relative Crowding Coefficient (RCC)

RCC was worked out using the formula proposed by de Wit (1960).

$$Kab = Yab \div [(Yaa - Yab)Zab]$$

$$Kba = Yba \div [(Ybb - Yba)Zba]$$

Kab and Kba = product of coefficient of species a and b respectively.

e) Cost- Benefit analysis

Benefit cost ratio was worked out by dividing the gross returns with total expenditure per hectare.

Plate 1. General field view

Plate 2. Normal row planting

Plate 3. Paired row planting

Plate 4. Chilli pure crop under fertigation

Plate 5. Amaranth pure crop under fertigation

Results

4. RESULTS

The experiment entitled "Chilli- Amaranth intercropping system under fertigation" was conducted during the year 2017 at Water Management Research Unit, Vellanikkara. The experimental data collected were statistically analysed and the results obtained were furnished under the following sections.

4.1 Biometric observations

Chilli

4.1.1 Plant height

Data regarding the effect of planting geometry, nutrient levels and irrigation level on the height of chilli at 30 DAP, 60 DAP, 90 DAP and at final harvest stage are given in Table 6. Throughout the growth stages, planting geometry had no significant influence on height of chilli. The nutrient levels and irrigation levels also had no significant influence on plant height at early stages, but in later stages they showed significance. Among different nutrient levels, taller plants was observed under 100 per cent of nutrient level at 90 DAP and final stage of harvest (57.80 cm and 58.82 cm, respectively). In case of different irrigation levels, IL 100 recorded significantly taller plants (57.73 cm and 58.37 cm respectively at 90 DAP and at final harvest). Pure crop of chilli planted at normal row with 100 per cent of nutrient and 100 per cent irrigation recorded the lowest plant height during 30 and 60 DAP (20.66 cm and 42.4 cm, respectively) and highest plant height during 90 DAP and at final stage of harvest (63.06 cm and 64.20 cm, respectively) compared to intercropped chilli.

Interaction effects had no significant influence on height of plants until 60 DAP, but at 90 DAP interaction effect between nutrient level and planting geometry revealed significance (Table 6a). At the stage of 90 DAP, maximum plant height (60.03 cm) was observed in normal row of planting with 100 per cent of the fertilizer dose. It was significantly superior to all other treatments. Lowest height (50.73 cm) was recorded by normal row planting with 50 per cent fertilizer dose.

Also interaction effects of planting geometry, nutrient levels and irrigation levels revealed significance on plant height at 90 DAP (Table 6b). Maximum height (61.67 cm) was observed by paired row planting with 100 per cent fertilizer dose and 100 per cent Epan.

Table 6. Influence of planting geometry, nutrient and irrigation levels on plant height (cm) of chilli at different growth stages

Treatments	At 30 DAP	At 60 DAP	At 90 DAP	At harvest
Planting geometry				
A1 Normal row planting	21.77	46.23	55.42	55.98
A2 Paired row planting	20.90	45.30	55.70	56.27
SEm±	1.077	0.729	0.903	1.43
CD (0.05)	NS	NS	NS	NS
Nutrients				
B1 100% NPK for both crops	20.90	46.17	57.80	58.82
B2 75 % NPK for both crops	22.25	46.02	55.23	57.58
B3 50% NPK for both crops	20.85	45.12	53.65	53.97
SEm±	1.32	0.892	1.106	1.76
CD (0.05)	NS	NS	3.244	5.15
Irrigation				
C1 100% Ep	21.88	46.04	57.73	58.37
C2 75% Ep	20.79	45.49	53.39	53.88
SEm±	1.08	0.73	0.90	1.43
CD (0.05)	NS	NS	2.64	4.21
Chilli pure crop	20.66	42.4	63.06	64.20
A×B interaction CD (0.05)	NS	NS	4.58	NS
A×B×C interaction CD (0.05)	NS	NS	6.49	NS

Table 6(a). Interaction effect of planting geometry and nutrient levels on plant height (cm) of chilli at 90 DAP

Treatments	NL100	NL 75	NL 50
Normal row	60.03	55.50	50.73
Paired row	55.56	54.96	56.56
SEm±	1.56		
CD (0.05)	4.58		

Table 6 (b). Interaction effect of planting geometry, nutrient and irrigation levels on plant height (cm) of chilli at 90 DAP

Treatments	Normal row planting		Paired row planting	
	IL 100	IL 75	IL 100	IL 75
NL 100	60.40	59.67	61.67	49.46
NL 75	60.13	50.86	56.67	53.26
NL 50	50.80	50.67	56.73	56.40
SEm±	2.21			
CD (0.05)	6.49			

4.1.2 Number of leaves

Planting geometry, nutrient levels and irrigation levels had no significant influence on the number of leaves of chilli at different growth stages (Table 7). Compared to intercropped treatments, pure crop of chilli recorded lowest leaf number (25) at 30 DAP and maximum leaf number (89) during 90 DAP. After 60 DAP and 90 DAP none of the interaction was found significant but at 30 DAP, interaction effect between planting geometry and nutrient levels was observed (Table 7a). Normal row planting with 100 per cent of fertilizer dose and paired row planting with 50 per cent of fertilizer dose recorded maximum number of leaves (31) and was found on par.

4.1.3 Number of branches

The effect of various treatments on number of branches per plant of chilli at different growth stages are given in Table 8.

Planting geometry had no significant influence on number of branches at different growth stages. Nutrient levels had significant influence on the number of branches at 30 DAP and at the stage of final harvest. Among different nutrient levels, higher number of branches were recorded by NL 50 at 30 DAP (3.4) and NL 100 at the stage of final harvest (7.45). While irrigation levels had significantly influenced the character at the early growth stage (30 DAP). Irrigation level at 75 per cent of Epan had significantly higher number of branches of 3.42 at 30 DAP. At 90 DAP and at harvest pure crop recorded maximum number of branches compared with all other treatments (6.6 and 7.8 respectively). Interaction effects had no significant influence on this factor at different growth stages.

Table 7. Influence of planting geometry, nutrient levels and irrigation levels on number of leaves per plant of chilli at different growth stages

Treatments	At 30 DAP	At 60 DAP	At 90 DAP
Planting geometry			
A1 Normal row planting	28	84	49
A2 Paired row planting	26	88	51
SEm±	1.10	2.95	3.06
CD (0.05)	NS	NS	NS
Nutrients			
B1 100% NPK for both crops	26	80	57
B2 75 % NPK for both crops	26	88	48
B3 50% NPK for both crops	30	90	46
SEm±	1.34	3.61	3.75
CD (0.05)	NS	NS	NS
Irrigation			
C1 100% Ep	27	90	53
C2 75% Ep	27	82	47
SEm±	1.10	2.95	3.06
CD (0.05)	NS	NS	NS
Chilli pure crop	25	81	89
A×B interaction CD (0.05)	NS	5.58	NS

Table 7(a). Interaction effect of planting geometry and nutrient levels on number of leaves per plant of chilli at 30 DAP

Treatments	NL 100	NL 75	NL 50
Normal row planting	31	26	29
Paired row planting	22	26	31
SEm±	1.9		
CD (0.05)	5.58		

Table 8. Influence of planting geometry, nutrient levels and irrigation levels on number of branches per plant of chilli at different growth stages

Treatments	At 30 DAP	At 60 DAP	At 90 DAP	At harvest
Planting geometry				
A1 Normal row planting	3.04	5.41	5.18	6.88
A2 Paired row planting	3.14	5.58	5.22	6.30
SEm±	0.15	0.36	0.24	0.41
CD (0.05)	NS	NS	NS	NS
Nutrients				
B1 100% NPK for both crops	2.57	5.53	5.05	7.45
B2 75 % NPK for both crops	3.32	4.98	5.07	6.93
B3 50% NPK for both crops	3.40	5.97	5.48	5.68
SEm±	0.18	0.44	0.29	0.50
CD (0.05)	0.52	NS	NS	1.46
Irrigation				
C1 100% Ep	2.77	5.90	5.37	6.60
C2 75% Ep	3.42	5.09	5.03	6.58
SEm±	0.15	0.36	0.24	0.41
CD (0.05)	0.43	NS	NS	NS
Chilli pure crop	2.00	5.33	6.60	7.80
Interaction	NS	NS	NS	NS

4.1.4 Leaf area per plant

The data presented in Table 9 indicated the effect of planting geometry, nutrient level and irrigation level on leaf area per plant. Planting geometry had no significance on the leaf area per plant at different growth stages. While nutrient levels and irrigation levels significantly influenced leaf area per plant only at 90 DAP and at 60 DAP respectively. At 90 DAP, 100 per cent nutrient dose observed higher leaf area (993.94 cm^2) and lowest by NL 50 (627.78 cm^2). At the stage of 60 DAP, IL 100 observed higher leaf area (1610.3 cm^2) which in turn was comparable with IL 75 (1117.18 cm^2). Pure crop recorded maximum leaf area (2113.21 cm^2) compared with all other treatments at 90 DAP. The interaction effect between different factors was not significant throughout the growth stages.

Table 9.Influence of different planting geometry, nutrient levels and irrigation levels on leaf area per plant (cm^2) of chilli at different growth stages

Treatments	At 30 DAP	At 60 DAP	At 90 DAP
Planting geometry			
A1 Normal row planting	206.60	1322.11	765.58
A2 Paired row planting	219.19	1405.33	808.66
SEm±	16.31	113.38	65.67
CD (0.05)	NS	NS	NS
Nutrients			
B1 100% NPK for both crops	187.90	1292.93	993.94
B2 75 % NPK for both crops	215.28	1311.40	739.63
B3 50% NPK for both crops	235.51	1486.83	627.78
SEm±	19.98	138.86	80.43
CD (0.05)	NS	NS	235.96
Irrigation			
C1 100% Ep	214.23	1610.30	856.82
C2 75% Ep	211.56	1117.14	717.42
SEm±	16.31	113.38	65.67
CD (0.05)	NS	332.61	NS
Chilli pure crop	177.22	1014.65	2113.21
Interactions	NS	NS	NS

4.1.5 Dry matter accumulation

Planting geometry and irrigation levels significantly influenced the dry matter production of chilli at 60 DAP and at 30 DAP respectively and the nutrient level had no significant influence on the dry matter accumulation (Table 10). At 60 DAP, paired row planting observed higher dry matter accumulation (300.41 kg/ha). At the stage of

30 DAP, IL 75 recorded higher dry matter accumulation of 113.17 kg/ha which in turn was comparable with IL 100 (84.36 kg/ha). Pure crop recorded maximum dry matter accumulation compared with all other treatments at later stages of growth (90 DAP and at final stage of harvest). Interaction effects between planting geometry and nutrient levels and between irrigation levels and nutrient levels were found significant at 30 DAP (Table 10 a and b). Paired row planting with 50 per cent of fertilizer dose recorded maximum dry matter accumulation (123.46 kg/ha). It was on par with normal row planting with 100 per cent of fertilizer dose. Among different treatment combinations between irrigation levels and nutrient levels, NL 50 with IL 75 revealed a higher value (129.63 kg/ha) which was on par with NL 100 with IL 75.

Table 10. Influence of planting geometry, nutrient levels and irrigation levels on dry matter accumulation (kg/ha) of chilli at different growth stages

Treatments	30 DAP	60 DAP	90 DAP	At harvest
Planting geometry				
A1 Normal row planting	98.77	211.93	672.84	1197.53
A2 Paired row planting	98.77	300.41	588.48	1345.68
SEm±	7.01	27.47	46.63	107.06
CD (0.05)	NS	80.59	NS	NS
Nutrients				
B1 100% NPK for both crops	98.77	234.57	577.16	1246.91
B2 75 % NPK for both crops	92.59	308.64	682.10	1203.70
B3 50% NPK for both crops	104.94	225.31	632.72	1364.20
SEm±	8.58	33.64	57.11	131.12
CD (0.05)	NS	NS	NS	NS
Irrigation				
C1 100% Ep	84.36	271.61	697.53	1382.72
C2 75% Ep	113.17	240.74	563.79	1160.49
SEm±	7.01	27.47	46.63	107.06
CD (0.05)	20.55	NS	NS	NS
Chilli pure crop	98.76	209.87	1148.15	1851.85
A×B interaction CD (0.05)	35.60	NS	NS	NS
B×C interaction CD (0.05)	NS	NS	NS	35.60

Table 10(a). Interaction effect of planting geometry and nutrient levels on dry matter accumulation (kg/ha) of chilli at 30 DAP

Treatments	NL 100	NL 75	NL 50
Normal row planting	117.28	92.59	86.42
Paired row planting	80.25	92.59	123.46
SEm±	12.13		
CD (0.05)	35.60		

Table 10(b). Interaction effect of nutrient levels and irrigation levels on dry matter accumulation (kg/ha) of chilli at 30 DAP

Treatments	NL 100	NL 75	NL 50
IL 100	74.07	98.77	80.25
IL75	123.46	86.42	129.63
SEm±	12.13		
CD (0.05)	35.60		

4.1.6 Days to first flowering

The effect of various treatment on days taken to first flowering of chilli are given in Table 11. Planting geometry, nutrient levels and irrigation showed no significance difference on days to first flowering. Interaction effects also showed no significance to the days to first flowering

4.1.7 Number of fruits per plant

The number of fruits per plant was not significantly influenced by planting geometry, nutrient levels and irrigation levels (Table 11). Normal row planting recorded higher fruit number and was on par with paired row planting. The nutrient level at 50 per cent of fertilizer dose registered higher number of fruits (41.43) which was on par with the other two fertilizer levels. Among irrigation level, IL 100 recorded higher number of fruits (43.10). Pure crop observed higher fruit number of 46.58.

Interaction between planting geometry and nutrient levels was found significant (Table 11a). Paired row planting along with NL 50 recorded the highest number of fruits (49.76) followed by paired row planting with NL 100.

4.1.8 Fruit weight

The levels of irrigation had significant influence on the fruit weight (Table 11). Maximum fruit weight (21.61g) was recorded by plants receiving the irrigation level of 100 per cent Epan and was significantly superior to IL 75 (18.61g). With regard to planting geometry and nutrient levels, no significant influence could be observed. In case of nutrient levels, NL 100 observed a higher fruit weight of 20.58g which are statistically on par with NL 75 and NL 50. However, normal row planting recorded higher fruit weight of 20.77g. Interaction effects had no significant influence on fruit weight.

4.1.9 Yield

Planting geometry and nutrient levels, had no significant influence on yield of intercropped chilli (Table 11). Yield of intercropped chilli varied significantly amongst irrigation levels. Maximum yield was recorded at 100 per cent of Epan which was superior to irrigation level at 75 per cent. The nutrient levels could not bring significant variation in yield of chilli. Pure crop of chilli recorded the highest yield (11,701.82 kg/ha) compared with other treatments. Interaction effects had no significant influence on yield of chilli.

