RESOURCE CONSERVATION THROUGH STRIP CROPPING OF CHICKPEA, TARAMIRA AND LENTIL IN SPATE IRRIGATED AREA

By

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بسم الله الرحمن الرحيم

<u>DECLARATION</u>

I hereby declare that the contents of the thesis, "**Resource Conservation through Srtip Cropping of Chickpea, Taramira and Lentil in Spate Irrigated Area.**" are product of my own research and no part has been copied from any published source (except the references, standard mathematical and genetic models/equations/formulae/protocols etc.). I further declare that this work has not been submitted for award of any other diploma/degree. The university may take action if the information provided is found inaccurate at any stage.

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CERTIFICATE

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TO

MY BELOVED PARENTS

MY BROTHER

&

MY SISTER

WHO ALWAYS RAISE THEIR HANDS FOR MY SUCCESS AND HAPPINESS, SO MUCH OF WHAT I AM TODAY IS BECAUSE OF YOU AND I WANT TO TELL YOU THAT I THANK YOU, APPRECIATE YOU AND LOVE YOU

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(JAWAD AMIN)

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations and Symbols	Description
ha	Hectare
Kg	Kilogram
t	Tones
K_2O	Potash
N	Nitrogen
P	Phosphorus
SOP	Sulphate of potash
DAP	Diamonium phosphate
m^{-2}	Per meter square
cm	Centimeter
ET	Evapotranspiration
HI	Harvest index
HSD	Honest Significant Difference
ANOVA	Analysis of Variance
LER	Land Equivalent Ratio
RCC	Relative Crowding Coefficient
RCBD	Randomized Complete Block Design
%	Percentage

Abstract

An experiment was conducted to investigate the effect of strip inter cropping of legumes and oil seed crop on soil moisture conservation, soil properties, inter- cropping and yield related parameters during the Rabi season 2017-18 at three selected locations in Mithawan Hill Torrent (spate) irrigated fields of Dera Ghazi Khan. The latitude of study area is 29.731 to 29.862° N and longitude is 70.314 to 70.487° E. The experiment was laid out in RCBD having three replications. The strips of chickpea, taramira (arugula), lentil alone were evaluated. Chickpea-taramira alternate strip, chickpea-lentil alternate strip, taramira-lentil alternate strip and chickpea-taramira- lentil alternate strips in combination were also investigated. Data was analyzed through ANOVA technique and differences among the treatments were tested using HSD Tukey's test. The results revealed that growing chickpea and taramira in alternate strip inter-crops saved soil moisture at 0-15 cm soil depth in the following order from highest to lowest i.e. chickpea-lentil>chickpea-taramira>taramira-lentil>chickpea-taramira-lentil>sole chickpea>sole lentil>sole taramira. At 15-30cm soil depth the soil moisture was conserved in the order from highest to lowest as sole chickpea>sole taramira>chickpea-taramira>chickpea-taramira-lentil>chickpea-lentil>taramira-lentil>sole lentil. Lentil and chickpea slightly improved soil physico-chemical properties. Intercropping of chickpea and taramira were effective while lentil could not succeed in prevailing spate irrigated situations of Mithawan hill torrent. The results obtained recorded maximum yield and yield related parameters like number of branches (7.38), plant height (38.04 cm), seed yield (800.16 kg ha-1) for sole strip of chickpea. Siliquae length (3.25 cm), plant height (92.41 cm), number of seeds per siliquae (19.67), seed yield (433.14 kg ha-1) for sole strip of taramira. Whereas for lentil, plant height (30.60 cm), number of pods (32.57) were maximum in sole strip. However, the minimum values for number of branches (5.82), plant height (30.75cm), seed yield (771.25 kg ha-1), of chickpea; Siliquae length (2.98cm), plant height (83.82 cm), number of seeds per siliquae (16.93), seed yield (375.23 kg ha-1) of taramira and plant height (22.39cm), number of branches per plant (23.29) and seed yield per plant (0.146 g) were recorded in chickpea, taramira and lentil alternate strip inter-crop respectively under the spate irrigated conditions of Mithawan command area Dera Ghazi Khan. Punjab (Pakistan). Based on the results it can be concluded that the farmers of Mithawan hill torrent command area should adopt growing of chickpea and taramira (arugula) in the form of alternate strips.

Chapter 1

Introduction

In the world by population Pakistan is the 6th biggest country and in South Asia, by size with an area total of 79.61m ha and 210 million population, the second biggest country is Pakistan (Anonymous, 2017). Due to increasing population over years, Pakistan is facing the shortage of water. The country population explosion has decreased the per capita water in Pakistan from 5,300 cubic meter to less than 1,000 cubic meters in 2016 (Anonymous, 2016). Country water resources are inadequate to meet future need of water including canal water and groundwater. The country annually cultivated area is 23.74 m ha, out of which about 19.27 m ha was under full control of irrigation (i.e. 6.91 m ha canal irrigated, 4.13 m ha ground water irrigated, 7.96 m ha combined with canal water and groundwater, and 0.27 m ha irrigated with waste water, 3.2 m ha rainfed (Barani) and 1.25 m ha was sailaba river ine, 2 m ha by spate irrigation (Ahmad, 2007; Baig et al., 2013; Frenken, 2012).

A spate irrigation system use seasonal floods for irrigation which is source of the supply of water from hill torrent, is the second largest source of irrigation after canal water irrigation in Pakistan (Ahmad et al., 2016). Inconsistency of the rainwater may affect uncertain spate irrigation at time of sowing (Javed et al., 2007). A major portion of potential land of about 13.25 m ha, out of which 6.35 m ha lying in the hilly areas and 6.9 m ha in the plains, can be brought under cultivation through efficient utilization of hill torrents water. Depending upon the occurrence of hill torrents and their management, however, only 0.72 to 2.0 m ha of land is annually cultivated with spate irrigation, which makes about 9% of the total annually irrigated area of Pakistan (Mirjat et al., 2011). The scarce water resources of the country including canal water and groundwater only cannot meet the future water requirements without managing the hill torrent water resources to its useful potential. But there is temporal and spatial inconsistency in the rainfall, which could result in an uncertainty of spate irrigation at the time of sowing (Javed et al., 2007). Spate irrigation is a system used for wetting land prior to planting. Use is made of seasonal rivers (wadis) producing flash floods in the uplands, which are directed by structures to irrigate fields in the lowlands. There is an average annual potential of around 23 billion m^3 of water from 14 major hill torrents (Sufi et al., 2011). Out of these, 13 hill torrents (excluding Kharan Closed Basin Hill Torrent Areas) have great potential for land and water resources development at about 1204 conservation sites. In Balochistan, the highest potential exist for hill torrents management where as other potential hill torrents include Dera Ismail Khan, Kachhi Basin, Bannu, Hazara, Kirther Range, Sehwan, Petaro, Karachi area and Dera Ghazi Khan (Ahmad, 2012). The efficient utilization of hill torrent water for spate irrigation will not only reduce the dependence on groundwater and canal water but also cut down energy cost in the study area. Hill torrent affected areas are characterized by heavy floods causing land degradation through extreme form of water erosion.

Legume crops conserve soil moisture (Morse, 1993), decrease erosion of the soil (Langdale et al., 1991), improve physical properties of soil (Blevins and Frye, 1993), and increase retention of nutrient (Dinnes et al., 2002). It is well known that crop growth depends mostly on soil fertility. Microorganisms are reliable for organic matter decomposition and thus have an effect on soil nutrient cycles and plants growth. Soil urease, phosphatase and invertase take part in essential roles in the series of major nutrients (N, P, and C), (Zeng et al., 2007; Saha et al., 2008). The contribution of nitrogen is the most commonly observed primary benefit of leguminous crops (Singh et al., 1992). Improvement of soil structure by the action of living and decaying cover crop tissue is commonly reported (Boyle et al., 1989). Soil structure is defined as the mixture or arrangement of primary soil particles into secondary units (SSSA, 1997). Soil structure is significant in describing the health of agricultural soils (Fageria, 2002). By modifying soil structure, soil hydraulic conductivity and infiltration is improved, aggregate stability and macro pores have been reported by Kumar and Goh (2000) by crop residue retained on soil surface. For the development of root, aeration, water infiltration soil structure is important. The cover crops increased the fertility of soil (Cavigelli and Thien, 2003). Biological properties of soil are closely related in controlling soil physical and chemical properties (Brye et al., 2004). Nitrogen fertilizer management is affected by legume and non-legume crops (Bauer and Roof, 2004). Bradyrhizobium is responsible for symbiotic nitrogen fixation in legumes. The rapidly growing bacteria contains genus Rhizobium, while weak grower’s bacteria the Bradyrhizobium (Brady and Weil, 2002). Soil pH, temperature, and moisture content can determine nitrogen fixation ability of legume crops.

Miller and Dick (1995) explored that cover crops give greater root activity and carbon inputs which improve soil aggregation and maintain higher organic carbon pools compared with conventionally managed (fallow) soil. Cover crop residues which conserve soil moisture is commonly used (Anonymous, 1998). Cover crops residues left on soil improve infiltration of rain water and also decrease evaporative losses, following in less moisture stress during periods of drought. Grass cover crops such as rye, barley, wheat, and sorghum-sudan grass have been usually proven to be very efficient in conserving the moisture of soil (Anonymous, 1998). Both legume and non-legume cover crops affect nitrogen fertilizer management (Bauer and Roof, 2004). Legume cover crops fix atmospheric nitrogen and decrease nitrogen fertilizer needs for next cash crops (Reeves, 1994). The rate of nitrogen fixed by cover crops is determined largely by the genetic potential of the legume species and by the amount of plant available nitrogen in the soil.

The techniques used to conserve agriculture resources are zero tillage, crop cover, crop residue cover, site specific nutrient management, laser land leveler, crop rotation, integrated farming system, rain water harvesting, off season tillage and ploughing, contour farming and strip cropping etc. Strip cropping is a form of mixed cropping in which a number of species of plants are grown side-by-side in adjacent strips. It is used in many regions to protect the soil against wind and water erosion and to decrease leaching losses of minerals (Bucur et al., 2007; Rogobete and Grozav 2011). Hence strip cropping in spate irrigated areas can be used as the potential way of water conservation in soil and reducing the soil erosion on sustainable basis.