Table 11. Influence of planting geometry, nutrient levels and irrigation levels on days to first flowering, fruit number, fruit weight and yield of chilli

Treatments	Days to 1st flowering	Number of fruits/plant	Fruit weight (g)	Yield (kg/ha)
Planting geometry				
A1 Normal row planting	45.39	40.51	20.77	6,709.37
A2 Paired row planting	45.28	40.36	19.44	7,170.29
SEm±	0.70	3.79	0.73	575.82
CD (0.05)	NS	NS	NS	NS
Nutrients				
B1 100% NPK for both crops	45.17	38.79	20.58	6,946.29
B2 75 % NPK for both crops	45.17	41.08	19.66	7,160.12
B3 50% NPK for both crops	45.42	41.43	20.08	6,713.09
SEm±	0.86	4.65	0.89	705.23
CD (0.05)	NS	NS	NS	NS
Irrigation				
C1 100% Ep	45.25	43.10	21.61	8,035.24
C2 75% Ep	45.57	37.77	18.61	5,844.42
SEm±	0.70	3.79	0.73	575.82
CD (0.05)	NS	NS	2.14	1,689.25
Chilli pure crop	45.26	46.58	20.33	11,701.82
A×B interaction CD (0.05)	NS	19.27	NS	NS

Table 11(a). Interaction effect of planting geometry and nutrient levels on number of fruits per plant of chilli

Treatments	NL 100	NL 75	NL 50
Normal row planting	48.23	40.19	33.09
Paired row planting	29.35	41.96	49.76
SEm±	6.57		
CD (0.05)	19.27		

Amaranth

4.1.9 Plant height

The effect of plant geometry, nutrient levels and irrigation levels had significant influence on plant height (Table 12). Normal row planting recorded higher plant height of 34.43 cm, which was superior to paired row planting (32.07 cm). At different nutrient levels, nutrient level at 50 per cent of fertilizer dose observed highest plant height (35.50 cm) compared to other two levels. The values recorded at NL 100 and NL 75 was on par. The taller plants (34.56 cm) were recorded under 75 per cent Epan than 100 per cent Epan. However, pure crop recorded the lowest height (30.93 cm) compared with all other treatments. Interaction effect between nutrient levels and irrigation levels showed significance difference on plant height (Table.12a). Maximum height of amaranth (36.60 cm) was recorded for plants receiving 50 per cent of recommended dose and irrigation at 100 per cent Epan. It was on par with the height obtained with NL 100 with IL 50. And the shorter plants were observed under NL 100 with IL 100.

4.1.10 Leaf area per plant

No statistically significant differences could be observed for leaf area per plant due to various treatments (Table 12). Normal row planting recorded higher leaf area per plant (5,600.96 cm^2) than paired row planting. Among nutrient levels, NL 50 obtained higher value of 5,706.07 cm^2 which was on par with other levels. In case of different irrigation levels, IL100 revealed higher leaf area per plant than IL75. Interaction effect of plant geometry and nutrient levels revealed significance on leaf area (Table 12b). Among the treatment combinations, normal row planting along with 75 per cent of fertilizer dose recorded superior value (6,418.23 cm^2) of leaf area. Lower leaf area of 4,667.87 cm^2 was recorded in paired row planting with 100 per cent nutrient level. Interaction effect of nutrient level and irrigation level showed significance (Table 12c). Leaf area (6,632.16 cm^2) was significantly higher for plants receiving irrigation at 100 Epan along with 50 per cent of nutrient dose which was superior to all other treatment combinations.

4.1.11 Number of leaves per plant

Only nutrient levels significantly affected number of leaves per plant. Higher number of leaves (76.95) were noticed under 50 per cent of nutrient dose and was followed by 75 per cent of nutrient dose (68.53). Plants under NL 100 registered statistically lower number of leaves of 58.87. In case of planting geometry and irrigation levels, significant differences could not be observed. Data presented in Table 12d revealed that interaction effect of nutrient levels and irrigation levels had significance on number of leaves per plant. Maximum value (88.10) was observed in the treatment combination of 50 per cent of nutrient dose along with 100 per cent of Epan and lowest (58.83) by 100 per cent of nutrient dose with 75 per cent of Epan. Among different nutrient combination with NL 75 with IL 75 revealed higher number of leaves per plant.

4.1.12 Dry matter accumulation

Among different treatments, irrigation levels significantly influenced the dry matter accumulation in amaranth (Table 12). Irrigation level at 75 per cent of Epan recorded significantly higher value (1624.68 kg/ha) than IL 100 (1287.36 kg/ha). While in planting geometry and nutrient levels, significant differences could not be observed. Higher dry matter accumulation was observed with NL 100 (1660.59 kg/ha) which was followed by NL 50. With regard to plant geometry, paired row planting obtained higher dry matter accumulation (1468.14 kg/ha) which was on par with normal row planting. However, pure crop recorded the maximum value (2738.67 kg/ha) compared with all other treatments. Interaction effects had no significant influence on dry matter accumulation of amaranth.

Table 12. Influence of planting geometry, nutrient levels and irrigation levels on plant height, leaf area and number of leaves of amaranth

Treatments	Plant height (cm)	Leaf area/plant (cm^2)	Number of leaves/ plant	Dry matter (kg/ha)
Planting geometry				
A1 Normal row planting	34.43	5,600.96	69.87	1443.90
A2 Paired row planting	32.07	5,256.10	66.37	1468.14
SEm±	0.72	214.30	2.11	99.62
CD (0.05)	2.11	NS	NS	NS
Nutrients				
B1 100% NPK for both crops	32.13	4,918.18	58.87	1660.59
B2 75 % NPK for both crops	32.12	5,661.34	68.53	1319.56
B3 50% NPK for both crops	35.50	5,706.07	76.95	1387.91
SEm±	0.88	262.46	2.59	122.01
CD (0.05)	2.58	NS	7.59	NS
Irrigation				
C1 100% Ep	31.94	5,673.16	69.84	1287.36
C2 75% Ep	34.56	5,183.90	66.39	1624.68
SEm±	0.72	214.30	2.11	99.62
CD (0.05)	2.11	NS	NS	292.26
Amaranth pure crop	30.93	5,558.09	62.80	2738.67
B×C interaction CD (0.05)	3.65	1088.9	10.72	NS
A×B interaction CD (0.05)	NS	1088.9	NS	NS

Table 12(a) Interaction effect of nutrient levels and irrigation levels on plant height (cm) of amaranth

Treatments	NL 100	NL 75	NL50
IL 100	28.33	30.90	36.60
IL 75	35.93	33.33	34.40
SEm±	1.244		
CD (0.05)	3.649		

Table 12(b) Interaction effect of planting geometry and nutrient levels on leaf area per plant (cm^2) of amaranth

Treatments	NL 100	NL 75	NL 50
Normal row planting	5,168.49	6,418.23	5,216.16
Paired row planting	4,667.87	4,904.45	6,195.97
SEm±	371.17		
CD (0.05)	1088.90		

Table 12(c). Interaction effect of nutrient levels and irrigation levels on leaf area per plant (cm^2) of amaranth

Treatments	NL 100	NL 75	NL 50
IL 100	5,029.46	5,357.87	6,632.16
IL 75	4,806.91	5,964.81	4,779.97
SEm±	371.17		
CD (0.05)	1088.90		

Table 12(d). Interaction effect of nutrient levels and irrigation levels on number of leaves of amaranth

Treatments	NL 100	NL 75	NL 50
IL 100	58.90	62.53	88.10
IL75	58.83	74.53	65.80
SEm±	3.65		
CD (0.05)	10.72		

4.1.13 Number of branches per plant

Levels of irrigation significantly influenced the number of branches (Table 13). Maximum number of branches (7.11) was observed at irrigation at 75 per cent of Epan and was significantly superior to IL 100 (6.24). Planting geometry and nutrient levels had no significance on number of branches. However, pure crop recorded lower number of branches (6.06) compared to all other treatments. Interaction effect of plant geometry with nutrient level and nutrient level with irrigation level was found to be significant on number of branches (Table 13a and Table 13b). In the case of interaction effect between planting geometry and nutrient levels, paired row planting with NL 100 recorded superior value (7.56) and normal row planting along with NL 100 observed lower value (5.63). Among different nutrient level combination with normal row planting, NL 50 with normal row planting obtained higher value (6.90). In the case of interaction effect between nutrient level and irrigation level, plants receiving nutrient level at 75 per cent of fertilizer dose and irrigation at IL 75 revealed higher number of branches (8.16).

4.1.14 Leaf shoot ratio

Only irrigation at different levels significantly influenced the leaf shoot ratio (Table 13). Irrigation at 100 per cent of Epan had higher value (1.22), which was superior to irrigation at 75 per cent of Epan (0.94). Neither plant geometry nor nutrient levels revealed any significance on the leaf shoot ratio. At different nutrient levels, NL 75 had higher leaf shoot ratio of 1.25 which was on par with NL 100 and NL 50. Among plant geometry, paired row planting had higher leaf shoot ratio. The different interaction effects were not significant for leaf shoot ratio.

4.1.15 Yield

Nutrient levels revealed significance on the yield of amaranth (Table 13). Nutrient level of 100 per cent of fertilizer dose produced superior yield (26,227.57 kg/ha) and was superior to NL 75 and NL 50. However, planting geometry and irrigation levels had no significance on yield. Total yield produced by amaranth under normal row planting (24,640.84 kg/ha) was on par with paired row planting (23,427.23 kg/ha). And total yield produced by amaranth receiving irrigation at IL 75 (24,497.64 kg/ha) was on par with IL 100 (23,570.43 kg/ha). Pure crop of amaranth produced less yield (20,559.35 kg/ha) than intercropped amaranth. Interaction effect of plant geometry with nutrient levels and plant geometry with nutrient and irrigation level had significance on total yield produced (Table 13c and Table 13d). Among the different treatment combinations between planting geometry and different nutrient levels, normal row planting with 100 per cent of nutrient dose recorded higher yield of 28,162.31 kg/ha and was on par with paired row planting receiving NL 50 (26,191.87 kg/ha). In the case of interaction effect between plant geometry with different nutrient and irrigation level, a higher yield (31,104.93 kg/ha) was registered by intercropped amaranth planted at normal row receiving NL 100 and IL 100.

Table 13. Influence of planting geometry, nutrient levels and irrigation levels on number of branches, leaf shoot ratio and yield of amaranth

Treatments	Number of branches per plant	Leaf shoot ratio	Yield (kg/ha)
Planting geometry			
A1 Normal row planting	6.38	1.06	24,640.84
A2 Paired row planting	6.98	1.11	23,427.23
SEm±	0.22	0.07	648.78
CD (0.05)	NS	NS	NS
Nutrients			
B1 100% NPK for both crops	6.60	1.00	26,227.57
B2 75 % NPK for both crops	6.73	1.25	21,824.02
B3 50% NPK for both crops	6.70	1.00	24,050.52
SEm±	0.27	0.09	794.60
CD (0.05)	NS	NS	2,331.06
Irrigation			
C1 100% Ep	6.24	1.22	23,570.43
C2 75% Ep	7.11	0.94	24,497.64
SEm±	0.22	0.07	648.78
CD (0.05)	0.65	0.21	NS
Amaranth pure crop	6.06	1.00	20,559.35
A×B interaction CD (0.05)	1.12	NS	3296.61
B×C interaction CD (0.05)	1.13	NS	NS
A×B×C interaction CD (0.05)	NS	NS	4662.12

Table 13(a). Interaction effect of planting geometry and nutrient levels on number of branches

Treatments	NL 100	NL 75	NL 50
Normal row planting	5.63	6.60	6.90
Paired row planting	7.56	6.86	6.50
SEm±	0.38		
CD (0.05)	1.12		

Table 13(b). Interaction effect of nutrient levels and irrigation levels on number of branches of amaranth

Treatments	NL 100	NL 75	NL 50
IL 100	6.40	5.30	7.03
IL 75	6.80	8.16	6.36
SEm±	0.38		
CD (0.05)	1.13		

Table 13(c). Interaction effect of planting geometry and nutrient levels on yield (kg/ha) of amaranth

Treatments	NL 100	NL 75	NL 50
Normal row planting	28,162.31	23,851.05	21,909.16
Paired row planting	24,292.83	19,796.99	26,191.87
SEm±	1123.72		
CD (0.05)	3296.61		

Table 13(d). Interaction effect of planting geometry, nutrient levels and irrigation levels on yield (kg/ha) of amaranth

Treatments	Normal row planting		Paired row planting	
	IL 100	IL75	IL100	IL 75
NL 100	31,104.93	25,219.70	22,510.73	26,074.93
NL 75	22,309.20	25,392.89	19,795.89	19,798.09
NL 50	20,490.63	23,327.69	25,211.19	27,172.55
SEm±	1589.19			
CD (0.05)	4662.12			

4.2 Plant analysis

Chilli

4.2.1 Uptake of N

Throughout the growth stages, nutrient level had no significant influence on upake of N in chilli (Table 14). Planting geometry significantly influenced the nitrogen uptake only at 60 DAP. Maximum nitrogen uptake of 9.62 kg/ha was observed at the paired row planting. While irrigation levels significantly influence the N uptake at 30 DAP and at the stage of final harvest. Irrigation level of IL 75 recorded the highest nitrogen uptake at 30 DAP (3.25 kg/ha) and at harvest the highest N uptake was recorded by IL 100 (17.50 kg/ha). Except at harvest, pure crop had shown significantly superior N uptake at different growth stages.

The interaction between planting geometry and nutrient levels was significant as regards nitrogen uptake at 30 DAP. Among the treatment combinations, paired row planting with NL 50 recorded higher value (4.01 kg/ha) and was superior to others. In the case of interaction between irrigation and nutrient levels at 30 DAP, NL 100 with IL 75 had observed significantly higher nitrogen uptake value of 3.74 kg/ha. It was on par to NL 50 with IL 75 (3.67 kg/ha).

4.2.2 Uptake of P

Uptake of P shows a similar trend to that of uptake of N. The levels of nutrients had no influence on uptake of P different the growth stages (Table 15). Planting geometry significantly influenced the P uptake at the stage of 60 DAP. Maximum P uptake of 1.73 kg/ha was observed for paired row planting, which was significantly superior to normal row planting. However, levels of irrigation had significant influence on P uptake at 30 DAP and at harvest. Higher value (0.35 and 5.85 kg/ha) was observed for IL 75 and IL100, at 30 DAP and at harvest respectively. At 90 DAP and at harvest, pure crop recorded highest value of P uptake.

Only at the stage of harvest, different interaction effects revealed significance on uptake of P. The interaction effect between planting geometry and irrigation level had significance at the stage of harvest. Maximum uptake (0.39 kg/ha) was recorded at paired row planting with IL 75. Among the treatment combination of planting geometry and nutrient levels, paired row planting with NL 50 was observed significantly higher value (0.46 kg/ha) and superior to other treatments. In the case of interaction effect of different nutrient and irrigation levels, significantly maximum value was recorded by IL 75 with NL 50 (0.41 kg/ha).

4.2.3 Uptake of K

Levels of nutrients and planting geometry had no significant influence on uptake of K at all the growth stages (Table 16). Levels of irrigation had significant influence on K uptake at 30 DAP and at the stage of final harvest. Maximum value of K uptake (3.45 and 35.67 kg/ha) was observed at IL 75 and IL 100 at 30 DAP and at harvest respectively. Chilli pure crop had shown significantly higher value of K uptake at different stages of growth compared to other treatments except at 30 DAP. The effect of interaction between planting geometry and nutrient levels had significant influence at 30 DAP. Higher value of uptake (3.71 kg/ha) was observed in paired row planting with NL 50 at 30 DAP. Normal row planting with NL 100 showed higher uptake of K (3.57 kg/ha). In the case of interaction between nutrient and irrigation levels IL 75 with 50 per cent of nutrient level had shown significantly superior value (3.95 kg/ha) of K uptake.

Table 14. Influence of planting geometry, nutrient levels and irrigation levels on uptake of N (kg/ha) by chilli at different growth stages

Treatments	30 DAP	60 DAP	90 DAP	At harvest
Planting geometry				
A1 Normal row planting	2.74	5.58	19.34	14.59
A2 Paired row planting	3.02	9.62	18.03	13.86
SEm±	0.25	0.99	2.25	1.46
CD (0.05)	NS	2.91	NS	NS
Nutrients				
B1 100% NPK for both crops	2.90	7.03	15.72	12.24
B2 75 % NPK for both crops	2.67	9.62	20.64	16.64
B3 50% NPK for both crops	3.06	6.15	19.70	13.81
SEm±	0.30	1.21	2.76	1.79
CD (0.05)	NS	NS	NS	NS
Irrigation				
C1 100% Ep	2.51	8.36	21.34	17.50
C2 75% Ep	3.25	6.84	16.03	10.95
SEm±	0.25	0.99	2.25	1.46
CD (0.05)	0.73	NS	NS	4.29
Chilli pure crop	4.59	9.73	34.54	15.42
A×B interaction CD (0.05)	1.26	NS	NS	NS
B×C interaction CD (0.05)	1.26	NS	NS	NS

Table 14(a). Interaction effect of planting geometry and nutrient levels on uptake of N (kg/ha) by chilli at 30 DAP

Treatments	NL 100	NL 75	NL 50
Normal row planting	3.51	2.59	2.11
Paired row planting	2.30	2.75	4.01
SEm±	0.43		
CD (0.05)	1.26		

Table 14(b). Interaction effect of nutrient levels and irrigation levels on uptake of N (kg/ha) by chilli at 30 DAP

Treatments	NL 100	NL 75	NL 50
IL 100	2.07	3.01	2.45
IL 75	3.74	2.33	3.67
SEm±	0.43		
CD (0.05)	1.26		

Table 15. Influence of planting geometry, nutrient levels and irrigation levels on uptake of P (kg/ha) by chilli

Treatments	30 DAP	60 DAP	90 DAP	At harvest
Planting geometry				
A1 Normal row planting	0.27	1.14	4.15	4.07
A2 Paired row planting	0.31	1.73	3.94	4.78
SEm±	0.02	0.17	0.47	0.54
CD (0.05)	NS	0.51	NS	NS
Nutrients				
B1 100% NPK for both crops	0.27	1.26	3.45	5.47
B2 75 % NPK for both crops	0.26	1.82	4.66	4.30
B3 50% NPK for both crops	0.34	1.21	4.03	3.51
SEm±	0.03	0.21	0.58	0.66
CD (0.05)	NS	NS	NS	NS
Irrigation				
C1 100% Ep	0.24	1.48	4.63	5.85
C2 75% Ep	0.35	1.38	3.47	2.99
SEm±	0.02	0.17	0.47	0.54
CD (0.05)	0.06	NS	NS	1.58
Chilli pure crop	0.28	0.66	5.08	6.55
A×C interaction CD (0.05)	NS	NS	NS	0.083
A×B interaction CD (0.05)	NS	NS	NS	0.10
B×C interaction CD (0.05)	NS	NS	NS	0.10

Table 15(a). Interaction effect of planting geometry and irrigation levels on uptake of P (kg/ha) by chilli at harvest

Treatments	IL 100	IL 75
Normal row planting	0.24	0.29
Paired row planting	0.23	0.39
SEm±	0.028	
CD (0.05)	0.083	

Table 15(b). Interaction effect of planting geometry and nutrient levels on uptake of P (kg/ha) by chilli at harvest

Treatments	NL 100	NL 75	NL 50
Normal row planting	0.32	0.27	0.22
Paired row planting	0.23	0.25	0.46
SEm±	0.04		
CD (0.05)	0.10		

Table 15(c). Interaction effect of nutrient levels and irrigation levels on uptake of P (kg/ha) by chilli at harvest

Treatments	NL 100	NL 75	NL 50
IL 100	0.17	0.26	0.27
IL 75	0.37	0.25	0.41
SEm±	0.04		
CD (0.05)	0.10		

Table 16. Influence of planting geometry, nutrient levels and irrigation levels on uptake of K (kg/ha) by chilli

Treatments	30 DAP	60 DAP	90 DAP	At harvest
Planting geometry				
A1 Normal row planting	3.14	6.10	14.38	30.30
A2 Paired row planting	2.88	7.47	13.41	28.27
SEm±	0.22	0.78	1.83	3.48
CD (0.05)	NS	NS	NS	NS
Nutrients				
B1 100% NPK for both crops	2.92	6.54	11.67	25.71
B2 75 % NPK for both crops	2.88	8.29	15.71	29.87
B3 50% NPK for both crops	3.23	5.53	14.30	32.27
SEm±	0.27	0.96	2.24	4.26
CD (0.05)	NS	NS	NS	NS
Irrigation				
C1 100% Ep	2.57	7.61	16.20	35.67
C2 75% Ep	3.45	5.97	11.59	22.90
SEm±	0.22	0.78	1.83	3.48
CD (0.05)	0.63	NS	NS	10.20
Chilli pure crop	2.84	8.82	34.26	38.93
A×B interaction CD (0.05)	1.09	NS	NS	NS
B×C interaction CD (0.05)	1.09	NS	NS	NS

Table 16(a). Interaction effect of planting geometry and nutrient levels on uptake of K (kg/ha) by chilli at 30 DAP

Treatments	NL 100	NL 75	NL 50
Normal row planting	3.57	3.10	2.75
Paired row planting	2.28	2.65	3.71
SEm±	0.37		
CD (0.05)	1.09		

Table 16(b). Interaction effect of nutrient levels and irrigation levels on uptake of K (kg/ha) by chilli at 30 DAP

Treatments	NL 100	NL 75	NL 50
IL 100	2.08	3.11	2.52
IL75	3.76	2.64	3.95
SEm±	0.37		
CD (0.05)	1.09		

Amaranth

The effect of planting geometry, nutrient levels and irrigation levels on uptake of N, P and K of amaranth was furnished in the Table 17.

4.2.4 Uptake of N

Planting geometry had no significant influence on N uptake. Among different planting geometry, normal row planting revealed higher value of 39.95 kg/ha and was on par with paired row planting. The effect due to nutrient level was significant on N uptake. NL 100 record the highest value of N uptake (43.22 kg/ha) and NL 50 recorded the lowest value. Among different irrigation levels IL 75 observed significantly higher value of 40.72 kg/ha. Amaranth pure crop recorded highest value of N uptake (58.95 kg/ha) compared to all other treatments.

Interaction effect between planting geometry and irrigation levels had significance on uptake of N. Among different treatment combination, paired row planting with IL 75 had higher N uptake value of 41.01 kg/ha. In case of interaction effect between planting geometry and nutrient levels, normal row planting with NL 100 had shown significantly superior value (54.89 kg/ha).

Table 17. Influence of planting geometry, nutrient and irrigation levels on uptake of N, P and K (kg/ha) by amaranth

Treatments	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Planting geometry			
A1 Normal row planting	39.95	13.17	50.93
A2 Paired row planting	32.91	13.76	58.21
SEm±	2.55	0.98	4.12
CD (0.05)	NS	NS	NS
Nutrients			
B1 100% NPK for both crops	43.22	14.24	62.28
B2 75 % NPK for both crops	35.33	13.67	52.93
B3 50% NPK for both crops	30.74	12.48	48.50
SEm±	3.12	1.20	5.05
CD (0.05)	9.14	NS	NS
Irrigation			
C1 100% Ep	32.14	10.12	50.21
C2 75% Ep	40.72	16.81	58.93
SEm±	2.55	0.98	4.12
CD (0.05)	7.47	2.87	NS
Amaranth pure crop	58.95	23.22	104.75
A×B interaction CD (0.05)	12.93	4.06	17.11
A×C interaction CD (0.05)	10.56	4.97	NS
A×B×C interaction CD (0.05)	NS	7.03	29.63

Table 17(a). Interaction effect of planting geometry and irrigation levels on uptake of N (kg/ha) by amaranth

Treatments	IL 100	IL 75
Normal row planting	39.47	40.43
Paired row planting	24.81	41.01
SEm±	3.60	
CD (0.05)	10.56	

Table 17(b). Interaction effect of planting geometry and nutrient levels on uptake of N (kg/ha) by amaranth

Treatments	NL 100	NL 75	NL 50
Normal row planting	54.89	36.76	28.18
Paired row planting	31.55	33.89	33.29
SEm±	4.41		
CD (0.05)	12.93		

4.2.5 Uptake of P

Levels of irrigation had significant influence on uptake of P in amaranth. Irrigation level at 75 per cent of Epan was recorded highest value of P uptake (16.81 kg/ha) than IL100. Planting geometry and nutrient levels had no significant influence on uptake of P. Among different planting geometry, higher uptake (13.76 kg/ha) was noticed for paired row planting and was on par with normal row planting. In case of different irrigation levels, IL 100 revealed higher uptake of P was on par with IL 75. Compared to intercropped amaranth pure crop recorded highest P uptake of 23.22 kg/ha.

Interaction effect between planting geometry and irrigation levels had significance and higher value was observed in paired row planting with IL 75 (18.90 kg/ha). In case of interaction effect between planting geometry and nutrient levels, paired row planting with NL 100 recorded significantly highest value of 17.39 kg/ha. Interaction between planting geometry, nutrient and irrigation level also shown significance on P uptake. Among the different treatments, paired row planting with IL 75 and NL 75 recorded maximum P uptake (25.89 kg/ha).

Table 17(c). Interaction effect of planting geometry and irrigation levels on uptake of P (kg/ha) by amaranth

Treatments	IL 100	IL 75
Normal row planting	11.61	14.72
Paired row planting	8.63	18.90
SEm±	1.38	
CD (0.05)	4.06	

Table 17(d). Interaction effect of planting geometry and nutrient levels on uptake of P (kg/ha) by amaranth

Treatments	NL 100	NL 75	NL 50
Normal row planting	17.39	10.90	11.21
Paired row planting	11.09	16.45	13.75
SEm±	1.69		
CD (0.05)	4.97		

Table 17(e). Interaction effect of planting geometry, nutrient and irrigation levels on uptake of P (kg/ha) by amaranth

Treatments	Normal row planting		Paired row planting	
	IL 100	IL 75	IL 100	IL 75
NL 100	17.42	17.36	8.33	13.86
NL75	10.15	11.65	7.00	25.89
NL 50	7.27	15.14	10.57	16.93
SEm±	2.39			
CD (0.05)	7.03			

4.2.6 Uptake of K

No significant influence was recorded by planting geometry, nutrient and irrigation levels on uptake of K in amaranth. Though not significant paired row planting, NL 100 and IL 75 recorded higher uptake of K with respect to planting geometry, nutrient levels and irrigation levels. Amaranth pure crop recorded highest K uptake of 104.75 kg/ha compared to intercropped amaranth. Interaction effect between planting geometry and irrigation levels had significance on K uptake and maximum K uptake (69.06 kg/ha) was recorded in paired row planting with IL75. It was on par with normal row planting with IL 100. In case of interaction between planting geometry, nutrient and irrigation levels, paired row planting with IL 75 and NL 75 was observed highest value (81.75 kg/ha).

Table 17(f). Interaction effect of planting geometry and irrigation levels on uptake of K (kg/ha) by amaranth

Treatments	IL 100	IL75
Normal row planting	53.06	48.80
Paired row planting	47.36	69.06
SEm±	5.83	
CD (0.05)	17.11	

Table 17(g). Interaction effect of planting geometry, nutrient and irrigation levels on uptake of K (kg/ha) by amaranth

Treatments	Normal row planting		Paired row planting	
	IL 100	IL75	IL 100	IL 75
NL 100	80.79	49.52	53.15	65.67
NL 75	52.64	43.25	34.10	81.75
NL 50	25.74	53.64	54.84	59.75
SEm±	10.10			
CD (0.05)	29.63			

4.3 Soil analysis

Data regarding the effect of planting geometry, nutrient and irrigation levels on soil pH and organic carbon was presented in Table 18.

4.3.1 Soil pH

Planting geometry, nutrient levels, irrigation levels and interactions have no significant influence on soil pH.

4.3.2 Soil organic carbon

Planting geometry, nutrient levels, irrigation levels and interactions have no significant influence on soil organic carbon.

Table 18. Influence of planting geometry, nutrient and irrigation levels on soil pH and soil organic carbon

Treatments	pH	Organic carbon (%)
Planting geometry		
A1 Normal row planting	5.782	1.41
A2 Paired row planting	5.823	1.396
SEm±	0.037	0.015
CD (0.05)	NS	NS
Nutrients		
B1 100% NPK for both crops	5.763	1.382
B2 75 % NPK for both crops	5.865	1.422
B3 50% NPK for both crops	5.779	1.405
SEm±	0.037	0.018
CD (0.05)	NS	NS
Irrigation		
C1 100% Ep	5.768	1.409
C2 75% Ep	5.837	1.397
SEm±	0.037	0.015
CD (0.05)	NS	NS
Chilli pure crop	5.85	1.37
Amaranth pure crop	5.57	1.38
Interaction	NS	NS

4.3.3 Soil available nitrogen content

Planting geometry, nutrient levels, irrigation levels and their interactions had no significance on soil available nitrogen content (Table 19). Soil available nitrogen content of intercropped and pure crop treatments were less compared to the initial soil nitrogen.

4.3.4 Soil available phosphorus content

Significant difference was not indicated by planting geometry and irrigation levels with regard to the available phosphorus content of the soil (Table 19). NL 50 (33.49 kg/ha) had shown significantly superior values of available phosphorus content in nutrient levels.

4.3.5 Soil available potassium content

Planting geometry nutrient levels and irrigation levels had no significant effect on soil available potassium content of soil, while nutrient levels showed significance (Table 19).

Table 19. Influence of planting geometry, nutrient and irrigation levels on available N, P and K content of soil

Treatment	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Planting geometry			
A1 Normal row planting	177.80	30.11	81.28
A2 Paired row planting	187.89	30.27	83.88
SEm±	4.45	0.644	1.73
CD (0.05)	NS	NS	NS
Nutrients			
B1 100% NPK for both crops	185.85	28.75	81.59
B2 75 % NPK for both crops	184.18	28.32	82.47
B3 50% NPK for both crops	178.50	33.49	83.68
SEm±	5.45	0.79	2.12
CD (0.05)	NS	2.32	NS
Irrigation			
C1 100% Ep	180.89	29.96	83.07
C2 75% Ep	184.80	30.42	82.09
SEm±	4.45	0.64	1.73
CD (0.05)	NS	NS	NS
Chilli pure crop	176.40	33.33	114.59
Amaranth pure crop	172.20	27.58	108.21
Interaction	NS	NS	NS

4.4 Bio suitability parameters of cropping system

4.4.1 Land Equivalent Ratio

The data on LER were analysed statistically and given in Table 20. Irrigation levels had no significant effect on LER. Planting geometry and nutrient levels had significant influence on LER. Normal row planting recorded significantly superior LER (2.84) compared with paired row planting. NL 100 was observed significantly higher LER (2.81) compared with other nutrient levels. Interaction effect between planting geometry and nutrient levels had significance and higher value was observed in normal row planting with NL 100 (3.26). Among treatment combinations with paired row planting, NL 50 with paired row planting recorded higher LER of 2.70. In case of interaction effect between nutrient and irrigation levels, NL 100 with IL 100 recorded significantly highest value of 3.06. Interaction between planting geometry, nutrient and irrigation level showed significance on LER. Among the different treatments, normal row planting with IL 100 and NL 100 recorded maximum LER (3.79).

4.4.2 Land Equivalent Coefficient

Planting geometry and nutrient levels had no significance on LEC (Table 20). Irrigation levels revealed significance in LEC and maximum value was recorded at 100 per cent Epan (1.54). Interaction effect between planting geometry and nutrient levels also had significance on LEC. Highest value of LEC (1.85) was observed in normal row planting with NL 100, which was on par with paired row planting with NL 50 (1.71).

4.4.3 Area Time Equivalent Ratio

Levels of irrigation significantly influenced on ATER and maximum value (2.56) was recorded at 100 per cent of Epan (Table 20). Planting geometry and nutrient levels had no significant effect on ATER. Interaction effect between planting geometry and nutrient levels revealed significance on ATER and maximum value (2.77) was observed in normal row planting with 100 per cent of nutrient level.

4.4.4 Crop Equivalent Yield

Effect of planting geometry, nutrient levels and irrigation levels did not significantly influence CEY (Table 20). Interaction effect between planting geometry and nutrient levels revealed significant effect on CEY and maximum value (19,201.58 kg/ha) was observed in normal row planting with NL 100 which was on par with paired row planting with NL 50 (18,763.43 kg/ha).