Intercropping is the growing of two or more crops together on the same pieces of land at the same time in a haphazard or systematic manner that the growth of some or all the component plant types overlap in space and time (Elemo et al., 1990). In an intercropping systems, two or more crops grow simultaneously on the same field that the period connected is long enough to include the vegetative stage (Gomes and Gomez, 1983). It was indicated that not less than 60-70% of the cropped land is devoted to the growing of crops in mixtures. Intercropping has long been practiced by small scale farmers in the tropics. In particular, cereal and legume intercropping is recognized as a common cropping system in developing tropical countries (Ofori and Stern, 1987). Typically C_4 cereal crops such as maize (*Zea mays* L.), pearl millet (*Pennisetum glaucum* L.) and sorghum (Sorghum bicolor L.) are the dominant plant species, whereas C_3 legume crops such as beans (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata* (L.), groundnut (*Arachis hypogaea* L.), pigeon pea (*Cajanus cajan* L).) and soybean *(Glycine max* L).) are the associated or secondary species. Canopy structures and rooting systems of cereal crops are generally different from those of legume crops.

Growing legumes and cereals together for food is not only popular among subsistence farmers in the tropics, who produce the bulk of food in developing countries, but it is also expanding to the warmer regions in the tropics (Fujita and Ofosu-Budu, 1996). Intercropping is receiving thought because it offers potential advantages for utilization of resource, decreased inputs and increased sustainability in crop production. Some of the mechanisms that carry out these advantages are related with environmental factors. In developing countries, intercropping may have positive effect on the future food problems (Egbe, 2005). This may be through efficient use of solar energy and other growth resources. Also optimization of land resource use could be achieved when crops are grown under intercropping. In most cereal–legume intercropping, cereal crops form higher canopy structures than legume crops, and the roots of cereal crops grow to a greater depth than those of legume crops. This suggests that the component crops most likely have differing spatial and temporal use of environmental resources. Intercrops may make use of environmental resources such as radiation, water and nutrients more proficiently than mono cropping (Willeys, 1990). Most studies on intercropping have alert on the legume-cereal intercropping, a fruitful and sustainable system, its supply utilization (water, light, nutrients), and its effect on nitrogen input from symbiotic nitrogen fixation into the cropping system and decrease of negative shock on the environment (Jensen, 1996; Willey, 1979). For cereals, Duivenbooden et al. (1996) calculated an optimum N: P≈ 7. Legume and cereal plants are the most popular combination for the intercropping system because the nitrogen (N) fixed by legumes is then available to cereals (Doereiner, 1997) and this combination has been generally used in forage making. Song et al., 2007 and Wang et al., 2007 explored that the few studies on microorganisms in soil intercropping systems or in intercropping with rhizobial inoculation have been reported.

Sorghum yield in Pakistan for instance is below 1 t ha^{-1}, whereas in spate irrigation system else where they are in excess of 2.5 t ha^{-1}. A more recent survey by Henriet et al., (1997) showed that mixed cropping was the pre-dominant system in the Sudan savannah of Nigeria with millet/cowpea, sorghum/cowpea, sorghum/groundnut and millet. Intercropping of these crops serve as means of maximizing the use of limited farm land, food security of farmers, higher yields are obtained, suppressing the germination of striga weed seeds and reducing the level of inorganic fertilizer requirement. Crop yield is regularly constrained by accessibility of major nutrients, including nitrogen and phosphorus (Sterner and Elser 2002). Chickpea in association with rapeseed in 3:1 row proportion recorded significantly more pods per plant, seeds per pod, and 1000 grain weight. Maximum reduction in yield attributes was recorded in chickpea intercropped with rapeseed in 1:1 row proportion due to greater shading and competition effect of the intercrops on chickpea (Das et al., 2017).

Growing oilseeds proved to be promising for spate irrigated areas (Anonymous 2016). In spate irrigated areas of Pakistan, oilseed crop like taramira (*Erusa Staiva Mill*.) (arugula) and legume crops like chickpea (*Cicer arietinum* L.*)* are traditionally grown in spate irrigated fields and farmers can become self-reliant in edible oilseeds crops in spate irrigated areas. Such crops suit well, as their water requirement is less and they perform better even in dry spells. Soil aggregation can be improved by using crops which biologically fix nitrogen. Pulses meet food need of the increasing human population especially in the sub-continent. Lentil (*Lens culinaris Medik* L.) is amongst the most nutritious legume (Kumar et al., 2017). The chickpea and taramira (arugula) crops are included in the cropping pattern of rabi season in Mithawan hill torrent command area (Ahmad et al., 2016). However there is no information available on cultivation of lentil in spate irrigated areas of Punjab like Mithawan hill torrent affected command area Dera Ghazi Khan.

The detailed studies on the effect of legumes and oilseeds grown in the form of alternate strip inter crops for water conservation, impact on soil fertility and yield in spate irrigated areas are currently lacking. Hence, the proposed study was designed with objective

- To evaluate feasible strip inter-cropping options and its impact on soil fertility status, water conservation and yield of chickpea, taramira (arugula) and lentil in spate irrigated lands of Punjab (Pakistan).

Chapter 2

Review of Literature

2.1. Spate Irrigation

In arid and semi-arid areas, the oldest irrigation method is spate irrigation. Spate irrigation is managed in the Middle East (Saudi Arabia, Yemen), North Africa (Algeria, Tunisia Morocco), the Horn of Africa (East Africa) (Kenya, Tanzania) and (Ethiopia, Eritrea, Sudan, Somalia) (Mehari, 2007; Van Steenburgen and Mehari, 2008; Oudra, 2008) in West Asia (Pakistan, Afghanistan, Iran). Spate irrigation is classified as a method of harvesting flash floods from the riverbed through the canals to bounded fields that might be present at far off place than source of water (Steenbergen and Lawrence, 2005). The term spate denotes the floodwater initiating from irregular rainfall in river catchments upper portion that had diverted in the lower part from rivers that are passing and outspread to agricultural land. Spate is rich in nutrient because it is usually loaded with the eroded material. Spate irrigation has importance because during storm water produced from hillside and use only when the water is in excess for upper stream user. Due to this reason it may be assumed that water from spate irrigation is of high value relatively with low cost. Spate irrigation method could play significant part in production of crops required for nutrition of livelihoods and increased food security, in those regions where there is no perennial river or rainfall is also not sufficient that is why it is not a surprise that spate irrigation is from one of the ancient system of irrigation in semi-arid and arid regions like in Baluchistan Province. In Pakistan method of spate irrigation has been present since 3000 BC (FAO, 1987). About 9 to 13 million people are dependent directly on spate irrigation and the area under spate irrigation is nearly 2.6 million ha in Pakistan (Steenbergen and Mehari, 2008).

2.2. Spate Irrigation and Crop Production

Michael (2000) explored that normally, spate irrigation is risk-free and low-input farming, however still there are doubts in floods size, timing, and frequency. Floods may have very low quantity of water that may cause water scarcity or could have high water quantity that might damage the crops and whole infrastructure of irrigation could be affected. Because of these limitations, cropping of low moisture requiring crops is done. As a result crops that are resistant to drought are grown for example maize (Zea mays), sorghum (Sorghum bicolor), cowpea (Vigna unguiculata) and millet (Eleusine coracana Gaertn) In Boru Dodota scheme most of farmers prefer to grow native barley, wheat, and maize varieties, which are not high yielders (Birhanu and Mengistu, 2007). From the year 2007, data showed that extra irrigation using spate, improved crops yield in year 2007 than in year 2006. Over the good year's average for bean and maize, the rise of yield was 275% and 167%, separately (Steenbergen et al., 2011). Similarly, farmers in Kobo and Raya valleys because of suspicions in availability of water, grow sorghum by using small amount of fertilizers alike to the situation by rain fed methods, by using advance inputs and by choosing favorable crops. In good years, when amount of floods and rainfall are sufficient, the yield of sorghum could be increased up to 7 tons ha^{-1}, however during bad years it may fail entirely. That is why availability of water by spate irrigation or other different methods rises productivity of crop in the regions. However, the benefit could be enhanced if improved varieties of crops are used having high value.

2.3. Challenges of Spate Irrigation Systems

Steenbergen et al. (2005) said that spate irrigation as compared to perennial irrigation is more risky. No floods or higher incidence of flood may also affect crop production. This difference in amount of flood might be injustice as some lands get more water as compared to others. Instead, uneven large amount of flood could be harmful in the command areas and wadi beds. High amount of sediment in water, particularly granular material could decrease the efficiency of spate irrigation structures, because they have not been designed to handle that sediment flood. However, fine sediments could enhance physical conditions and fertility of soil if taken to the field, but proper care should be done to avoid the control area against canals and furrows. Canals sedimentation could be harmful to the system effectiveness depending upon the size of deposited material. Soil borne diseases of plants and weeds could enter into the field by sediment and floodwater, which is a risk and could not be managed simply (Ibrahim 2010; Ogba-Michael). In Boru Dodota, farmers conclude that spate water was responsible for the invasion of new species of weeds, however they deliberate that this problem could be tolerable as compared to the profit they get from enhanced crops, soil health and productivity of livestock.

Instead of focusing on just diversion work there are number of ways to improve spate irrigation. It is ideal prospective activities comprising management of soil moisture and enhancing water efficiency. In order to conserve soil moisture after process of irrigation, one more method used is animal grip power, which is suitable for mulching and ploughing. Main plan is to direct flows in the direction of reasonably solid regions of command to increase the probability of irrigation. Due to it, preparation of land before irrigation is less risky for the farmers.

Take most recent crops like oilseeds, cucurbits, and pulses. Crop, which is common in one region is usually not grown in other region. The seeds from large catchment, dumped during flood in favorable soil moisture of the spate systems. In Pakistan, better storage and seed cleaning by investing in the technology of post-harvest minimized the grain losses from 0% to 7%. Improving the livestock output will provide overall benefit to watering points, veterinary facilities, and animal feed access, also marketing of the livestock goods. The groundwater and spate irrigation arrangement could sustain manufacturing systems that are among the most useful everywhere (Steenbergen and Meharri, 2005).