4.4.4 Relative Crowding Coefficient

The mean values on RCC were presented in Table 20.There is no significant effect on the RCC of intercropping system due to planting geometry, nutrient levels, irrigation levels and their interactions.

Table 20. Influence of planting geometry, nutrient and irrigation levels on parameters for evaluating the suitability of chilli- amaranth intercropping system

Treatments	LER	LEC	ATER	RCC	CEY (kg/ha)
Planting geometry					
A1 Normal row planting	2.84	1.35	2.39	-8.59	16565.71
A2 Paired row planting	2.39	1.31	2.42	-58.89	16541.18
SEm±	0.07	0.14	0.10	48.07	642.66
CD (0.05)	0.22	NS	NS	NS	NS
Nutrients					
B1 100% NPK	2.81	1.48	2.51	-10.41	17437.32
B2 75 % NPK	2.46	1.21	2.34	-80.17	15889.72
B3 50% NPK	2.58	1.30	2.37	-10.65	16333.30
SEm±	0.09	0.17	0.12	58.88	787.10
CD (0.05)	0.27	NS	NS	NS	NS
Irrigation					
C1 100% Ep	2.67	1.54	2.56	-57.13	17463.41
C2 75% Ep	2.56	1.12	2.25	-10.35	15643.48
SEm±	0.07	0.14	0.10	48.07	642.66
CD (0.05)	NS	0.40	0.29	NS	NS
A×B interaction CD (0.05)	0.38	0.69	0.51	NS	3265.51
B×C interaction CD (0.05)	0.38	NS	NS	NS	NS
A×B×C interaction CD (0.05)	0.54	NS	NS	NS	NS

Table 20(a). Interaction effect of planting geometry and nutrient levels on LER

Treatments	NL 100	NL 75	NL 50
Normal row planting	3.26	2.79	2.46
Paired row planting	2.36	2.12	2.70
SEm±	0.13		
CD (0.05)	0.38		

Table 20(b). Interaction effect of nutrient and irrigation levels on LER

Treatments	NL 100	NL 75	NL 50
IL 100	3.06	2.44	2.49
IL 75	2.55	2.47	2.66
SEm±	0.13		
CD (0.05)	0.38		

Table 20(c). Interaction effect of planting geometry, nutrient and irrigation levels on LER

Treatments	Normal row planting		Paired row planting	
	IL 100	IL 75	IL 100	IL 75
NL 100	3.79	2.74	2.33	2.38
NL 75	2.71	2.87	2.17	2.08
NL 50	2.31	2.61	2.68	2.72
SEm±	0.18			
CD (0.05)	0.54			

Table 20(d). Interaction effect of planting geometry and nutrient levels on LEC

Treatments	NL 100	NL 75	NL 50
Normal row planting	1.85	1.30	0.89
Paired row planting	1.11	1.11	1.71
SEm±	0.23		
CD (0.05)	0.69		

Table 20(e). Interaction effect of planting geometry and nutrient levels on ATER

Treatments	NL 100	NL 75	NL 50
Normal row planting	2.77	2.42	1.99
Paired row planting	2.25	2.25	2.75
SEm±	0.17		
CD (0.05)	0.51		

Table 20(f). Interaction effect of planting geometry and nutrient levels on CEY (kg/ha)

Treatments	NL 100	NL 75	NL 50
Normal row planting	19,201.58	16,592.39	13,903.16
Paired row planting	15,673.06	15,187.06	18,763.43
SEm±	1113.12		
CD (0.05)	3265.51		

4.5 Economics of cultivation

The data pertaining to the economics (Rs./ha) of cultivation of chilli- amaranth intercropping system under different planting geometry, nutrient and irrigation levels are presented in Table 21. The data indicated that gross return, net return and B:C ratio were not significantly influenced by planting geometry, nutrient and irrigation levels.

4.5.1 Gross return

Gross return was not significantly influenced by planting geometry, nutrient and irrigation level. Among different treatments, pure crop of chilli and amaranth recorded lower gross return of Rs.585,091.09 and Rs. 411,187.06 respectively. Interaction effect between planting geometry and nutrient level had observed significance on gross return. Normal row planting with NL 100 recorded higher gross income of Rs. 960,078.80, which was on par with paired row planting with NL 50 (Rs. 938,171.70). And the lowest gross return was observed in normal row planting with NL 50 (Rs. 695,158.20).

4.5.2 Net return

Planting geometry, nutrient levels and irrigation levels had no significant effect on net return. In contrary, interaction effect between planting geometry and nutrient levels had significance. Among different treatment combinations, normal row planting with 100 per cent of nutrient level was recorded higher net income (Rs. 553,065.70). In case of different treatment combinations with paired row planting, NL 50 with paired row planting obtained higher net income (Rs. 546,264.60).

4.5.3 B:C ratio

Effect of planting geometry, nutrient and irrigation levels had not marked influence on the B:C ratio. Though, interaction effect between planting geometry and nutrient level was revealed significance. Higher B:C ratio was recorded for paired row planting with 50 per cent of nutrient level (2.39) and was on par with normal row planting with 100 per cent of nutrient level (2.36).

Table 21. Effect of planting geometry, nutrient levels and irrigation levels on economics of chilli- amaranth intercropping system

Treatments	Gross return (Rs.)	Net return (Rs.)	B:C ratio
Planting geometry			
A1 Normal row planting	828,285.40	430,125.40	2.08
A2 Paired row planting	827,059.30	426,299.20	2.07
SEm±	32,133.15	32,132.98	0.08
CD (0.05)	NS	NS	NS
Nutrients			
B1 100% NPK for both crops	871,865.90	463,552.70	2.14
B2 75 % NPK for both crops	794,486.20	395,026.30	1.99
B3 50% NPK for both crops	816,664.90	426,057.90	2.09
SEm±	39,354.92	39,354.70	0.10
CD (0.05)	NS	NS	NS
Irrigation			
C1 100% Ep	873,170.70	472,960.70	2.18
C2 75% Ep	782,174.00	383,463.90	1.96
SEm±	32,133.15	32,132.98	0.08
CD (0.05)	NS	NS	NS
Chilli pure crop	585,091.09	197,716.60	1.51
Amaranth pure crop	411,187.06	24,548.28	1.06
A×B interaction CD (0.05)	163275.62	163274.73	0.40

Table 21(a). Interaction effect of planting geometry and nutrient levels on Gross return (Rs.)

Treatments	NL 100	NL 75	NL 50
Normal row planting	960,078.80	829,619.30	695,158.20
Paired row planting	783,653.00	759,353.00	938,171.70
SEm±	55656.25		
CD (0.05)	163275.62		

Table 21(b). Interaction effect of planting geometry and nutrient levels on Net return (Rs.)

Treatments	NL 100	NL 75	NL 50
Normal row planting	553,065.70	431,459.40	305,851.10
Paired row planting	374,039.80	358,593.10	546,264.60
SEm±		55655.95	
CD (0.05)		163274.73	

Table 21(c). Interaction effect of planting geometry and nutrient levels on B:C ratio

Treatments	NL 100	NL 75	NL 50
Normal row planting	2.36	2.08	1.79
Paired row planting	1.91	1.89	2.39
SEm±		0.14	
CD (0.05)		0.40	

Discussion

5. DISCUSSION

The experiment entitled "Chilli-Amaranth intercropping system under fertigation" was conducted at Water Management Research Unit, Vellanikkara during the year 2017. The results obtained from the experiment presented in the previous chapter are discussed below under following sections.

1. Performance of crops under intercropping system under fertigation
2. Effect of planting geometry on the performance of intercropping system under fertigation
3. Nutrient management in chilli- amaranth intercropping system under fertigation
4. Water management in chilli- amaranth intercropping system under fertigation
5. Soil nutrient status as influenced by intercropping under fertigation
6. Evaluation of chilli based intercropping system under fertigation

Fertigation has gained widespread popularity as an efficient and economically viable method for water and nutrient management. But the study of intercropping system under fertigation is limited. Hence with the objective of assessing the bio economic suitability of intercropping system under fertigation, the strategy of growing chilli- amaranth under intercropped situation with different planting geometry, nutrient levels and irrigation levels has been done.

5.1 Performance of crops under intercropping system under fertigation

The experiment was conducted to study the bio economic suitability of chilli+amaranth intercropping system under fertigation. A long duration crop, chilli with wider spacing was taken as the base crop and a closer spaced short duration crop amaranth was intercropped with chilli to study the yield performance of intercropping system under different planting geometry, nutrient and water level. From the result it was observed that the performance of crop differ when it was grown as intercrop and pure crop. Here the plant population of chilli under pure and intercrop was same. In this experiment the yield performance of chilli under sole crop was significantly higher

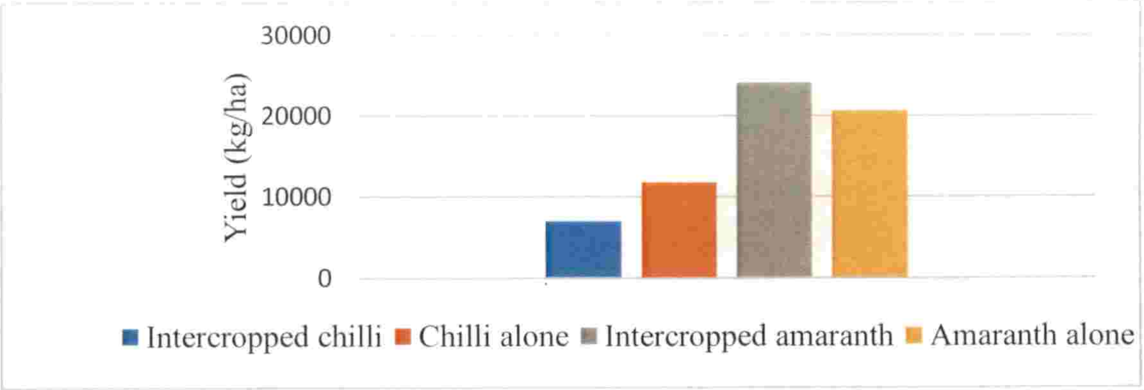


Fig. 2 Performance of crops under intercropping system

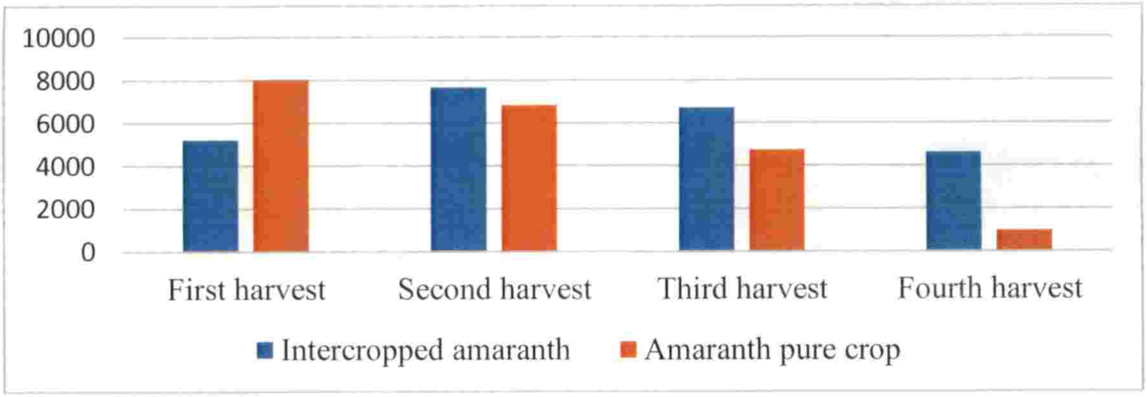


Fig. 3 Yield of amaranth in different harvest

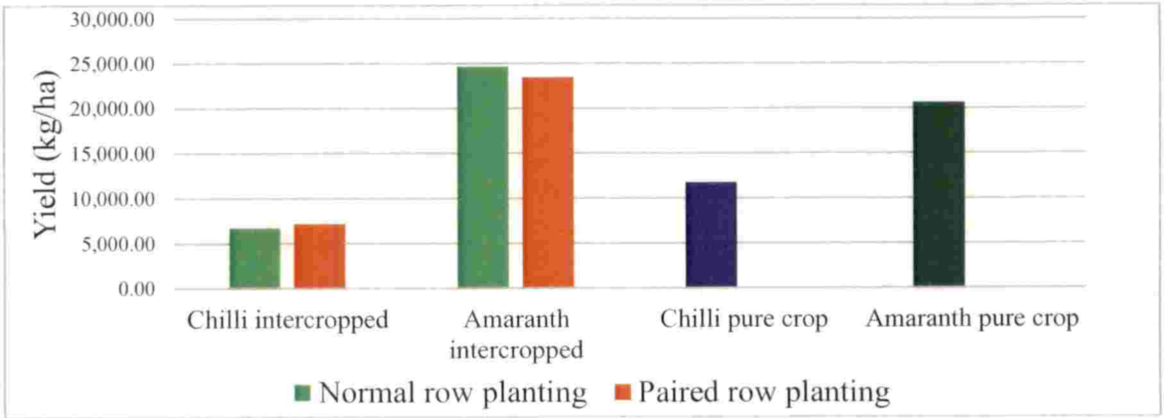


Fig. 4 Influence of planting geometry on yield of intercropping system

compared to the performance of chilli under intercropping system (Fig. 2). This may be due to the better development of growth and yield parameters and nutrient uptake of sole crop of chilli compared to intercropped chilli. The better development of growth and yield parameters under sole crop system may be due to the lesser competition for growth resource in pure crop system compared to intercropped system. In the case of amaranth, the yield performance of amaranth under intercropping situation was significantly higher compared to pure crop amaranth (Fig. 2). Even though the plant population of amaranth under intercropping system was less compared to pure crop amaranth, the yield of amaranth under intercropping system was higher. This was due to the higher yield obtained from the intercropped amaranth for the second, third and fourth harvest (Fig.3). For pure crop amaranth the yield obtained at first harvest was higher compared to intercropped amaranth. But for intercropped amaranth, the cumulative effect of higher yield obtained from the subsequent harvest leads to higher yield. The yield increase of amaranth under intercropping system was due to the receipt of continuous nutrients through fertigation. For amaranth, the fertigation schedule was for five weeks. But for intercropped amaranth in addition to the fertigation of amaranth, nutrients were received from the fertigation given to chilli crop. This resulted in the higher dry matter production and nutrient uptake of intercropped amaranth and finally higher yield for intercropped amaranth compared to pure crop.

The effect of planting geometry, nutrient levels and irrigation levels on the growth and yield performance of crop under intercropping system and the biological and economic efficiency of the intercropping system are discussed below.

5.2 Effect of planting geometry on the performance of intercropping system under fertigation

5.2.1 Effect of planting geometry on intercropped chilli

Intercrops can be accommodated in between the spaces of base crop by modifying the planting pattern. Two type of planting patterns were adopted viz., normal row planting and paired row planting system. In this study, yield of chilli was similar under normal and paired row planting (Fig. 4). That is planting geometry had no significance on yield of chilli under intercropping system. Similar results were obtained by Palaniappan *et al.* (1975). Growth and yield attributing characters were not significantly influenced by planting geometry in the intercropped chilli. Growth characters like plant height (Table 6, Fig. 5), number of leaves per plant (Table 7, Fig. 6), number of branches (Table 8, Fig. 7), leaf area per plant (Table 9, Fig. 8), dry matter accumulation (Table 10), and yield attributing characters like days to first flowering, number of fruits per plant, fruit weight (Table 11) and NPK uptake of intercropped chilli were similar under both normal row planting and paired row planting (Fig. 10). In a study conducted on radish based intercropping system, growth and yield characters among different planting pattern in intercropping system is not significant may be due to the reason that utilization of sunshine for photosynthesis is uniform among crops (Brintha and Seran, 2009).

The yield of chilli under pure crop was more than both systems of planting (Fig. 4). Oseni (2010) reported that yield of sorghum was comparatively higher in sole crop system than that in paired or normal row intercropping, presumably due to absence of competition from intercrop (cowpea).

The NPK uptake of chilli under pure crop (64.28, 12.57, 84.85 kg/ha) was more than normal row system and paired row system (Fig. 10). This might be due absence of competition and minimum intercrop density under pure crop system or due to higher competitive ability of intercrop amaranth. Anitha and Geethakumari (2001) noted the poor nutrient uptake of chilli in chilli amaranth intercropping system was due to the aggressive growth nature of amaranth. Kumawat *et al.* (2012) observed that NPK uptake where higher in sole crop of pigeon pea than different planting pattern due to competition free environment under sole crop.

5.2.2 Effect of planting geometry on intercropped amaranth

The yield of amaranth was not significantly influenced by planting geometry (Fig. 4), because planting geometry showed no significant difference on growth and

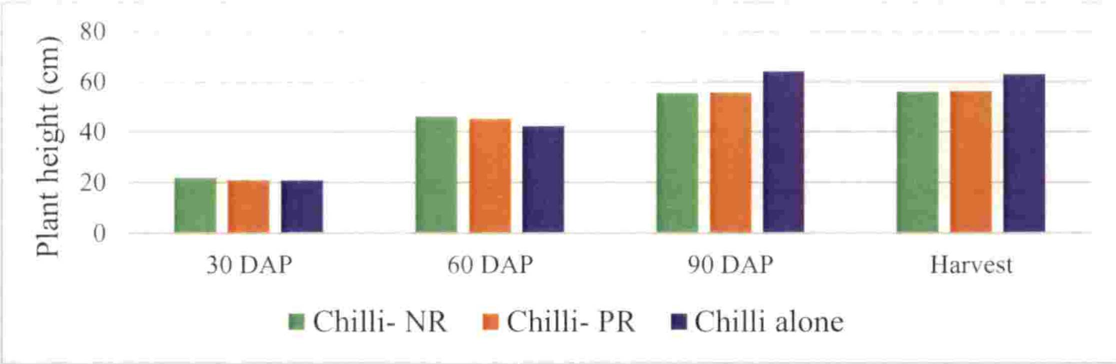


Fig. 5 Effect of planting geometry on plant height of intercropped chilli

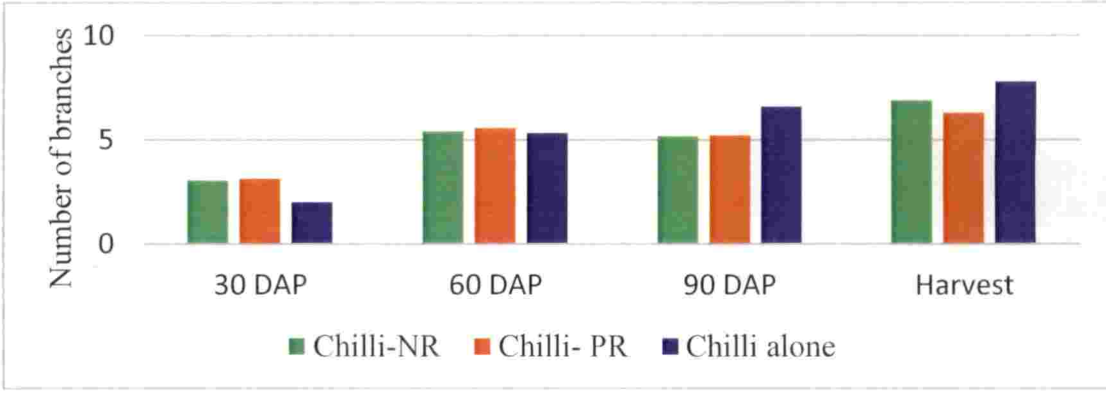


Fig. 6 Effect of planting geometry on number of branches of intercropped chilli

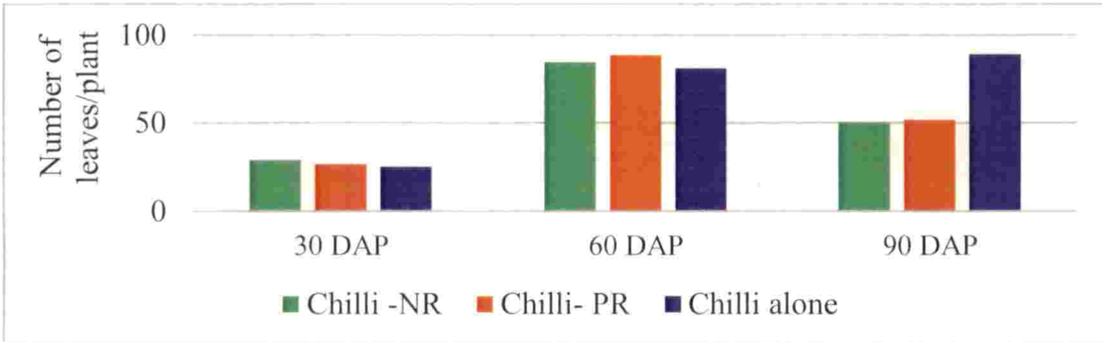


Fig. 7 Effect of planting geometry on leaves number of intercropped chilli

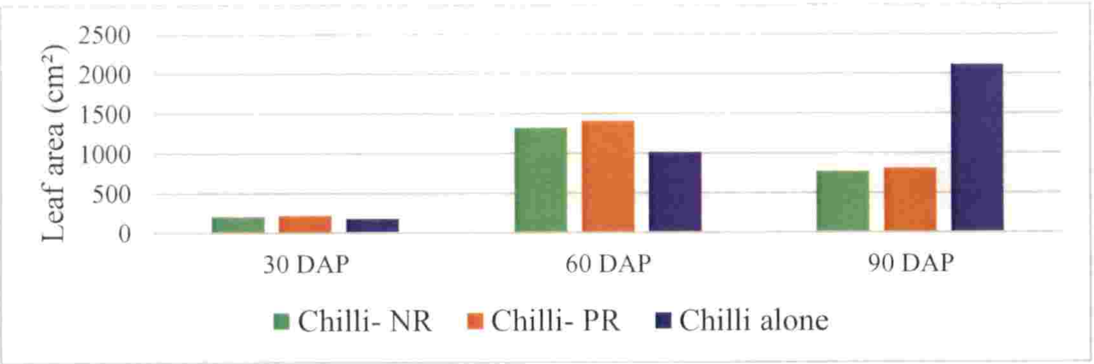


Fig. 8 Effect of planting geometry on leaf area of intercropped chilli

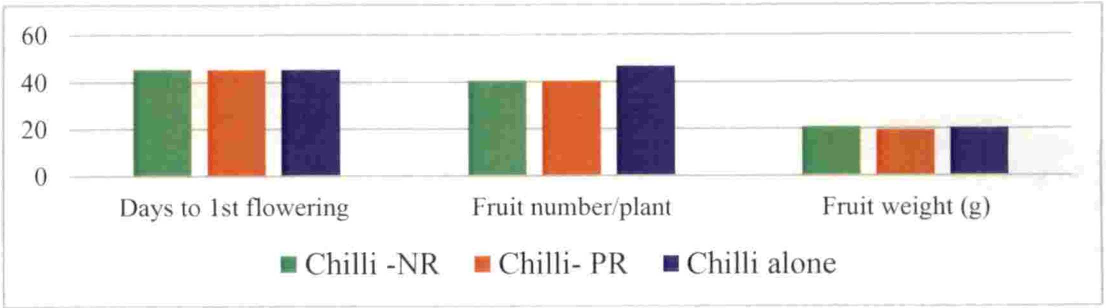


Fig. 9 Effect of planting geometry on yield attributes of intercropped chilli

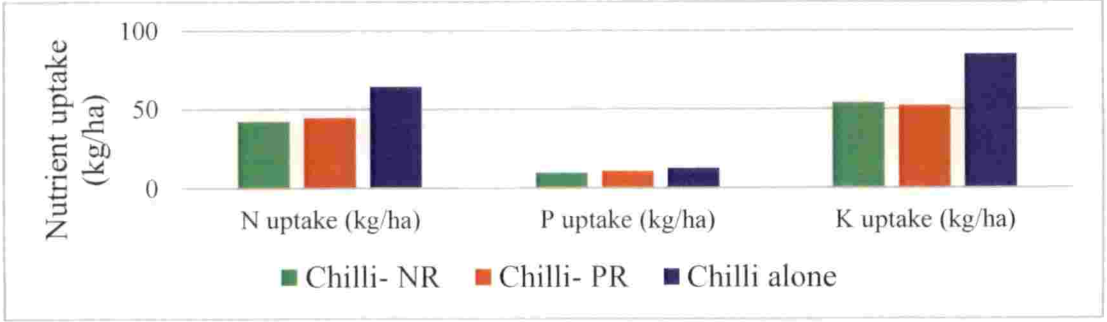


Fig. 10 Effect of planting geometry on NPK uptake of intercropped chilli

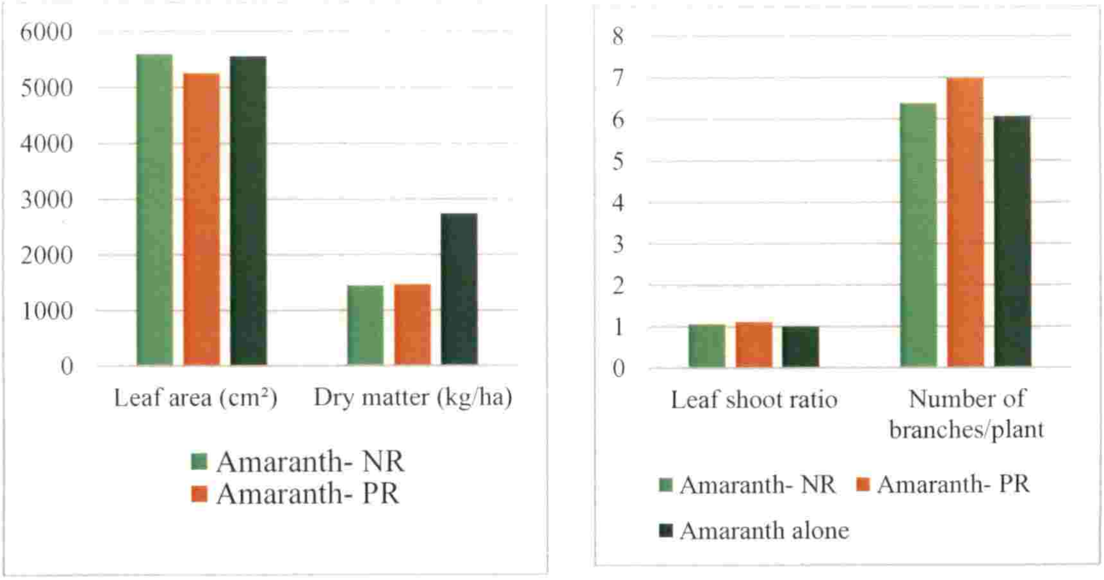


Fig. 11 Effect of planting geometry on growth attributes of intercropped amaranth

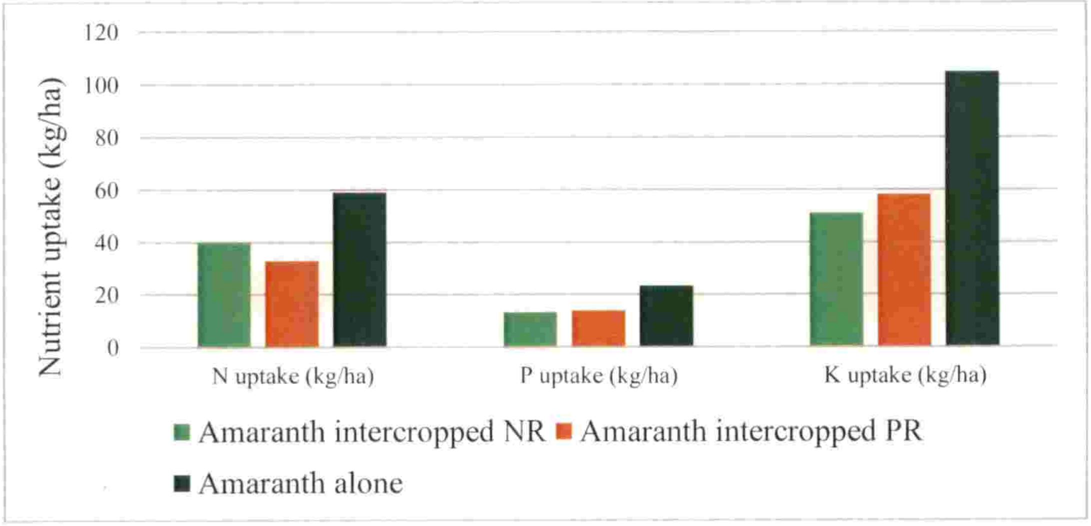


Fig. 12 Effect of planting geometry on NPK uptake of intercropped amaranth

yield attributes like leaf area, number of branches per plant, dry matter accumulation, leaf shoot ratio (Fig. 11) and NPK uptake(Fig. 12). Thus the yield of amaranth was similar under normal and paired row system.

The yield and dry matter accumulation of intercropped amaranth under both planting geometry were more than yield of pure crop amaranth. Anitha and Geethakumari (2001) observed higher yield of amaranth under chilli- amaranth intercropped system than pure crop due to higher competitive nature of amaranth. The higher plant height (Table 12), number of leaves per plant (Table 12), number of branches per plant (Table 13) and leaf shoot ratio (Table 13) produced by amaranth under intercropped system may have resulted in higher yield compared to pure crop amaranth. A similar trend was recorded by Anitha and Geethakumari (2001).

Interaction effect of plant geometry with nutrient level and plant geometry with nutrient and irrigation level had significance on total yield produced by amaranth (Table 13c) and Table 13d). Among different treatment combinations between planting geometry and different nutrient levels, normal row planting with 100 per cent of nutrient dose recorded higher yield of 28,162.31 kg/ha. In the case of interaction effect between plant geometry with different nutrient and irrigation level, a higher yield (31,104.93 kg/ha) was registered by normal row planting receiving 100 per cent nutrient dose for both crop and irrigation at 100 per cent of Epan. Kumawat *et al.* (2012) also noticed higher yield and net return of pigeon pea in intercropping system with combination of normal row planting with 100 RDF due to efficient utilization of resources.

5.3 Nutrient management in chilli- amaranth intercropping system under fertigation

Nutrient recommendation for crop under pure crop was developed for all crops. But when it was intercropped, the nutrient requirement may vary. Hence it is essential to find out the nutrient requirement of the system as a whole. In this experiment, three nutrient doses were given for the intercropped situation *viz.*, 100 per cent NPK recommendation for the both the crops (NL 100), 75 per cent NPK recommendation for both crops (NL 75) and 50 per cent NPK recommendation for both the crops (NL 50). For the pure crops of chilli and amaranth were given 100 per cent of their respective nutrient recommendation as per POP. For pure crop and intercropped chilli the fertilizer were given as 10 fertigation schedules (Table 5) and for pure and intercropped amaranth the fertilizer were given as five fertigation schedule (Table 5). Hence for amaranth under intercropped system received fertigation upto 10 weeks. Intercropped plants received more nutrients that is the nutrients applied for both the crops.