2.4. Strip Cropping and Spate Irrigation

Macnish, (1980) recorded that water can be conserved through strip cropping in spate irrigated areas. To control the water and wind erosion in the cultivated spate lands, strip cropping has been used for many years. The land is shaped in long strips across the slope or perpendicular to current wind. Gijzen and Goudriaan (1989) explored that a modeling technique is used to access light distribution that occupy the significant part of row crops in strip cropping. The model relied upon relation of geometry, considering for the spatial space between the rows of crops, direction of row, canopy height and width, sun location and leaf area distribution in the row (Schneider’s, 1999).

Verdelli et al. (2012), Jurik and Van (2004), Ghaffarzadeh et al. (1994), Lesoing and Francis (1999) discovered that due to high yield of important species in the border rows, yield of strip mono cropping have more interception of radiation. Upgraded yield was more than the low yield in the shaded border rows of secondary crops. Therefore, in order to obtain improvement in entire output, attainable radiations for the closest secondary crops should be enhanced. Intercropping is a management method in which two or more different ranges or crops grow at the same time in combination of distinctive row in same land (Katyayan, 2005). Intercropping could increase the resource utilization effectiveness (Nasri et al., 2014). Intercrops staggered the periods of growth, time of maturity and get beneficial resource needs for the sunlight, water and nutrients (Sullivan, 2003). In the rice roots, intercropping plateau mung bean / rice enhanced the arbuscular mycorrhizae formation (Li et al., 2009). Authors described upgraded mycorrhizae formation with the help of intercropping in rice. The uptake of total phosphorus increase by 57%, in mung bean nodulation increased by 54% and total N and P requirement by 64% and 65%, respectively. In relation to accumulation of nutrient and biomass, intercropping of soybean/wheat and maize/wheat expressed an apparent benefit over solitary cropping (Li et al., 2001).

In several regions of world, various cropping systems are used, and in temperate areas, farmers utilized strip intercropping of dry beans or soybeans, and corn. On hilly lands strip cropping probably minimize the erosion, allow replacement of the crop in field if strips changed season to season, and improve yields of the entire system. Numerous experiments in Midwest U.S. and Eastern U.S. have outcomes that state the changes in yields between locations. Corn that has grown in fine strips give yield between 10 to 40% as compared to mono cropping, however in thin strips dry beans or soybeans had decreased yield from 10 to 30% because of competition for nutrient, light and water. No smooth or flawless research has been done to measure the native significance of the economical periphery among rows of legume and corn. Occasionally entire yield of strip cropping is under the average performance of monoculture. When there is adequate amount of rainfall, production of strip crops increase yield from 10 to 20% than in sole crop.

In different areas small-scale farmers had adapted intercropping. Particularly, in tropical countries intercropping of legume and cereal is a usual system of cropping (Ofori and Stern, 1987). Normally, C_3 legume crops like soybean (*Glycine max* L.), beans (*Phaseolus vulgaris* L.), pigeon pea (*Cajanus cajan* L.), groundnut (*Arachis hypogaea* L.), and cowpea (*Vigna unguiculata* L. wap) are the derived species while C_4 cereal crops like sorghum, maize, and pearl millet (*Pennisetum glaucum* L.) are the principle species of plants. Legume crops and cereal crops usually have different systems of rooting and canopy structure. Growing cereals and legumes for food is not just for continued existence of tropical farmers that make majority of food in the developing countries, but increases to the warmer areas (Fujita and Ofosu-Budu, 1996). Intercropping system is attaining attention as it upgraded sustainability in production of crops, minimize inputs, and it recommends potential yield for utilization of resource.

Inspite of increasing attention during current years, intercropping system is poorly understood in contrast with sole crop system. Intercropping can often give higher yield advantages over sole cropping. Some of the methods that carries these advantages is related with environmental factors. In developing countries, intercropping might have positive effect on the future food related problems (Egbe, 2005). This might be due to differential use of growth resources and ability to utilize the sunlight. When the crops grown by using the method of intercropping, land resource use optimization could be accomplished and enhanced the plant population density. In intercropping of most cereal legume, cereal crops root develop greater as compared to legume crops, and cereal crops make advanced canopy in legume crops. This suggests that crops have differential environmental resource use temporally and spatially.

Intercropping is of great importance because of its significant advantages regarding yield. For example, improved usage of crops growth resources and enhanced reliability from one to another season. Gillor and Wilson, (1991) described that when a legume and a crop grow together (intercropping), then nitrogen nutrition of that crop which is usually a cereal increased via taking nitrogen directly from legume to the cereal legumes. With the adaptability to infrequent cropping system form smooth ability of crops to fix nitrogen, may decrease production (Jeyabal and Kuppuswamy, 2001). As a result by adding legume to cropping system, productivity improved potentially (Maingi et al., 2001). Intercropping of legumes is a source of nutrients to plants that complement to enhance inorganic fertilizer (Banik and Bagchi, 1994). Legume intercropping under eastern plateau has important role in reducing erosion of soil (Giller and Cadisch, 1995).

2.5. Soil Fertility Management in Spate Systems

Steenbergen et al., (2010) explored that silty and loamy soils usually have good water holding capacity in spate irrigation system. In Yemen, some areas like the Wadi Abyan erosion of wind has a harmful effect on loamy regions because it causes fine particles on well-established loamy regions to be puffed away. Sandy clays and Sandy loams are generally found, in specific the tails of the spate systems is more difficult in areas that are only cultivated rarely.

Williams (1979) said that in watered soils infiltration rate differs in loam density, consistency and soil managing systems. Kahlown and Hamilton (1996) explained that the infiltration rate is between 7.5 to 20 mm per hour in elevated land systems. High land infiltration rates are between 15 to 23 mm hour^{-1} in Baluchistan (Mehari, 2007), and in Yemen in Wadi Rima it is between 40 to 60 mm hour^{-1} (Makin, 1977). They are reported as moderately rapid to rapid in Wadi Bana and Abyan Delta in Yemen (Atkins 1984).

Soil fertility is not commonly an issue in many spate areas. Carrying organic material eroded from the catchments, productiveness is confirmed by the steady replacement of good silts. Low availability in nitrate is the most general soil fertility problem in spate irrigated areas (Atkins, 1984; Mehari, 2007). Organic matter is among the major sources of soil fertility specifically phosphorus and nitrogen, improves water retention capacity and soil infiltration. Most comparatively reduction in carbon-based material content are soils in spate systems. Definite ground extents in Wadi Laba in Eritrea, Mehari (2007) explored that an average percent of organic matter is 2.5, 1.7 and 0.9 in upper midstream, upstream, and downstream fields respectively. The maximum and minimum percentage of carbon-based material in soil ranges from 1 to 5 (Randall and Sharon, 2005).

Organic matter of soil and productiveness could be enhanced by incorporating crop deposits into the loam (however crop deposits are regularly used as feed), by rising leguminous crops. In Iran planting fodder trees has been stimulated in flood water regions (Kowsar, 2005). Atriplex lentil form is, Acacia salicina, Acacia cyanophylla and Acacia victoriae are the trees that helped a number of sheep and cattle, giving better stock of organic compost during animal dung. This in sequence, has involved the manure beetle, and soil has been released by the digging action of it and penetration periods of flood water become greater.

Cover crops are main component of cropping system because of their part in improving soil health. An experiment was performed in greenhouse in order to evaluate the usefulness of copper in nine legume cover crops .The level of copper taken was 0, 5, 10 and 20 mg Cu $kg^{-1}$of soil. With increasing soil copper level in the range of 0 to 20 mg kg^{-1} soil shoot dry weight, highest root extent and root dry weight notably improved in a quadratic way.

With the use of 13 mg Cu kg^{-1}extreme shoot dry weight was found. With the use of 12 and 14 mg Cu kg^{-1} of soil, maximum root dry weight and maximum root length were found. The copper concentration in the plant tissue reduced in a quadratic fashion where Copper uptake better with increasing Cu application rate from 0 to 20 mg kg^{-1} soil. Copper usage effectiveness among cover crops species was enhanced significantly. This increased soil pH and extractable soil absorptions of Copper, Zinc, Manganese and Iron in the soil mixture (Fageria, N. K., 2002) need manure and organic content to increase the fertility of soil and yield. Biological material in soil stable soil masses, makes soil easier to grow, raises exposure to air, and improves water holding and buffer storage skill; organic matter in soil easily available to nutrients (Carter and Stewart, 1996). The soil mineral content depends on type of soil (Schimel et al., 1994), frequency and cultivation type (Heenan et al., 1995), harvesting and waste handling (Webb et al., 2003). Physical, chemical, and biological features and subsequently crop yields are improved by the mineral and manure content in the soil (Franzluebbers, 2002).

Soil structure is defined as the combination or preparation of main soil elements into sub ordinate parts (SSSA, 1997). Structure of soil is important in explaining the strength of soil (Fageria, 2002). Structure of soil has been proven important part for water entry, exposure to air and development of plant root. Growth structure of soil or accumulation by the action of living and rotten cover crop tissue is largely expressed (Haynes and Francis, 1993). Miller and Dick (1995) proved that cover crops give greater root action and carbon inputs which advances soil accumulation and keep higher carbon-based pools in comparison with conventionally achieved (fallow) soil. Cassel et al., (1995) explored that digging practice leaves crop remains on the loam plane can decrease or remove surface coating, increase penetration, and decrease surface overflow and loss of soil while improving crop production. Baumhardt and Lascano (1996) stated major development in penetration proportion with crop remains left on soil associated with bare soil.

The organic properties of soil are directly linked to the chemical environment in the soil and for controlling soil tilth (Brye et al., 2004). Sustainable soil is result of microorganism activity in the soil by the breakdown of organic stuff and nutrient storage (Turco et al., 1994). Cover crops can give advantageous environmental situations such as wetness, temperature, accessibility of C for the production of soil microorganisms. Fungi and bacteria as well as soil micro fauna and algae are the active part of microbial activity in the soil (Kumar and Goh, 2000). It counts for more than one to three percent of carbon-based content and two to six percent of carbon-based nitrogen in soil. Soil microbes is a main source (mineralization) of availability of nutrients to plants (Kumar and Goh, 2000). Thorup-Kristensen et al. (2003) stated that the degradation potential of the soil for insecticides is also influenced by cover crops. Bottomley et al., (1999) found that composition of the herbicide 2, 4-D in both external and subsoil deposits after a rye cover crop is associated to no cover crop in a vegetable harvesting system.