5.3.1 Effect of nutrient levels on intercropped chilli

Result of the study revealed that the yield of chilli was not significantly influenced by nutrient levels, that is by reducing the fertilizer recommendation the yield of intercropped chilli was not affected (Fig. 13). But compared to pure crop yield, the intercropped yield were significantly less. This was due to the competition for nutrients by amaranthus under intercropped situation. Similar results were reported by Mamun *et al.* (2002). They observed the yield of chilli would be decreased by increasing the population of mustard, though competition increases under intercropped situation. It is also evident that pure crop recorded higher growth characters like plant height of 190.32 cm, (Table 6), number of leaves per plant of 195 (Table 7), number of branches of 21.73 (Table 8) and leaf area of 3305.08 cm^2 (Table 9) than intercropped system. This better development of leaf area resulted better yield contributing characters like dry matter accumulation, number of fruits and fruit weight (Fig.14). These better parameters of chilli may be due to higher uptake of nutrients by pure crop (64.28 kg N/ha, 12.57 kg P/ha and 84.85 kg K/ha) than intercropping system. The growth and yield parameters and nutrient uptake of intercropped chilli received different nutrient doses were not significantly different. Hence resulted in a similar yield of chillies under intercropped system receiving different nutrient levels.

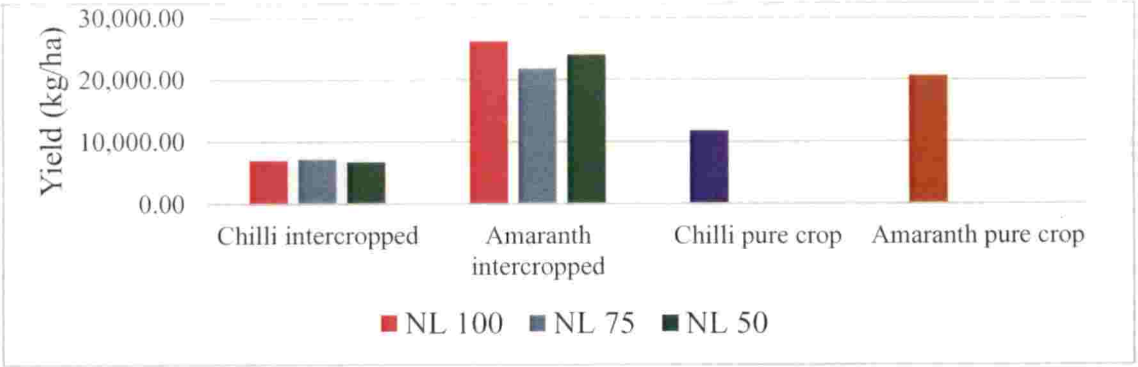


Fig. 13 Influence of nutrient levels on yield of intercropping system

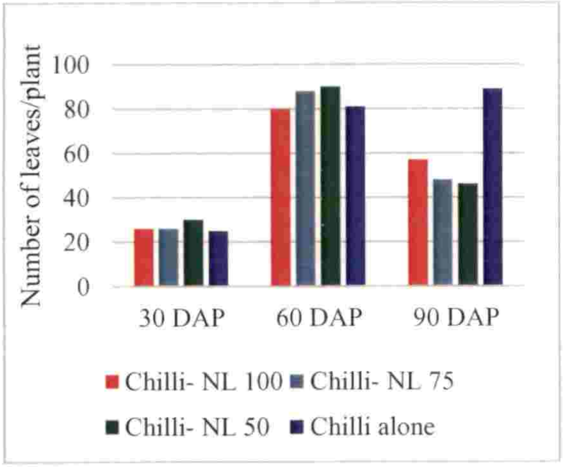


Fig. 14 Effect of nutrient levels on number of leaves/plant of chilli

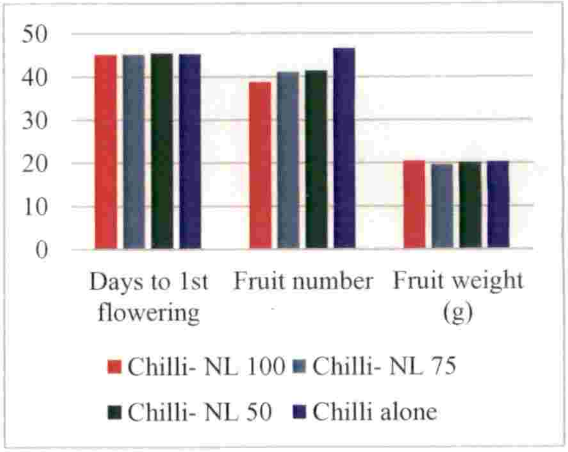


Fig. 15 Effect of nutrient levels on yield attributes of chilli

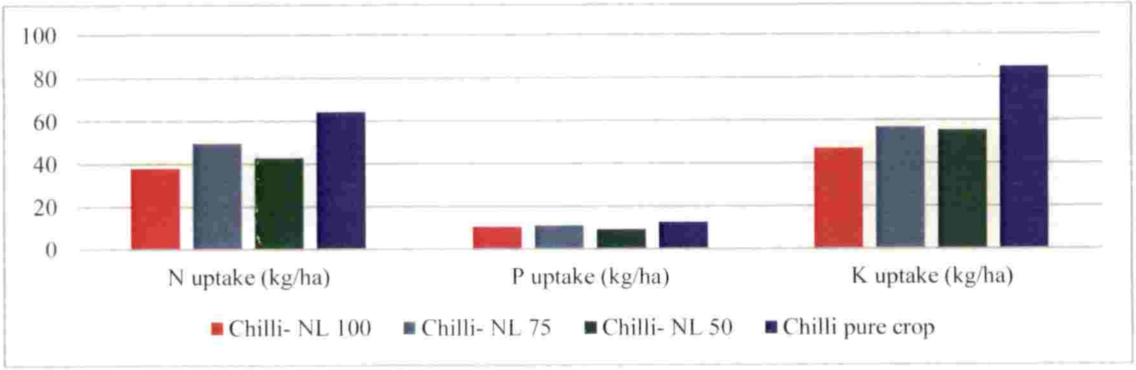


Fig. 16 Effect of nutrient levels on NPK uptake of chilli

5.3.2 Effect of nutrient levels on intercropped amaranth

Intercrop yield of amaranthus was significantly influenced by different nutrient levels (Fig.14). Higher yield was noticed for NL 100 (26,227.57 kg/ha) followed by NL 50 (24,050.52 kg/ha). The yield increase of intercropped amaranth receiving 100 per cent NPK both crops may be due to the higher availability of nutrients. Dry matter production (Fig. 17) and NPK uptake (Fig.18) were higher when received 100 per cent NPK for both crops. This resulted in better nutrient uptake and there by yield. Jensen (1996) opined that due to complementary use of soil and atmospheric nitrogen by component crops in intercropping system, resulted in better yield advantage in pea-barley intercropping system.

The better performance of amaranth than chilli in chilli-amaranth intercropping system may be due to better exploitation of nutrients and other resources by amaranthus. Though the higher yield of amaranth was from the intercropped system than pure crop indicates the dominant nature of amaranthus in chilli- amaranthus intercropping system. And this may due to the continuous availability of nutrients to amaranth in intercropping system, *ie.,* intercropped amaranth received five more weeks fertigation given to chilli. For pure crop of amaranth fertigation was given upto five weeks after planting (Table 5). Results also revealed that the yield of pure crop of amaranth was higher at first harvest compared to intercropped amaranth, but for the subsequent harvest intercropped amaranth produced high yield and was reflected in the higher total yield of intercropped amaranth.

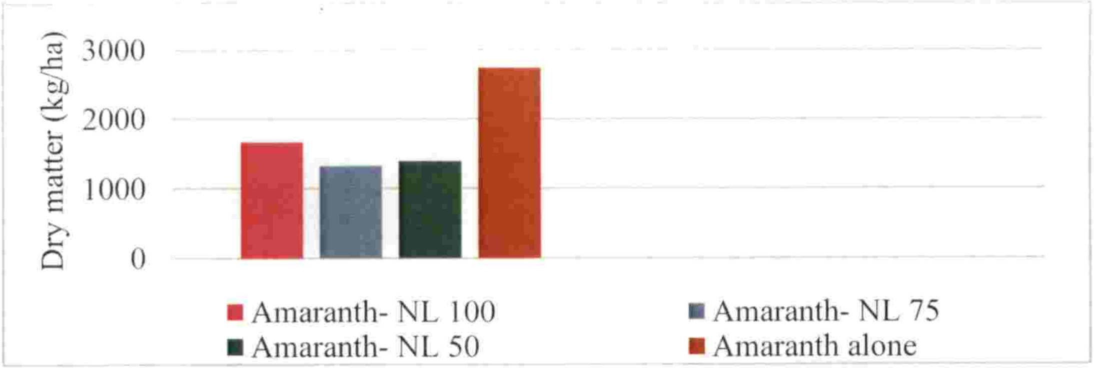


Fig. 17 Effect of nutrient levels on dry matter production of amaranth

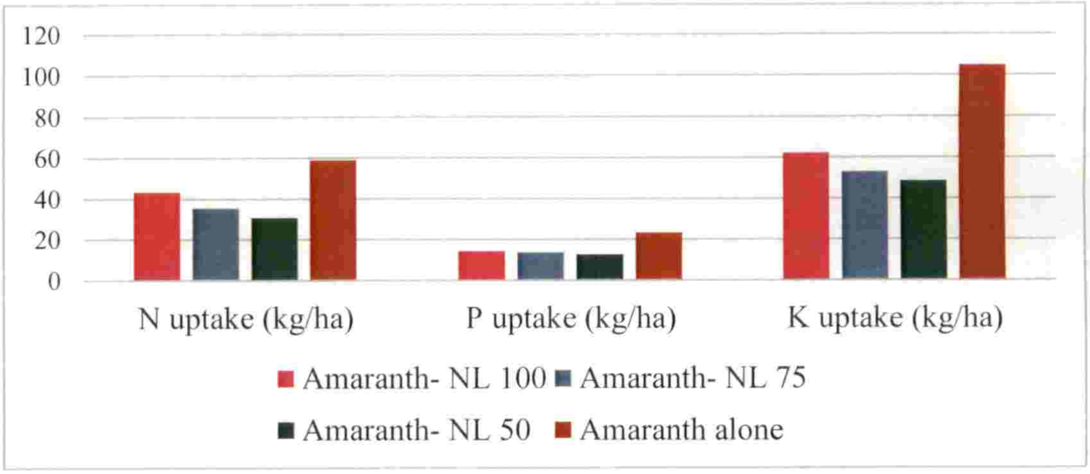


Fig. 18 Effect of nutrient levels on NPK uptake of amaranth

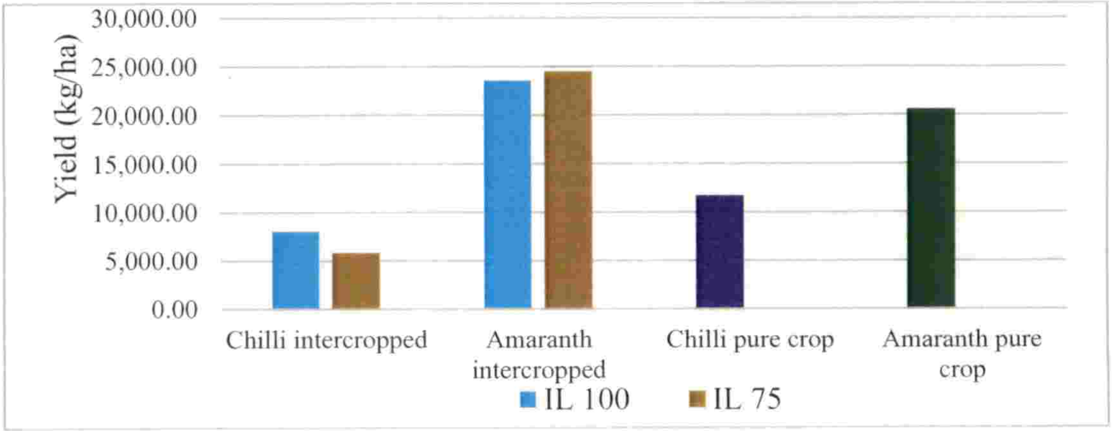


Fig. 19 Influence of irrigation levels on yield of cropping system

5.4 Water management in chilli-amaranth intercropping system under fertigation

In this experiment drip irrigation was given for pure and intercropped treatment. Pure crop of chilli and amaranth were given irrigation at 100 per cent Epan. For intercropped treatments irrigation at 2 levels viz., 100 per cent of Epan and 75 per cent of Epan were given. That is, for pure crop of chilli and amaranth and for intercropped plots with 100 per cent Epan received the same quantity of water.

5.4.1 Effect of irrigation levels on intercropped chilli

Levels of irrigation given to intercropped treatments plants revealed that yield of intercropped chilli receiving water at 100 per cent Epan was significantly higher compared to intercropped chilli receiving water at 75 per cent of Epan (Fig. 19). The yield reduction was 27.26 per cent by reducing the water to 75 per cent. The development of growth and yield attributes and uptake of nutrients were significantly higher for intercropped chilli receiving water 100 per cent Epan compared to intercropped chilli receiving water at 75 per cent Epan. There by high yield for intercropped chilli receiving irrigation at 100 per cent Epan. Performance of intercropped amaranth was not significantly influenced by the irrigation levels.

Chilli recorded significantly higher yield when chilli was grown under pure crop system with 100 per cent of Epan followed by intercropped system with IL 100 (Fig. 19). Sani *et al.* (2015) studied on effect of irrigation levels on corn- soybean intercropping system and concluded that highest yield was obtained with pure crop of soybean. This may due to absence of competition and also due to higher NPK uptake of chilli (64.28, 12.57 and 84.85 kg/ha) under sole cropping system (Fig.23). It was observed that the growth parameters like plant height (190.32 cm), leaf number (195), branches number (21.73) and leaf area (3305.08 cm^2) produced by chilli in pure crop was superior than different irrigation levels under intercropping system. Also figure 19 indicates that IL 100 shows better performance of chilli under intercropping system. That is, lower irrigation level (IL 75) was not sufficient to meet demand of chilli in

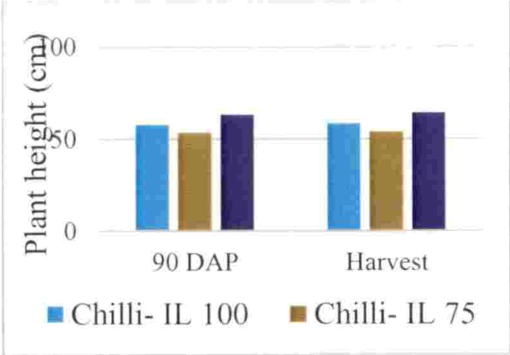


Fig. 20 Effect of irrigation levels on plant height of chilli

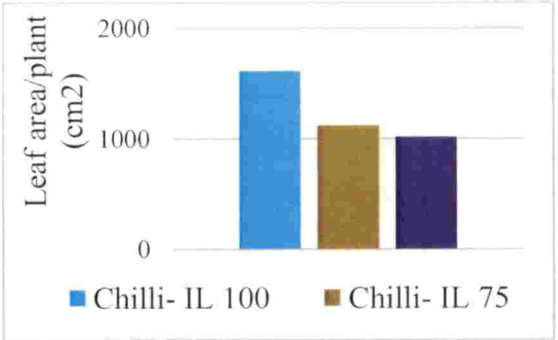


Fig. 21 Effect of irrigation levels on leaf area/plant of chilli

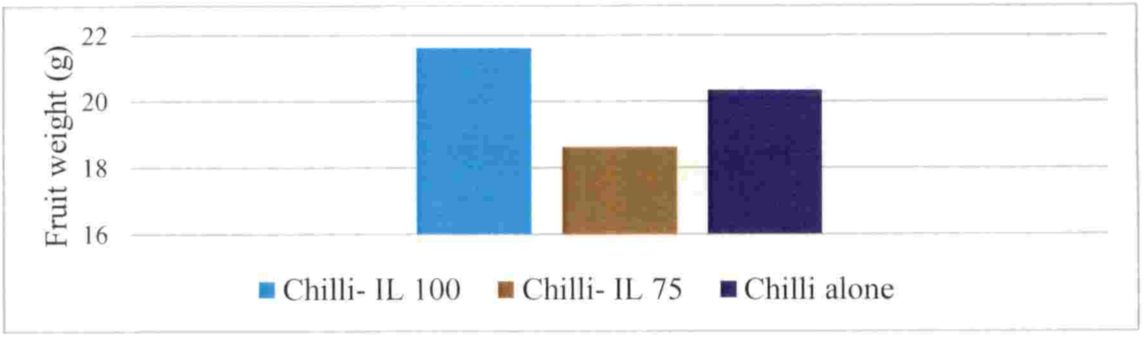


Fig. 22 Effect of irrigation levels on fruit weight of chilli

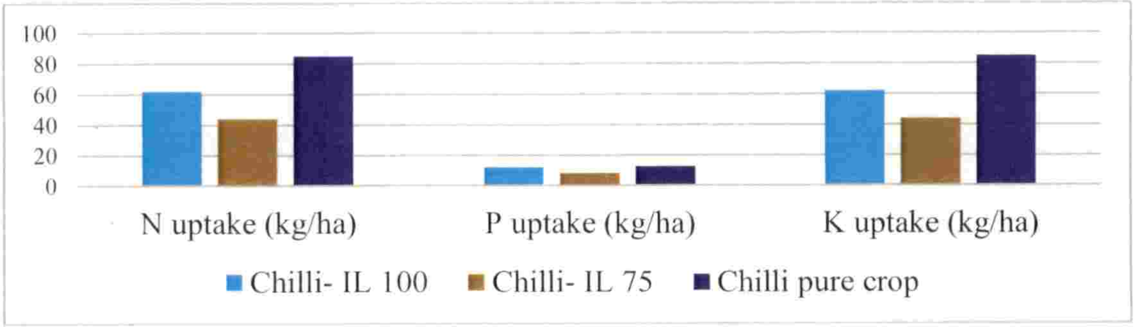


Fig. 23 Effect of irrigation levels on NPK uptake of chilli

intercropping system. These resulted in poor performance of NPK uptake and growth and yield attributes and thereby lower yield with IL 75.