2.6. Cover Crops and Soil Improvement

Suitable strain of fixation of nitrogen bacteria must be inoculated to legume cover crops. Persistent legumes secure nitrogen through any point in time of active development. In yearly legumes, nitrogen fixation is maximum at blossoming. It stops with seed formation. Rhizobia return to the surroundings to expect their next meet with roots of legumes. Bacteria possibly remain in soil for three to five years, even though, often at very short time to provide most favorable nitrogen fixation capability with legumes (Anonymous, 1998).

Kuo and Jellum (2002) said that the efficiency of different kinds of cover crops / set of cover crop variety on soil nitrogen accessibility and yield of successive crops had been widely evaluated. Cover crops build up inorganic soil nitrogen relating with major crop, holding it in natural shape, and prevent from run off. The nitrogen is consequently released to the subsequent crop as the cover crop decay (Dinnes et al., 2002).

2.7. Reducing Soil Erosion

Dabney et al. (2001) explored that water and wind erosion takes place due to loss of topsoil and extreme biggest cause to weakening of soil chemical, physical, and biological characteristics and to encourage decrease production of the majority crop lands. In cover crops, erosion caused by increasing the soil natural material which increase soil water infiltration and water holding ability of soil. Soil erosion is notably reduced with more infiltration and less run-off from all rainwater events. Cover crops rising after soybean improved surface cover, and reduced rill erosion (Kaspar et al., 2001).

2.8. Conserving Soil Moisture

Smith et al., (1987) described that conserving soil humidity with cover crop is usually useful. Cover crop residue remain on soil increases infiltration and decrease evaporative losses, results in less moisture during drought times. Cover crops like barley, rye, wheat, sorghum, and sudan grass had been account very helpful in soil moisture conservation (Smith et al., 1987). Gallaher (1977) showed that soil remain wetter and yield was advanced whenever rye was grown outside mulch, than upper ground portions of rye was not giving anything away in conservation tillage network. Daniel et al. (1999) explain that rye has the maximum biomass of many cover crop varieties experienced and soil has more water content than rye. The greatest difference in water contents among mulched and bare soil is capable to dry season of seven to fourteen days (Smith et al., 1987).

2.9. Crop Yield and Spate Irrigation

To enhance crop yield, improvement in soil biological, physical, and chemical environment with the help of cover crops should be done. Increase in yield of crop varies according to ecological areas and among crops varieties. Further, enhancement in yield relied upon subsequent crop and cover crop management. Evans et al. (1991) suggested that the amount of nitrogen in the soil is the main factor in the response of cereals following legumes compared with cereals follow non legumes. Yet, response of grain yield is not dependent completely upon nitrogen quantity available in the soil. Chalk (1998) described that the insect cycle and diseases that can disturb cereal monoculture, soil structure enhancement, allelopathic and phytotoxic effects of various crops that are responsible for yield.

Fageria et al., (2005) discovered that succeeding row crops play important role in improving biological, physical, and chemical characteristics of soil and give biological nitrogen fixiation to main crop, also reveals breakdown due to low C to N ratio. Legume cover crops also assist in absorption of low available nutrients in soil and assist in increasing nutrient concentration of plants in top soil layer. Best quality of cover crop is to provide sufficient nitrogen fixation in soil cover or dry matter from the atmosphere. Cover crops might be leguminous or non-leguminous. Legume mixtures and growing grass proved good method in achieving benefits from cover crops. Yield benefit crops in strip cropping increase capability of the component crops in order to enhance occupy and utilization of biophysical resources that are attainable if alone crops are grown. Existing species struggle for these natural resources which might decrease the profits of component crops. A lot of reduction in the yield of individual species which are not enough to decrease the whole yield of the combination with respect to yield of sole crops (Ogindo and Walker, 2005). From extensively different crops, for instance wheat and chickpea from canopy growth we can have productive combinations in those regions of southern Australia where the rain is low in winters. With studies limited to warm summer growing periods the growth of chickpea and wheat species is not common (Ali, 1993). The growth of wheat and chickpea increases between 7 and 10 kg ha^{-1} with every millimeter increase in extra supply of water via irrigation.

Ali (1993) said that improved growth for millet groundnut combination with larger light interruption virtual to the one that is attained by the individual crops of any kind. Improved canopy cover is important for use of water by crop and evaporation and its division between transpiration, and successive water use efficiency (Gregory et al., 2000). On the other hand, it is not sure whether growth of canopy and use of water increases in cereal belts of southern Australia by a combination of wheat and chickpea.

Yield benefit in combined cropping are largely proficient because of usage of resources like light, water and nutrients irrespective of individual crop. A study on wheat maize intercropping system showed that efficient use of nitrogen was notably greater in intercropping compare to sole cropping. Zhang and Li (2003) conducted field experiments on wheat maize and wheat soybean intercropping and he observed that there was increase in nitrogen uptake up to 50 and 59 percent correspondingly in case of wheat maize intercropping, 23 and 19 percent in case of wheat and soybean intercropping, respectively.

Barillot et al. (2014) reported higher radiation use capability in wheat-pea inter-cropping as compared to sole crop. Inter- cropping effect of wheat and bean was performed by Eskandari (2011) that defined inter-cropping system a noticeable effect on environmental resources in terms of light interruption, water and nutrient uptake in comparison to sole cropping. It is stated by Li et al., (2001) that intercropping is helpful in terms of growth and nutrient attainment. It was explored that it is helpful up to 40-70 percent in case of wheat combined with maize and when wheat was intercropped with soybean, it was 28 -30 percent.

Intercropping system has often greater yield than individual cropping system (Dahmardeh et al., 2009). Raouf et al. (2003) explains that when wheat varieties high and dwarf were subjected to intercropping at seeding ratio of 40:60 resulted into 9 to 13 percent higher yield that was gained in one large monoculture cultivar. With exactly similar seeding ratio highest LER (1.12) was experimentally obtained. Highest LER (1.719) in wheat and cowpea combined cropping was stated by Khatun et al. (2012) and in wheat mustard inter-cropping it was lowest (1.46), by means of dissimilar intercrop procedure. A greater increase of LER in wheat and fenugreek combined cropping was also stated by Wasaya et al. (2013). Inter crop with greater LER (1.78) than the mixed crop (1.66) was most effective for sustainable outcome in the rain fed areas for a greater net return.

In spate irrigation, moisture conservation is equally sensitive since in various system floods reach well ahead of the sowing season .Moisture conservation is vital because crop yields may be severely slow down by moisture scarcity. Yields may increase with more than two factors in response to enough moisture management (Steenbergen et al., 2004). There are two kinds of watering, single watering (where a field received an irrigation gift in a season) or various irrigations during a season, preferably prepare the land after each irrigation.

Camacho (1987) explored that irrigation application result in an average of 400 mm total storage of the soil in spate irrigation. Mu Allem (1987) stated that the application of

600-1,000 mm of water in a single pre planting irrigation is sufficient to raise all spate irrigated crops provided that the moisture-holding capacity of the soil is satisfactory.

Climate of Pakistan is mostly arid to semi-arid, and therefore, crop production entirely dependent on irrigation of the total cultivated area, 82% area is irrigated and 18% is rain fed. Pulses occupy 5% of the total cropped area in the country. Chickpea is the most important pulse in terms of area (73% of the total pulses area) and production (76% production), followed by mungbean (18% of total area) and 5% area each for blackgram.

Chickpea is the major pulse of Pakistan, and thus playing an integral part in cropping patterns. Chickpea is grown as a rainfed crop whereas mungbean is grown as irrigated crop (Zubair, 2012). Lentil and blackgram has been replaced by other cash crops in Sialkot and Narowal districts because of availability of tube well water (Zubair, 2012). Some of intercropping based multiple cropping is sowing of chickpea or lentil in between the rows of sugarcane and strip cropping of soybean, oat and maize. Cereals such as wheat, rice, sorghum, pearl millet and oilseed crop (groundnut) also play an integral part in the crop rotation.

Chapter 3

Materials and Methods

3.1. Site

The experiment was conducted during the Rabi season 2017-18 at three selected locations in Mithawan Hill Torrent spate irrigated fields of Dera Ghazi Khan that lies between latitude 29.731^{o} N to 29.862^{o}N and longitude 70.314^{o}E to 70.487^{o} E with altitude of about 2107 m above mean sea level. The physico-chemical analysis of soil was carried out before sowing and after harvest using standard procedures. The experiment was laid out in RCBD, having three replications. The sowing time was October 08, 2017.

3.2. Crop Husbandry

Seed rate used for lentil, chick pea, and taramira (arugula) crops was 20, 90 and 5 kg ha^{-1}, respectively. Seeds of lentil, chickpea and taramira (arugula) were line sown using seed drill. The net plot size was 44 m×5.45 m. Lentil rows were kept 30 cm apart, chickpea 45 cm apart with plants spaced at 23 cm for both crops whereas taramira (arugula) rows spaced at 45 cm with plants within row spaced at 15 cm. Urea, DAP and SOP fertilizers were applied at the sowing time at 17 kg urea and 50 kg each of DAP and SOP per acre, respectively. Conserved soil moisture and rainfall received during the growing season were the only source of water available for crops to grow till maturity and harvest. Weed damage was not significant on the study sites because chickpea and lentil crops being cover crops quickly covered the soil and physically suppressed weeds with subsequent competitive advantage over weeds. Likewise insects and disease damage was not observed in the experimental plots. All the other agronomic procedures were kept normal and uniform for all the treatments.

The experimental treatments applied in the experiments were

S_1: Chickpea Sole strip

S_2: Taramira (Arugula) Sole strip

S_3: Lentil Sole strip

S_4: Chickpea + Taramira (Arugula) alternate strip

S_5: Chickpea + Lentil alternate strip

S_6: Taramira (Arugula) + Lentil alternate strip

S_7: Chickpea+ Taramira (Arugula) + Lentil alternate strip

Parameters Recorded

During the course of study following parameters were recorded.

3.3. Soil Moisture (%)

Periodic Soil moisture % was measured by the Gravimetric method (Anonymous, 2007).

$$\text{Soil Moisture (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.4. Soil Characteristics

Pre-sowing and post-harvest analysis of study soil was under taken by collecting composite samples from 0-15 cm, 15-30 cm and 30-45 cm soil depths. The soil samples were analyzed for soil texture, EC, pH, OM, NO_3-N, Phosphorus, Potash, Saturation %.

3.5. Inter Cropping Parameters

Land Equivalent Ratio

LER was calculated to study intercropping competition and yield advantages in intercropping compared with sole cropping.

$$\text{LER} = \text{LER (chickpea)} + \text{LER (intercrop)}$$

Where,

$$\text{LER (chickpea)} = \frac{\text{Intercropped yield of chickpea}}{\text{Sole crop yield of chickpea}}$$

$$\text{LER (intercrop)} = \frac{\text{Intercropped yield of chickpea Taramira (arugula), and Lentil}}{\text{Sole crop yield of chickpea Taramira (arugula), and Lentil,}}$$

Relative Crowding Co-efficient (RCC)

Relative crowding coefficient plays an important role in determining the competition effect and advantages in intercropping. Relative crowding co-efficient (k) was proposed by Dewit (1960). It was calculated by following formula

$$K_{ab} = \frac{Y_{ab} \_ Z_{ba}}{Y_{aa}-Y_{ab} - Z_{ab}}$$

Where,

K_{ab}= Relative crowding co-efficient

Y_{ab}= Intercrop yield of crop "a"

Y_{aa}= Pure stand yield of crop "a"

Y_{bb}= Intercrop yield of crop "b"

Y_{ba}= Pure stand yield of crop "b''

Z_{ab}=stands for proportion of crop "a"

Z_{ba}=stands for proportion of crop "b" in an intercropping system.

Area-Time Equivalent Ratio (ATER)

The Heibcsh (1980) introduced the duration of time the crop remained on land from planting to the harvest. The method is known as area-time equivalent ratio. The formula used to calculate the area-time equivalent ratio was

ATER = ATER (chickpea) + ATER (intercrop) Where

$$\text{ATER} = \frac{\text{LER (chickpea) x Time taken by chickpea crop}}{\text{Duration of inter crops in days}}$$

$$\text{ATER} = \frac{\text{LER (intercrop) x Time taken by intercrop crop}}{\text{Duration of inter crops in days}}$$

3.6. Agronomic Parameters

Plant Height (cm)

Ten plants were measured separately at harvest from each plot of each replication and then average plant height was calculated.

1000 Seed Weight (g)

Samples of seeds were taken from each treatment randomly. 1000 grains were counted and weighed on an electric balance and average was calculated.

Number of Pods per Plant (Chickpea and Lentil)

Number of pods per plant were counted from randomly selected plants of chickpea and lentil plots from each treatment in each replication at physiological maturity and averages were worked out.

Number of Seeds per Pod (Chickpea and Lentil)

Seeds were taken out from pods from chickpea and lentil plants. Ten plants were counted and then converted to seeds per pod after taking average.

Number of Branches per Plant (Chickpea and Lentil)

Number of plants bearing branches was counted from ten randomly selected plants from each treatment of both the crop plants and the averages were worked out.

Siliquae per Plant (Taramira /Arugula)

Total number of siliquae per plants was recorded by selecting ten plants of taramira (arugula) randomly from each plot of each replication and then averaged.

Siliquae Length (cm) (Taramira / Arugula)

Ten mature siliquae of taramira (arugula) were randomly selected from each plot of each repeat, their height was measured with measuring tape and averages were calculated.

Number of Seeds per Siliquae (Taramira /Arugula)

Seeds taken out from siliquae of ten plants were counted and then converted to seeds siliquae^{-1} by taking average.

Biological Yield (kg ha^{-1})

After sun drying and before threshing total above ground plant biomass per plot was weighed and converted into kg ha^{-1}.

Seed Yield (kg ha^{-1})

The harvested samples of chickpea, taramira (arugula) and lentil were sun dried and threshed manually. Seeds per plot were weighed and converted into kg ha^{-1}.

Harvest Index (HI) (%)

It was recorded for each plot by using the formula:

$$\text{HI \%} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw)}} \times 100$$

3.7. Statistical Analysis

Data was analyzed through ANOVA technique and differences among the treatments were tested using HSD Tukey's test (Steel et al., 1997).

3.8. Experimental Layout

Resource Conservation through Strip Cropping of Chickpea, Taramira and Lentil in Spate Irrigate Area

R1	Chickpea Sole Strip	Sub path	Taramira (Arugula) Sole Strip	Sub path	Lentil Sole strip	Sub Path	Chickpea and Lentil Strip	Sub path	Chickpea and Taramira (Arugula) Strip	Sub path	Taramira (Arugula) and Lentil Strip	Sub Path	Chickpea+ Taramira (Arugula)+ Lentil Strip
							Path						
R2	Chickpea Sole Strip	Sub path	Taramira (Arugula) Sole Strip	Sub path	Lentil Sole Strip	Sub Path	Chickpea and Lentil Strip	Sub path	Chickpea and Taramira (Arugula) strip	Sub path	Taramira (Arugula) and Lentil Strip	Sub Path	Chickpea+ Taramira (Arugula)+ Lentil Strip
							Path						
R3	Chickpea Sole Strip	Sub path	Taramira (Arugula) Sole Strip	Sub path	Lentil Sole Strip	Sub Path	Chickpea and Lentil Strip	Sub path	Chickpea and Taramira (Arugula) Strip	Sub path	Taramira (Arugula) and lentil Strip	Sub Path	Chickpea+ Taramira (Arugula)+ Lentil Strip

Design: Randomized Complete Block Design

Replications: Three

Net Plot Size: 44 m x 5.45 m

Chapter 4

Results and Discussion

4.1. Soil Moisture (%) and Strip Inter-cropping of Legumes and Arugula Crop in Spate Irrigated Area

4.1.1. Soil Moisture at 0-15 cm Soil Depth

Fig.4.1.1 shows the soil moisture status of strip of sole or inter-crop of chickpea, taramira (arugula) and lentil cropping system at the soil depth of 0-15 cm. In the first strip of chickpea alone, the soil moisture before the sowing was 12.73%, after the crop harvest it was 9 %. The moisture used by chickpea was 3.73 %. In second alone strip of taramira (arugula) the soil moisture percentage was 13.58 % pre sowing and after the harvest it was 9.26% showing the soil moisture exhausted from soil in taramira (arugula) sole strip crop during the growing season as 4.32 %. The soil moisture percentage in lentil alone strip before the harvest was 14.56 % and after the harvest it was reduced to 10.46 %. The total soil moisture lost throughout growing season by lentil turned out to be 4.1 %.

The fourth strip where the alternate strip of two crops chickpea and taramira (arugula) were grown, the soil moisture percentage in this strip before the sowing was 11 % whereas 8.33% after the harvest. The soil moisture taken by the two crops and lost through evaporation, seepage and leaching etc came out to be only 2.67 %. The strip five consisted of alternate strip of chickpea and lentil, the soil moisture percentage calculated before sowing was 12.66 % and the soil moisture used in evapotranspiration seepage and leaching etc in this alternate strip was only 2.2%. The sixth strip of two alternate crops was taramira (arugula) and lentil. The soil moisture percentage was 13.39 % before sowing and after the harvest it was 9.93%. The soil moisture taken by the two crops and lost through evaporation, seepage, leaching came out to be 3.46%. The last strip consisted of three alternate strips of chickpea, taramira (arugula) and lentil. The soil moisture percentage at sowing was 14.30 % and after the harvest the soil moisture % calculated was 10.60 %. The total moisture lost in alternate strips during the growing season was 3.7 %.

Table 4.1.1. Total Soil Moisture (%) Lost Over Growing Season (at 0-15 cm Soil Depth)

Treatments	**Soil Moisture Lost Over Growing Season (%)**
Chickpea alone	2.73
Taramira (Arugula) alone	4.32
Lentil alone	4.1
Chickpea-Taramira (Arugula) alternate strip	2.67
Chickpea-Lentil alternate strip	2.2
Taramira (Arugula)-Lentil alternate strip	3.46
Chickpea-Taramira (Arugula)-Lentil alternate strip	3.7

The minimum soil moisture (2.2%) lost by chickpea and lentil strip and water vaporization from soil surface was probably due to the reason that chickpea is leguminous cover crop with spreading growth habit with reduced evaporation losses. The maximum soil moisture (4.32%) used by taramira (arugula) alone strip in the form of transpiration and lost in the form of evaporation could be due to the reason that taramira (arugula) being long statured crop as compared to leguminous crops require more moisture for their growth. As this crop is not a cover crop and does not smothers the land effectively results in higher evaporation and transpiration rate so the subsequent moisture extraction from soil was also high. Chickpea and taramira both being leguminous plants fix nitrogen and improve soil organic matter, soil structure which might have improved soil water holding capacity and conserved soil moisture more efficiently.