. 5.4.2 Effect of irrigation levels on intercropped amaranth

Irrigation levels did not significantly influenced the intercrop yield of amaranthus (Fig. 19). Compared to pure crop yield, yield was more at IL 75 and IL 100 and these irrigation levels had a similar effect on yield. This indicates IL 75 might be enough for intercropped amaranthus. It may be due to superior value growth parameters like plant height (34.56 cm) and number of branches (7.11) with IL 75 (Table 12). Degefa *et al.* (2016) reported 75 per cent ET of irrigation depth and 12 days of irrigation intervals is a better practice of water management in sugarcane- soyabean intercropping system.

5.4.3 Water productivity of intercropping system

Water productivity of chilli + amaranth intercropping system receiving irrigation at 100 per cent of Epan and 75 per cent Epan was significantly higher compared to pure crop of chilli and amaranth receiving 100 per cent of Epan. The water productivity increase at 100 per cent Epan for intercropped chilli + amaranth was 170 per cent and 54 per cent higher compared to pure crop chilli and pure crop amaranth respectively. Water productivity (WP) was not significantly influenced by irrigation levels and also higher WP was noted for IL 75 (Fig. 26). Since there is significant effect of irrigation levels on amaranth yield, we can save water by adopting IL 75. Higher yield of amaranth in the intercropping system resulted in higher water productivity compared to pure crop.

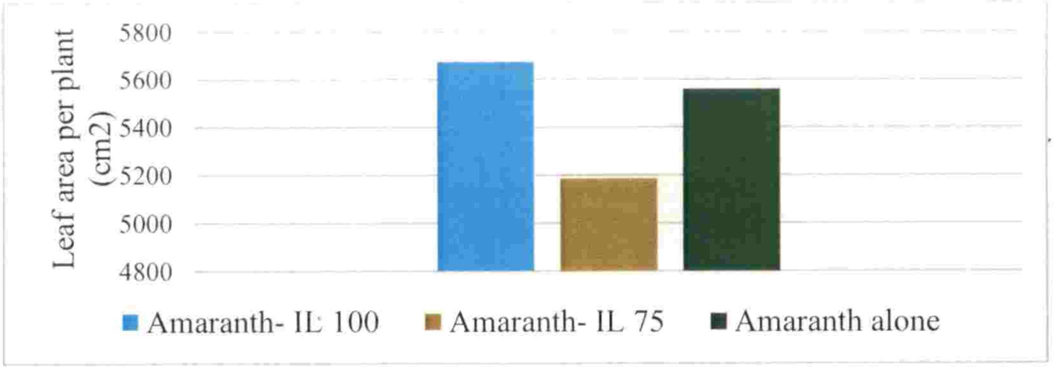


Fig. 24 Effect of irrigation levels on leaf area/plant of amaranth

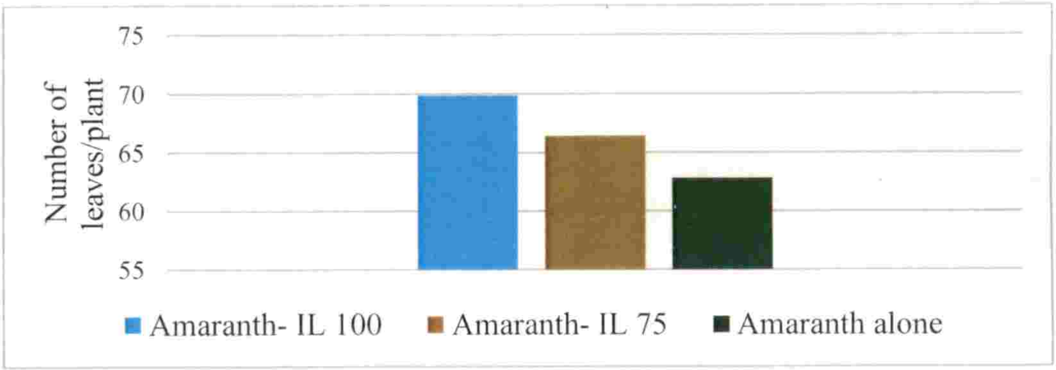


Fig. 25 Effect of irrigation levels on number of leaves/plant of amaranth

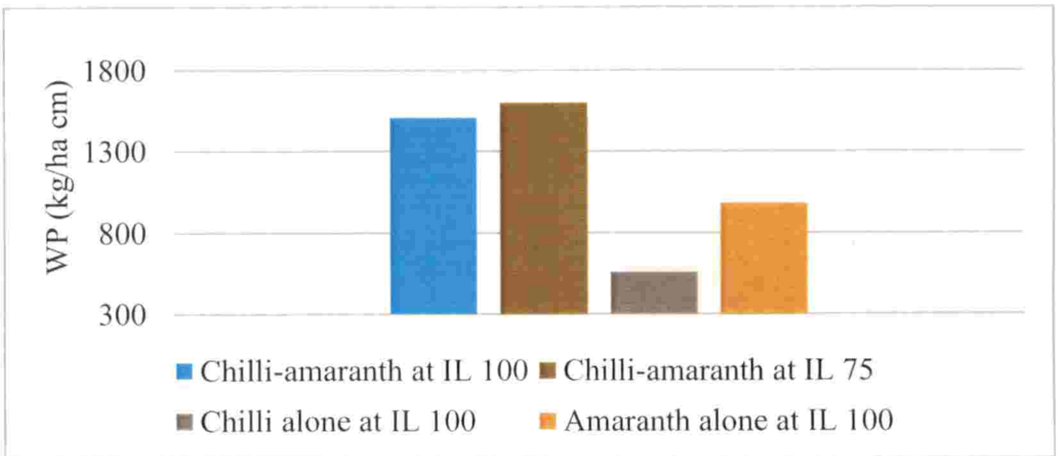


Fig. 26 Water productivity of intercropping system

5.5 Soil nutrient status as influenced by intercropping under fertigation

Soil pH (Table 18), organic carbon (Table 18), N, P and K (Table 19) were analysed before and after the experiment. Results revealed that soil pH showed a slight increase compared to initial pH irrespective of the treatments (Table 18). This may be due to uniform application of lime before the experiment. Organic carbon of the soil after the experiment was less in intercropped and pure cropped plots compared to the initial soil organic carbon (Table 18). Soil available nitrogen and potassium also showed the same trend (Table 19). The available P content of the soil after the experiment showed not much variation compared to the initial P content of the soil. This may be due to the higher nutrient uptake of crops. Here amaranth crop used was a multicut variety and was harvested at four times (Fig. 3). Though it is a leafy vegetable the entire plant was removed at last harvest. And because of this complete crop removal there may be no crop residue addition to the soil from the plants, resulted in lower nutrients in the soil. Ayoola (2011) recorded that there was reduction in soil NPK and organic carbon in cassava + maize intercropping system with application of NPK alone due to early release of nutrients for utilization by maize, leading to depletion of the inherent stsatus by the longer maturing cassava.

5.6 Evaluation of chilli based intercropping system under fertigation

Evaluation of bio economic suitability of intercropping system is done using several indices. The biological efficiency of intercropping is determined by LER, LEC, ATER, RCC and CEY by comparing the productivity of a given area of intercropping with that of sole crop (Table 20). Gross return, net return and B:C ratio is used for assessing the economic benefit.

Biological efficiency of intercropping system

5.6.1 Land Equivalent ratio (LER)

An ideal parameter for evaluating the bio suitability of intercropping system is LER, which represents the relative land area under sole crop to produce same yield as that of intercropping. LER value higher than one indicates that the intercropping system is more productive. It is used for determining whether it is more beneficial to go for intercropping than to produce them separately. LER is the generally used single index for expressing the yield advantage. The results revealed that the LER of chilli-amaranth system grown under different planting geometry, receiving different nutrient levels and water levels was more than one (Table 20). This indicated the advantage in land use of intercropping chilli and amaranth over sole cropping. Biological suitability due to higher land equivalent ratio (2.74) was reported in chilli-amaranth intercropping system by Anitha and Geethakumari (2006).

Planting geometry and different levels of nutrients had significant influence on the LER (Table 20). Normal row planting recorded significantly higher LER (2.84) than paired row planting indicating that the intercropped system performed better under normal row planting (Fig. 28). A similar trend was noticed by Anitha and Geethakumari (2001).

Intercropping system receiving 100 per cent recommended NPK for both crops recorded significantly higher values of LER compared to other levels of nutrients (Fig. 28). Awasthi *et al.* (2011) observed chickpea- fennel intercropping system with 100 per cent of RDF efficiently performed under intercropping system. The higher LER with the normal row planting and NL 100, may due to higher yield recorded in subsequent treatments. Hence to reap the maximum benefit from the intercropping system both crops in the intercropping system were given 100 per cent recommended nutrient dose. Anitha (1995) revealed that compared to lower doses of nutrients, NL 100 recorded significantly higher LER (3.1). LER of intercropping system receiving irrigation at 100 per cent Epan and 75 per cent Epan performed similarly indicating that effective utilization of water in the intercropping system even under lesser quantity of irrigation.

5.6.2 Land Equivalent Coefficient (LEC)

LEC is another parameter used for assessing the yield advantage of cropping system. Any intercropping system involving two crops become beneficial, when it had an LEC of more than 0.25 indicating that each crop in the system should give at least 50 per cent of their sole crop yield. Joseph and Balan (2008) reported higher LEC value for ash gourd + amaranth intercropping system (0.925) which indicated that loss in yield was compensated by higher LER of amaranth and thus resulted in higher LEC.

Planting geometry failed to show any significant difference in the LEC value of intercropping system (Fig. 29). A similar result was also observed by Anitha (1995). The LEC obtained under different nutrient levels were not significant but the higher value was obtained with 100 per cent nutrient dose (Table 20). LEC of intercropped treatments receiving 100 per cent Epan was significantly higher compared to 75 per cent Epan (Fig. 29). This may due to significantly higher yield of chilli recorded with intercropping system receiving 100 per cent Epan.

5.6.3 Area Time Equivalent Ratio (ATER)

While calculating LER, the duration of field, dedicated to production is not considered. This was make up by calculating ATER, which consider the land occupancy period of the crop, that is the utilization of area and time by crops in the intercropping system. Joseph and Balan (2008) reported higher utilization of space and time with intercropping of ash gourd+ pole cowpea + amaranth due to better combined intercrop yield and temporal difference existed between the crops. The land occupancy period of chilli in the experiment was 194 days and that of amaranth was 93 days. Considering this, ATER was calculated for the system. Higher value of ATER is due to better combined intercropped yield and temporal difference which existed between the crop. The result indicated that the utilization of space and time under different planting pattern and different levels of nutrients were similar. Whereas space and time utilization was significantly higher with intercropping system receiving 100 per cent irrigation was noticed (Fig. 30).

5.6.4 Relative Crowding Coefficient (RCC)

RCC indicates whether a species of crop, when grown in mixed population was produced more or less yield than expected in pure stand. If the component has a coefficient less than, equal to or greater than one, it means that it has produced less yield, the same yield or more yield than expected. Planting geometry, nutrient levels and irrigation levels failed to show significance on RCC (Table 20).

5.6.5 Chilli Equivalent Yield (CEY)

In intercropping, if more than one species are involved it is difficult to compare the produce of crops. Hence the equivalent yield was calculated by converting the intercropped yield into base crop yield by considering the market rate of both the crops. Chilli equivalent yield was higher in chilli- amaranth intercropping system compared to sole crop due to maximum utilization of growth resources under intercropping system (Table 20). Anitha and Geethakumari (2006) reported that significantly higher chilli equivalent yield (10421 kg/ha) were recorded with chilli + amaranthus intercropping. Tarafder *et al.* (2003) revealed that the highest chilli equivalent yield (2732 kg/ha) and land equivalent ratio (1.34) was obtained from 20 per cent of onion population intercropped with chilli. Even though planting geometry, nutrient levels and irrigation levels did not show significance on CEY, normal row planting, NL 100 and IL 100 noticed higher CEY respectively (Fig. 27). It is the direct reflection of higher yield of intercrops.