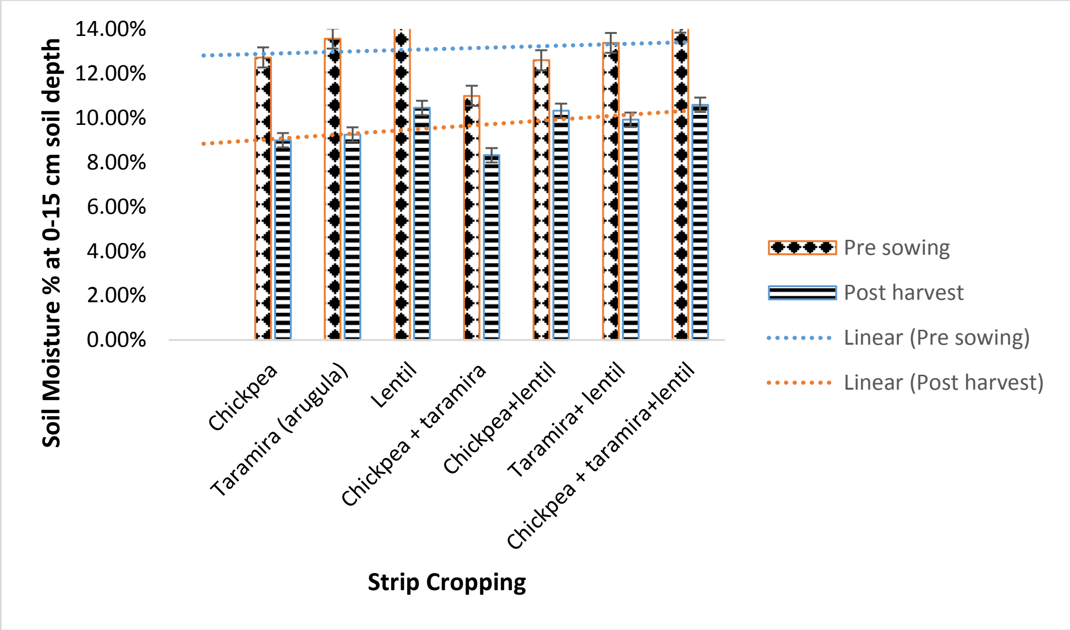

Fig.4.1.1. Effect of Sole and Intercropped Strips of Chickpea, Taramira (Arugula) and Lentil on Pre-Sowing and Post-Harvest Soil Moisture % at 0-15 cm Soil Depth

4.1.2. Soil Moisture at 15-30 cm Soil Depth

Fig. 4.1.2 shows the soil moisture status of strip cropping system having the depth of 15-30 cm. In the strip of chickpea alone the soil moisture before sowing was 13.30 % and after the harvest was 10.00 %. The soil moisture used by the crop and lost through ground surface appeared to be 3.30 % in alone strip of chickpea. In alone strip of taramira (arugula) the soil moisture percentage was 13.57 % and the soil moisture % after the crop harvest was 10.0 %. The soil moisture lost from soil during the crop season was 3.57%.

The soil moisture percentage in lentil alone strip before the sowing was 15.79 % and after the harvest was 8.10 %. The total soil moisture lost in this season of crop was 7.69 %. The soil moisture percentage in alternate strip of two crops chickpea and taramira (arugula) was 13.10 % pre-sowing and after the harvesting 8.86 %. Soil moisture lost during entire growing season turned out to be 4.24 %. The alternate strip of chickpea and lentil revealed pre-sowing soil moisture percentage 14.18 % and the moisture percent after harvest was 9.50 %. The moisture vaporized from plant leaves and ground surface was 4.68% during the crop season. Strip of two alternate crops i.e. taramira (arugula) and lentil exhibited the soil moisture percentage 14.96 % before sowing and after the harvest the soil moisture percentage was 8.29% with lost moisture was 6.67 %. In the three alternate strips of chickpea, taramira (arugula) and lentil, the soil moisture percentage at sowing was 14.22 % and after the harvest the moisture percentage calculated was 9.63 %. The total moisture lost from soil during the growing season appeared at 4.59 %.

At the depth of 0-15 cm, the maximum soil moisture was lost in the alone strip of taramira (arugula) (4.32%). The probable reason could be the roots activity which is more concentrated in upper soil layers. Furthermore arugula roots grow more radially and capture area horizontally in upper soil surface. The minimum moisture of the soil is used by the alternate strips of taramira (arugula) and lentil strip. In this strip, only 2.2% soil moisture lost from open ground surface during the entire growing season could probably be due to the reason that chickpea is leguminous cover crop with soil spreading growth habit with reduced evaporation losses. The chickpea-lentil strip also used the least soil moisture i.e. 2.67 % because the roots of chickpea grew deep in soil and the plant used moisture efficiently from deeper soil layers with least pressure on moisture extraction from upper soil layers.

Whereas at the depth of 15-30 cm, the maximum soil moisture was used in the alone strip of lentil (7.69%). The reason could be that lentil roots could not grow deeply in the soil and remained in the upper soil layer exerting heavy pressure on soil moisture extraction from upper soil layer desiccating it from soil moisture at the maximum compared with other treatments under test. The minimum soil moisture used in the alone strip of chickpea (3.30 %) can be attributed to the fact that at early stage of crop growth, the chickpea plant roots were in the upper soil layer using moisture from upper soil surface reducing the moisture extraction pressure at lateral stages from upper soil layers by sucking water from deeper soil layers. A mild rainfall received in the early growing season i.e. late November to early December favored the crop growth; though the amount of rainfall was not recorded to relate with plants growth. There is every possibility that the soil moisture at the upper soil layer due to rain might have increased with its subsequent use and uptake by the plants resulting in relatively more extraction from upper soil layers without any stress to compete for getting water for growth and development from the deeper soil layers. Furthermore, efficient use of soil moisture from upper and lower soil zones by the chickpea plants might also be the probable reason for low water extraction.

4.1.2. Total Soil Moisture (%) Lost Over Growing Season (at 15-30 cm Soil Depth)

Treatments	**Soil Moisture Lost Over Growing Season (%)**
Chickpea alone	3.30
Taramira (Arugula) alone	3.57
Lentil alone	7.69
Chickpea-Taramira (Arugula) alternate strip	4.24
Chickpea-Lentil alternate strip	4.68
Taramira (Arugula)-Lentil alternate strip	6.67
Chickpea-Taramira (Arugula)-Lentil alternate strip	4.59

The minimum moisture (3.3%) was lost in the chickpea alone strip. The reason could be that chickpea is the leguminous crop improving soil water holding capacity and reduced moisture extraction pressure for growth and development that is why chickpea used less moisture than other crops under study. The maximum soil moisture (6.67%) used under taramira (arugula)- lentil alternate strip could be due to the fact that taramira (arugula) is tall statured crop and requires more moisture for its growth. Blowing wind could have also accelerated evapotranspiration rate so used more soil moisture than chickpea and lentil Furthermore lentil plants were less established which could have increased evaporation.

At the soil depth of 15-30 cm, the maximum soil moisture was conserved in plots where chickpea sole strip was grown. The lentil alone strip resulted in significant losses in soil moisture in the form of evaporation. It could be attributed to the fact that number of plants of lentil were minimum as the plants could not establish themselves in the agro normals of spate irrigated settings of Mithawan hill torrent command area.

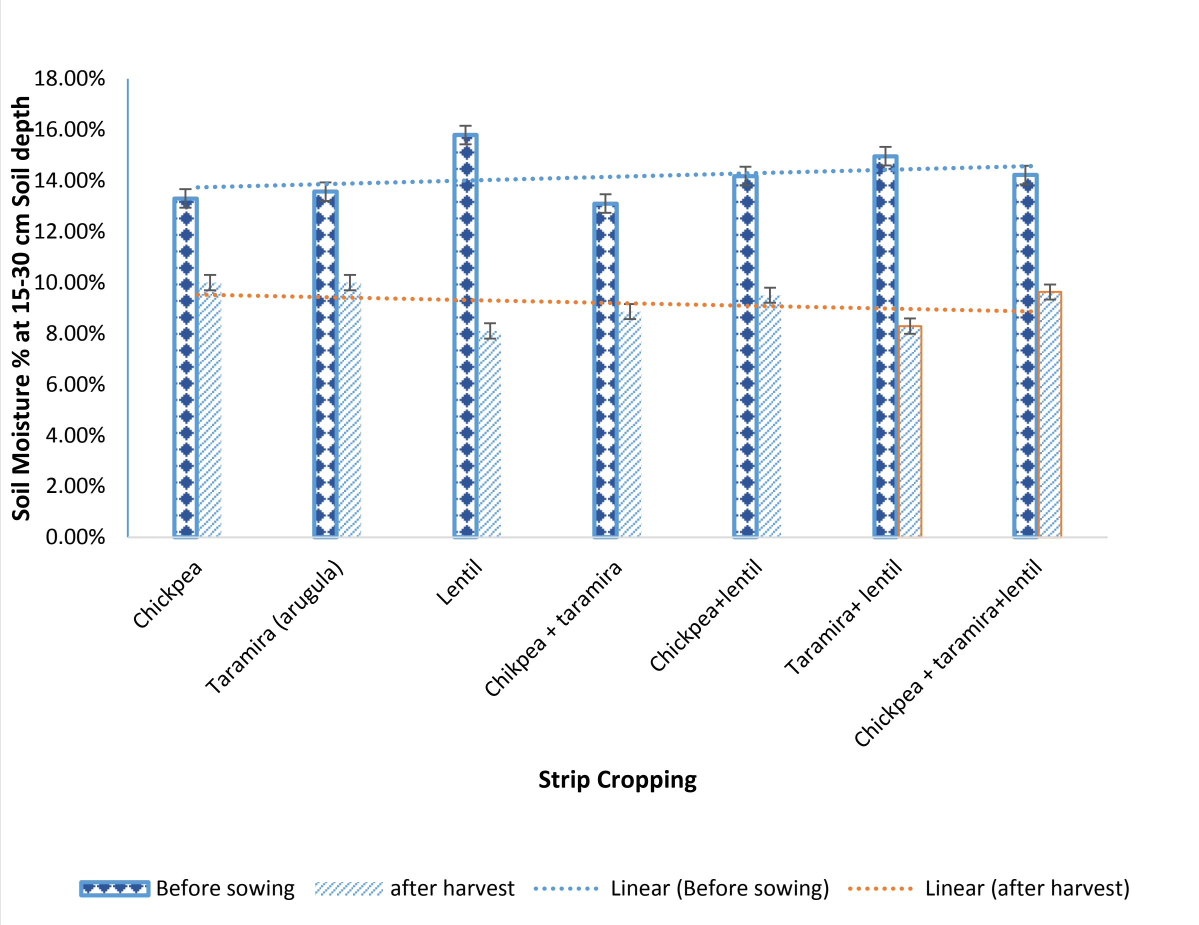

Fig. 4.1.2. Effect of Sole and Intercropped Strips of Chickpea, Taramira (Arugula) and Lentil on Pre-Sowing and Post-Harvest Soil Moisture % at 15-30 cm Soil Depth.

4.1.3. Soil Moisture at 30-45 cm Depth

The Fig. 4.1.3 represents the soil moisture percentage at soil depth of 30-45 cm on monthly basis from November 2017 to February 2018. The soil moisture percentage of the strips before sowing in chickpea strip was 11.56 %, in taramira (arugula) strip was 12.39 % and in lentil was 11.46%, respectively. The moisture of soil in chickpea-taramira (arugula) strip was 16.1%, in alternate strip of chickpea-lentil was 10.57%, in the alternate strip of taramira (arugula)-lentil was 14.96% and in the chickpea-taramira (arugula)- lentil alternate strip the soil moisture was 13%. As the crops grew, the soil moisture measured in the month November 2017 was increased primarily due to rainfall in study area. In chickpea alone strip soil moisture calculated was 16.07 %, in taramira (arugula) sole strip was 17.36%, in lentil sole strip was 20.1 %, in chickpea-taramira alternate strip was 18.35%, in chickpea-lentil alternate strip was 17.95%, in taramira (arugula)-lentil alternate strip was 20.32% and chickpea- taramira (arugula)-lentil alternate strip was 22.01 %.

In the third month i.e. December 2017 the moisture percent calculated in chickpea alone strip was 17.42 %, in taramira (arugula) alone strip was 21.97%, in lentil sole strip was 22.11 %, in chickpea-taramira (arugula) alternate strip was 21.78%, in chickpea-lentil alternate strip was 20.38%, in taramira (arugula)-lentil alternate strip was 21.64% and chickpea-taramira (arugula)-lentil alternate strips was 22.72 %, respectively. The increase in soil moisture during November and December was due to occurrence of rainfall. As the rain fall came the moisture of the soil increased and more moisture was available for uptake by plants.

The moisture percentage calculated for 4th month i.e. January 2018 in chickpea alone strip was 10.4 %, in taramira (arugula) alone strip 13.6%, in lentil alone strip was 10 %, in chickpea- taramira (arugula) alternate strip was 9.39%, in chickpea-lentil alternate strip was 10.7%, in taramira (arugula)-lentil alternate strip was 11.73% and chickpea-taramira (arugula)-lentil alternate strip was 9.73 %, respectively. Sudden decrease in moisture in January 2018 could be due to the reason that at this time the crops were at peak vegetative stage and used soil moisture efficiently for the better photosynthesis and dry matter accumulation.

In the 5th month of sowing i.e. February 2018, the soil moisture percentage of the strips was calculated. The percentage of soil moisture in chickpea strip was 9.3%, in taramira (arugula) strip was 9.23%, in lentil strip was 9.66 %, in chickpea-tarmira alternate strip was 8.13%, in chickpea-lentil alternate strip was 8.86%, in taramira (arugula)-lentil was 8.13% while in alternate strip of chickpea-taramira (arugula)-lentil was 9.53%, respectively. The reduction in the moisture could be due to the fact that the crops used the soil moisture efficiently for vegetative to reproductive stage, moisture was used for dry matter production, translocation and assimilation in economic part of crop plants.

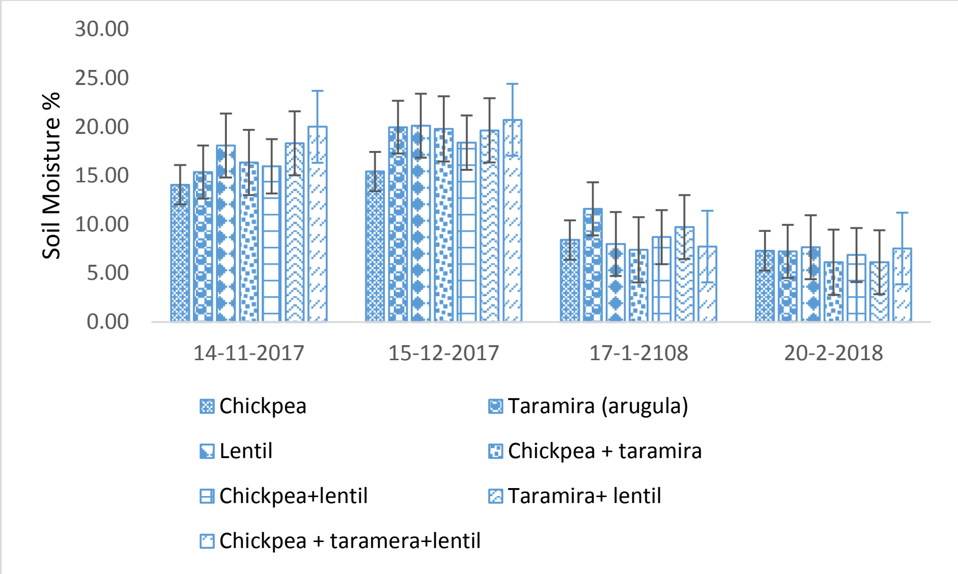

Fig. 4.1.3. Effect of Sole and Intercropped Strips of Chickpea, Taramira (Arugula) and Lentil on Pre-Sowing and Post-Harvest Soil Moisture % at 30-45 cm Soil Depth

4.2. Physico-Chemical Characteristics and Strip Cropping of Legumes and Arugula Crop in Spate Irrigated Area

Pre-sowing (15-30 cm soil depth) and post-harvest (0-15 cm soil depth and 15-30 cm soil depth) chemical analysis of soil revealed non-significant differences among the tested treatments. The electrical conductivity (EC) of the soil measured at pre sowing the soil depth of 15-30 cm was 2.04 dsm^{-1}. Whereas post-harvest EC measured at the soil depth of 15-30 cm was 1.93 dsm^{-1} and at the soil depth of 0-15 cm was 1.85 dsm^{-1}. The soil was found fit on the basis of EC at varying soil depths.

The pH of the soil at the depth of 15-30 cm was 8.10 when analyzed pre sowing. The post-harvest pH measured at the soil depth of 0-15 cm was 8.03 and at the depth of 15-30 cm the measured pH was 8.06. Due to the parental material of the study soil, pH was high having alkaline nature at different depths of soils. Stimulating microorganisms changes physical factors of soil such as pH, water holding capacity, temperature and aeration (Leather 1983; Liebel and Worsham 1983; Putnam and DeFrank 1983; Weston et al. 1989; Yenish et al. 1995; Liebman and Davis 2000).

The organic matter of the soil measured at pre-sowing stage at the soil depth of 15-30 cm was 0.62% which was slightly improved at post-harvest stage (0.65%) probably owing to growing legumes and decaying activity of plants roots and falling leaves etc at the depths of 0-15 cm. It was noteworthy that the soil organic matter was even better at 15-30 cm soil depth (0.69%). The slightly increased organic matter could be due to activity of the decaying plant roots in the crops rhizosphere. The other probable reason might be growing of leguminous crops and the plant debris, root decomposition by the action of micro-organisms which improve physical properties of soil and soil health. Soil organic matter, carbon dynamics and microbiological functions are enhanced by living mulches (Steenwerth and Belina, 2008). Organic matter increases microbial activity in the soil and prevents soil erosion (Hartwig and Ammon, 2002; Hanf, 1999).

The nitrate nitrogen measured at pre sowing stage at the depth of 15-30 cm was 5.10 mg kg^{-1} which was slightly improved at the post-harvest stage to 5.50 mg kg^{-1} at 0-15 cm soil depth. At 15-30 cm soil depth, nitrogen was improved to 5.90 mg kg^{-1}. The increase in the soil nitrate nitrogen could be owed to the leguminous crops grown which fixed nitrogen from the atmosphere through nodules in the roots and released after the decay of micro-organisms in the rhizosphere of leguminous plants. Legume living mulches fixes atmospheric nitrogen and improves soil physical properties (McVay et al., 1989; Latif et al., 1992). Improvement in soil fertility occurs through the addition of nitrogen in the soil rhizosphere by fixation of component legume crops (Hauggaard-Nielsen et al., 2001).

The chemical analysis of soil shows that available phosphorus at the depth of 15-30 cm at pre sowing stage was found to be 12.53 mg kg^{-1} and at post-harvest stage was 10.13 mg kg^{-1} at 0-15 cm soil depth. At the depth of 15-30 cm the available phosphorus measured was 10.75 mg kg^{-1}. The decrease in the phosphorus level at post-harvest stage at the depth of 0-15 cm can be attributed to utilization of the phosphorus by the crop plants. Relatively more phosphorus was found after the post-harvest stage at the depth of 15-30 cm when compared with upper soil layer of 0-15 cm. The probable reason for the slightly lower phosphorus at 0-15 cm soil depth is better uptake by plant roots because roots of taramira (arugula), lentil were most abundantly found in upper soil horizons where rhizosphere activity was more pronounced. In another study, Rao et al. (1999) found that achievement of P by the legume was noticeably greater than that by the grass, in spite of the P form being inorganic or organic. Chickpea can activate and take up some organic P by releasing phosphates into soil, and also run off some inorganic P for wheat. Wheat with a greater competitive ability acquires more P from the root zone of both wheat and chickpea, resulting in P depletion in the chickpea rhizosphere (Li et al., 2002).

The available potassium measured at the depth of 15-30 cm at pre-sowing was 103.00 mg kg^{-1} and at post- harvest potash was 80.00 mg kg^{-1} at 0-15 cm soil depth and at the depth of 15-30 cm was 87.00 mg kg^{-1}. Reason for the decrease in available potassium could be attributed to better uptake by the crop plants at soil depth of 0-15 cm and improved rhizosphere activity in this soil layer by taramira (arugula) and lentil. Phosphorus and potash might have been utilized by chickpea, taramira and lentil hence exhibiting reduced post-harvest levels.

Pre sowing soil saturation % at the depth of 15-30 cm was recorded to be 26.60 % however improved after crops harvest to 28.60 % at 0-15 cm soil depth. The soil saturation at the soil depth of 15-30 cm was even better i.e. 30.20 %. The probable reason for this increase in the saturation % might be increase in the organic matter by growing legumes and subsequent improvement in soil physical properties which improved soil water holding capacity. Relatively undisturbed soil indicated reduced evaporation with significantly greater soil water content. Higher soil moisture holding capacity coupled with less evaporation losses from the soil surface due to growing of legumes and improved soil health would have increased soil saturation capacity. Soil water infiltration is increased by cover crops (living mulches) (Bruce et al., 1992). Variations in soil depth and improved soil physic-chemical properties in deeper soil layers could be attributed to improved roots proliferation and penetration in deeper soil layers. Gan et al., (2011) also reported 41% root biomass found in upper 20 cm soil layer which indicates that rest of the roots biomass was found in deeper soil layers i.e. greater than 20 cm soil depth.