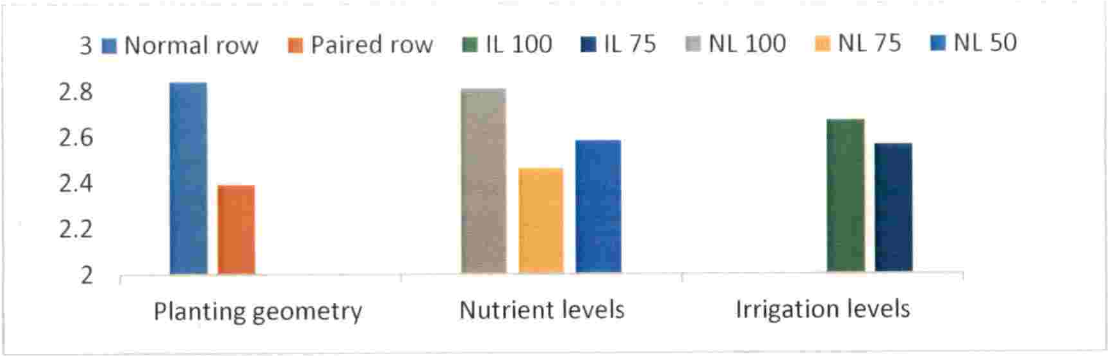


Fig. 27 LER of intercropping system

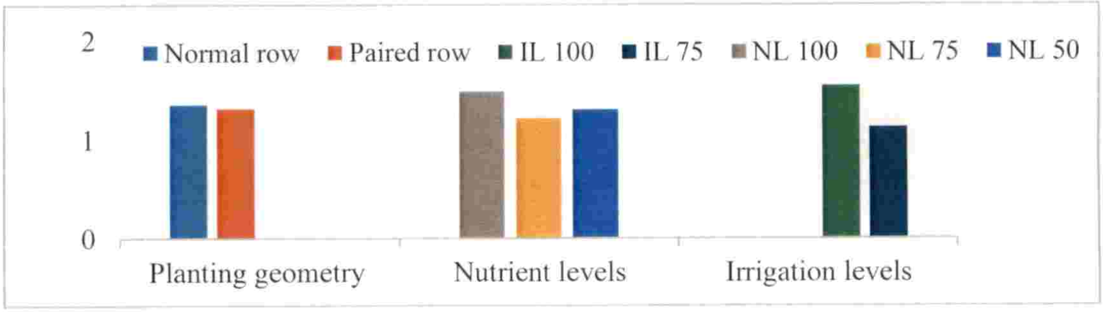


Fig. 28 LEC of intercropping system

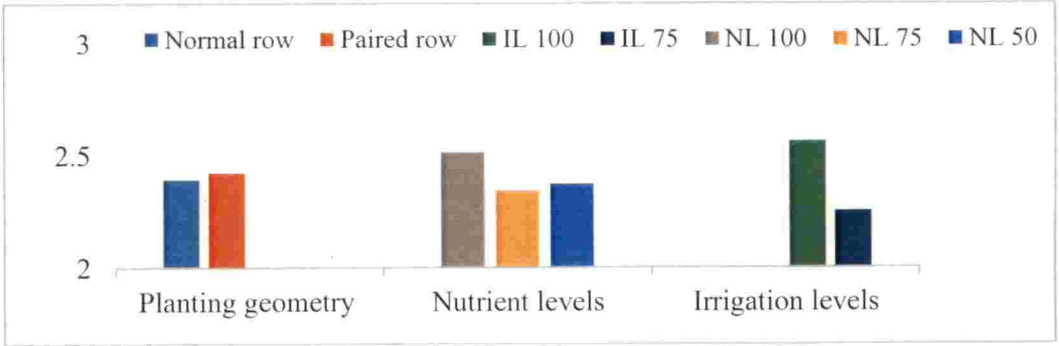


Fig. 29 ATER of intercropping system

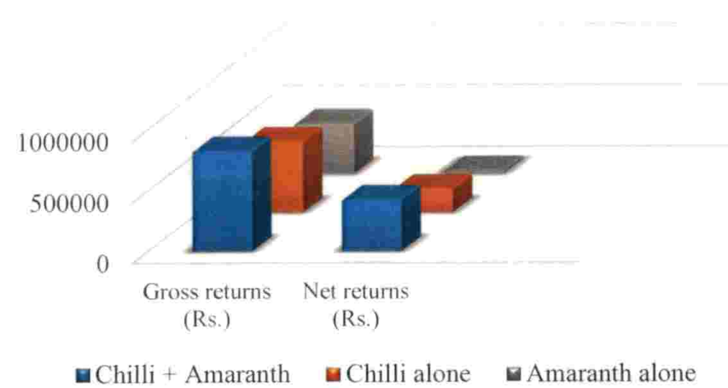


Fig. 30 Economic suitability of intercropping system

Economic suitability

Chilli- amaranth intercropping system recorded significantly high B:C ratio of 2.07 and high net return of Rs. 4,28,212 compared to pure crop of chilli and amaranth (Fig. 31) . The gross return and net return of chilli-amaranth intercropping system was 41.4 and 116 per cent higher compared to pure crop chilli and 101 and 164 per cent higher to pure crop of amaranth (Table 21). Mamun (2002) studied the economics of chilli– mustard intercropping system and indicated that an additional net income of Rs.1937 per ha was obtained from intercropping system than sole crop. Economic analysis done by Suresha *et al.* (2007) for chilli based cropping system revealed that highest gross returns (Rs. 108766/ha), net returns (Rs. 59261/ha) and B:C ratio (1.75) were recorded with chilli + garlic intercropping compared to sole chilli. This was due to the higher combined yield in intercropping system. Also, Anitha and Geethakumari (2006) reported that to reap maximum economic advantage from chilli based cropping system, the crops should be supplied with 100 percent of the recommended dose as per

POP. Planting geometry, nutrient levels and irrigation levels failed to show significance with gross return, net return and B:C ratio in the intercropping system.

Here the interaction effect between planting geometry and nutrient levels showed significant influence on gross return (Table 21a), net return (Table 21b) and B:C ratio(Table 21c). Normal row planting receiving 100 per cent of nutrient dose had higher value of gross return, net return and B:C ratio. This may be due to higher yield with that treatment.

The result of the study indicated that chilli-amaranth intercropping system under fertigation is a biologically efficient and economically viable system compared to pure cropping systems. To reap the maximum benefit from chilli-amaranth intercropping system under fertigation, planting should be done at normal row and both the crops should be given their 100 per cent NPK recommendations and irrigation should be given at 100 per cent Epan under fertigation.

Summary

6. SUMMARY

The present investigation entitled "Chilli-Amaranth intercropping system under fertigation" was carried out to study the bio economic suitability of chilli-amaranth intercropping system under different nutrient and water regimes. The cropping period was from January to July 2017.

The experiment was conducted at the Water Management Research Unit, Vellanikkara, Thrissur. The trial was laid out in randomized block design replicated thrice. The treatments consisted of chilli- amaranth intercropping system planted at two different planting geometries *viz*., normal row planting and paired row planting, three nutrient levels *viz*., 100, 75 and 50 per cent of NPK recommendation for both crops as fertigation and two irrigation levels *viz*., 100 per cent Epan and 75 per cent Epan. Biometric and yield observations, plant analysis, soil analysis, observations on biological suitability parameters and economics of cost and benefit analysis were worked out. The result of the study are summarized and listed herewith.

- Performance of crops under intercropping and pure crop system revealed that the yield of intercropped chilli was 41 per cent lower than chilli pure crop. However for amaranth, the yield was 17 per cent higher under intercropping compared to pure crop.
- Paired row pattern was adopted to accommodate more intercrops. However planting geometry had no significant influence on the yield performance of intercropped chilli and amaranth. Since normal row planting is sufficient for the chilli-amaranth intercropping system.
- The nutrient levels showed no significant difference on the yield of intercropped chilli, whereas yield of intercropped amaranth was significantly influenced.
- Intercrop yield of amaranth at 100 per cent of nutrient dose (26,227 kg/ha) was significantly higher than intercrop yield of amaranth at 75 (21,824 kg/ha) and 50 per cent of nutrient dose (24,050 kg/ha) and pure crop yield (20,559 kg/ha).

- Intercropped chilli receiving irrigation at 100 per cent Epan recorded 37 per cent higher yield compared to lower level of irrigation. However, the performance of intercropped amaranth was not significantly influenced by the irrigation levels.
- The water productivity increase at 100 per cent Epan for intercropped chilli + amaranth was 170 per cent and 54 per cent higher compared to pure crop chilli and pure crop amaranth respectively.
- Intercropping system under normal row planting produced significantly higher LER (2.84) compared to paired row planting. In addition, nutrient level of 100 per cent NPK recommendation showed higher LER (2.81) compared to lower doses. Irrigation at 100 per cent Epan recorded significantly higher value of LEC and ATER.
- LER more than 1.0, LEC more than 0.25 and higher values of ATER and CEY revealed the biological efficiency of chilli- amaranth intercropping system compared to pure crop system.
- The net return of chilli-amaranth intercropping system (Rs.428212) was 116 per cent higher compared to pure crop chilli (Rs.197716) and 164 per cent higher to pure crop of amaranth (Rs.24548).
- Higher gross returns, net returns and B:C ratio revealed the economic benefit of chilli- amaranth intercropping system compared to pure crop of chilli and amaranth.

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Appendices

Appendix 1. Weekly weather data during experimental period

Month	WEEK	Max.temp (°c)	Min. temp (°c)	Mean RH%	Total rain(mm)	Rainy days	Evaporation (mm)
Jan.	1	33.9	21.9	55.1	0	0	3.99
	2	34.2	20.9	55.9	0	0	3.59
	3	34.2	22.3	48.7	0	0	5.11
	4	33.9	25.5	51.4	0	0	5.93
	5	35.1	23.5	50.9	0	0	5.19
Feb	6	35.7	23.0	46.4	0	0	5.09
	7	35.4	23.8	42.6	0	0	7.76
	8	36.3	22.9	63.2	0	0	4.36
	9	37.4	24.5	50.1	0	0	6.34
Mar	10	35.2	24.5	71.4	2.7	0	3.81
	11	34.9	23.8	70.4	10.2	1	3.84
	12	36.3	25.0	70.4	0.3	0	4.14
	13	38.0	25.6	65.4	0	0	4.90
Apr	14	36.3	26.0	69.4	0	0	4.33
	15	35.6	26.1	71.8	18.6	1	3.41
	16	34.8	26.1	71.3	0	0	3.60
	17	35.6	26.1	69.3	0.5	0	3.70
	18	36.3	24.7	68.6	28.4	3	4.64
May	19	35.5	24.7	72.1	15.2	1	3.84
	20	35.0	25.8	72.2	16.2	1	3.70
	21	33.9	25.2	73.9	26.2	2	3.03
	22	31.1	24.0	84.6	113.2	7	2.64
Jun	23	30.8	24.1	83.8	60.6	5	2.34
	24	30.2	23.9	87.6	151.2	5	2.24
	25	31.7	23.6	85.6	104.4	6	3.03
	26	29.4	22.4	89.6	291.8	7	2.49
JUL	27	30.1	22.7	86.4	77.1	7	2.94
	28	30.3	22.9	84.5	97.5	4	2.46
	29	30.9	22.1	86.1	171.1	6	2.50
	30	31.6	23.0	80.6	30.3	5	2.67
	31	31.2	23.9	84.5	87.1	2	3.04

Appendix 2. Cost of cultivation of cropping system

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
Materials														
Ujwala seedlings	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	
Amaranth seed	500	500	500	500	500	500	600	600	600	600	600	600		900
FYM (t)	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Lime	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Application cost	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Fertilizers	35413	26560	17707	35413	26560	17707	35413	26560	17707	35413	26560	17707	15524	19889
PP Chemicals	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Application cost	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	500
Land preparation	7600	7600	7600	7600	7600	7600	7600	7600	7600	7600	7600	7600	7600	7600
Planting	50000	50000	50000	50000	50000	50000	52500	52500	52500	52500	52500	52500	50000	50000
Weeding	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000
Irrigation	6000	6000	6000	4500	4500	4500	6000	6000	6000	4500	4500	4500	6000	3000
fertigation	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Harvesting fruits	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000	50000
TOTAL COST	251513	242660	233807	250013	241160	232307	254113	245260	236407	252613	243760	234907	231124	230389
Fixed cost	625000	625000	625000	625000	625000	625000	625000	625000	625000	625000	625000	625000	625000	625000
Depreciation(20%)	125000	125000	125000	125000	125000	125000	125000	125000	125000	125000	125000	125000	125000	125000
Repairing and maintenance (5%)	31250	31250	31250	31250	31250	31250	31250	31250	31250	31250	31250	31250	31250	31250
TOTAL COST	**407763.3**	**398909.9**	**390057**	**406263.3**	**397409.9**	**388557**	**410363.3**	**401509.9**	**392657**	**408863.3**	**400009.9**	**391157**	**387374.5**	**386638.8**

Cost of input		**Fertilizers**		**Labour cost**		**Price of produce**	
Chilli seedlings	Rs. 1500	19:19:19	Rs. 180 kg^{-1}	Men	Rs. 525 day^{-1}	Chilli	Rs. 50 kg^{-1}
Amaranth seeds	Rs.250 kg^{-1}	Urea	Rs. 5.25 kg^{-1}	Women	Rs. 425 day^{-1}	Amaranth	Rs. 20 kg^{-1}
FYM	Rs. 200 per tonne	MOP	Rs. 19 kg^{-1}				
Lime	Rs. 10 kg^{-1}						

CHILLI-AMARANTH INTERCROPPING SYSTEM UNDER FERTIGATION

By

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ABSTRACT OF THE THESIS

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ABSTRACT

ABSTRACT

Intercropping is a way to augment production through intensifying cropping by combining different crops thereby utilisying the available resources more efficiently. The productivity of intercropping system can be enhanced by adopting suitable planting geometry and by proper nutrient and water management. Information on planting geometry and schedules of fertigation and drip irrigation can help in further increasing the productivity of the system. The present study was undertaken to assess the bio economic suitability of chilli- amaranth intercropping system under different nutrient and water regime.

The experiment entitled "Chilli-Amaranth intercropping system under fertigation" was conducted at Water Management Research Unit, Vellanikkara during January to July 2017. The trial was laid out in randomized block design replicated thrice. The treatments consisted of chilli- amaranth intercropping system planted at two different planting geometries *viz*., normal row planting and paired row planting, three nutrient levels *viz*., 100, 75 and 50 per cent of NPK recommendation for both crops as fertigation and two irrigation levels *viz*., 100 per cent Epan and 75 per cent Epan and two control viz., chilli pure crop and amaranth pure crop.

Performance of crops under intercropping and pure crop system revealed that the yield of intercropped chilli was 41 per cent lower than chilli pure crop. However for amaranth, the yield was 17 per cent higher under intercropping compared to pure crop. In addition to the fertigation of amaranth, amaranth receives nutrients from fertigation given to chilli crop. This resulted in the higher dry matter production and nutrient uptake of intercropped amaranth and finally higher yield.

Paired row pattern was adopted to accommodate more intercrops. However planting geometry had no significant influence on the yield performance of intercropped chilli and amaranth.

The nutrient levels showed no significant difference on the yield of intercropped chilli, whereas yield of intercropped amaranth was significantly

influenced. Intercrop yield of amaranth at 100 per cent of nutrient dose (26,227 kg/ha) was significantly higher than intercrop yield of amaranth at 75 (21,824 kg/ha) and 50 per cent of nutrient dose (24,050 kg/ha) and pure crop yield (20,559 kg/ha).

Intercropped chilli receiving irrigation at 100 per cent Epan recorded 37 per cent higher yield compared to lower level of irrigation. However, the performance of intercropped amaranth was not significantly influenced by the irrigation levels. The water productivity increase at 100 per cent Epan for intercropped chilli + amaranth was 170 per cent and 54 per cent higher compared to pure crop chilli and pure crop amaranth respectively.

LER (Land Equivalent Ratio), LEC (Land Equivalent Coefficient), ATER (Area Time Equivalent Ratio), RCC (Relative Crowding Coefficient) and CEY (Crop Equivalent Yield) were worked out for assessing biological efficiency of intercropping system. LER more than 1.0, LEC more than 0.25 and higher values of ATER and CEY revealed the biological efficiency of chilli- amaranth intercropping system compared to pure crop system. Intercropping system under normal row planting produced significantly higher LER (2.84) compared to paired row planting. In addition, nutrient level of 100 per cent NPK recommendation showed higher LER (2.81) compared to lower doses. Irrigation at 100 per cent Epan recorded significantly higher value of LEC and ATER.

Economic benefit of intercropping system was assessed using gross return, net return and B:C ratio. The net return of chilli-amaranth intercropping system (Rs.428212) was 116 per cent higher compared to pure crop chilli (Rs.197716) and 164 per cent higher to pure crop of amaranth (Rs.24548). The study indicated that there is an effective utilization of space, nutrients and water when amaranth was raised as intercrop with chilli. To get maximum biological and economic benefit from chilli-amaranth intercropping system, planting should be done at normal row with 100 per cent recommended dose of nutrients for both the crops and irrigation at 100 per cent Epan under fertigation during summer season.