Slight improvement in soil fertility parameters and soil health (though not significant) was probably because of growing legume plants (chickpea and taramira) and secondly due to strip cropping of the crops which kept soil integrity intact. Straw mulch covering the soil as does the cover crops is highly advocated as it imparts benefits like improvement in soil fertility, soil moisture holding etc (Jabran et al., 2016; Ramakrishna et al., 2006).

Table 4.2. Physico-Chemical Characteristics and Strip Inter-Cropping of Legumes and Arugula Crop in Spate Irrigated Area

Characteristics	**Unit**	**Pre-Sowing**	**Post-Harvest**	
		(15-30 cm soil depth)	(0-15 cm soil depth)	(15-30 cm soil depth)
Textural class	-	Loam	Loam	Loam
Chemical analysis				
EC	dsm^{-1}	2.04	1.85	1.93
pH	-	8.10	8.03	8.06
OM	%	0.62	0.65	0.69
$N0_3$-N	mg kg^{-1}	5.10	5.50	5.90
Available Phosphorus	mg kg^{-1}	12.53	10.13	10.75
Available Potassium	mg kg^{-1}	103.00	80.00	87.00
Saturation	%	26.60	28.60	30.20

4.3. Intercropping System and Strip Cropping of Legumes and Arugula Crop in Spate Irrigated Area

4.3.1. Land Equivalent Ratio (LER)

Land equivalent ratio (LER) is the relative area of sole crop required to produce the yield achieved in intercropping (Khan et al., 1988). The LER value obtained from the intercropping of three crops under test (i.e. chickpea, taramira and lentil) is 1.79 and in the sole strip inter cropping of chickpea, the LER value obtained was 0.97. It means the yield obtained in intercropping chickpea with lentil and taramira resulted an overall increase in returns of 1.79 % than the sole strip inter cropping of chickpea, taramira (arugula) or lentil. In intercropping, yield is frequently higher than in sole cropping system (Lithourgidis et al., 2007; Dahmardeh et al., 2009), (Fig 4.3.1). Khatun et al., (2012) reported highest LER (1.719) in wheat-cowpea intercropping and lowest (1.46) in wheat mustard intercropping, while using different intercrop combinations. Wasaya et al. (2013) also reported a clear increase of LER in wheat-fenugreek intercropping. They reported that intercropping resulted in greater LER (1.78) than the mixed crop

(1.66) and was found most effective for sustainable production in the rainfed areas for a higher net return.

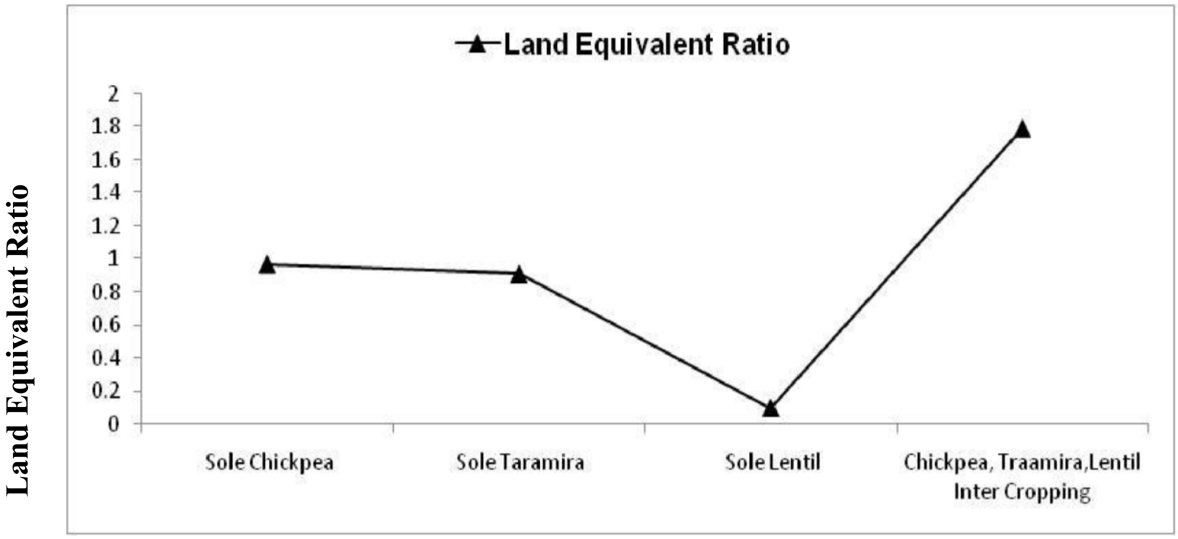

Fig. 4.3.1. Land Equivalent Ratio of Sole and Inter-cropping Systems of Chickpea, Taramira (Arugula) and Lentil in Spate Irrigated Area.

4.3.2. Relative Crowding Coefficient (RCC)

Relative Crowding Coefficient plays an important role in determining the competition effect and advantages in an intercropping system. According to Willey (1979), in inter cropping system each crop has its own RCC (K). To determine the yield advantage of intercropping, the product of coefficient of two components crops is formed that is usually designated as K. The component crop with higher K value is dominant than the crop having the low K value. If the product RCC of two species are equal, greater or lesser than one, it means the intercropping system has advantage or disadvantage, respectively. The relative crowding coefficient obtained for chickpea, taramira and lentil is 25, 9.44 and 0.13 respectively. It reveals that chickpea and taramira are dominant crops while lentil crop is dominated by other two crops. The component crop with higher “K” value is dominant and that with low “K” value is dominated. Shahid and Saeed (1997) also reported the dominant effect of mung bean, cowpea, mash bean and linseed when grown in association with other crops having a positive (+) aggressivity values. Jabbar et al., (2009) explained rice bean, cowpea and pigeon pea intercrops appeared to be dominant as they had higher values for “K” than the intercrops.

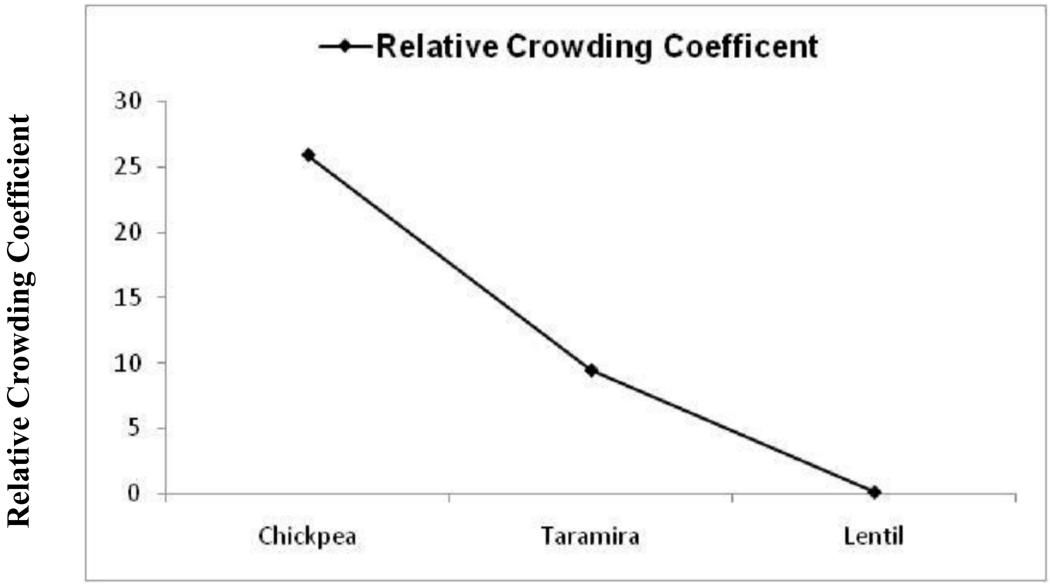

Fig. 4.3.2. Relative Crowding Coefficient of Sole Systems of Chickpea, Taramira (Arugula) and Lentil in Spate Irrigated Area

4.3.3. Area Time Equivalent Ratio (ATER)

As the land equivalent ratio does not account for the time which crop has occupied in the component crop in an inter-cropping system. To measure the time of component crop in inter cropping, the area time equivalent ratio was determined. The area time equivalent provides the more realistic yield advantages comparison of inter crop than in the sole crop. It consider the variations in the time taken by the component crop in an inter-cropping system.

In present study, the value of area time equivalent ratio for all the treatments was calculated and found to be similar as in the case for LER in the intercropping system. Though the harvesting time of chickpea and lentil was same but it varied from taramira crop which was harvested few days earlier than chickpea and lentil but this difference was non-significant. Furthermore the similar values of ATER to LER could be attributed to same time of plantation in strip inter-crops of three crops under test i.e. chickpea, taramira and lentil.

4.4. Agronomic Parameters

4.4.1. Chickpea

4.4.1.1. Plant Height (cm)

Chickpea based strip intercrops resulted in significant differences among all the treatments employed. Significantly maximum height (38.04 cm) of chickpea was attained in plots where chickpea was grown as a sole strip. Whereas alternate strip of chickpea-taramira (arugula) showed significantly less height of chickpea than sole strip cropping of chickpea. Likewise the alternate strip of chickpea-lentil resulted in shorter plants of chickpea when compared with sole strip intercropping of chickpea. While the alternate strip of two crops whether chickpea-taramira (arugula) or chickpea-lentil revealed significantly taller plants when compared with alternate strip inter cropping of three selected crops viz chickpea, taramira (arugula) and lentil. The significantly shortest plants of chickpea (30.75 cm) were observed in plots where all the three crops under study i.e. chickpea, taramira (arugula) and lentil were grown in alternate strip (Table 4.4.1.1).

The results are similar to the findings of Fortin et al., 1994; Głowacka, 2008 who stated that strip intercropping decreased plant height by an average of 25 cm. Decreased height of maize in the edge rows of the strip has been observed in some studies. The taller plants observed in chickpea alone strip can be due to good growth and development because of equal distribution and utilization of resources for chickpea plants each receiving sufficient sun light. In chickpea-taramira (arugula) strip, plant height of chickpea was shorter than the height of chickpea alone strip. The probable reason might be that taramira (arugula) plants are higher in length than the chickpea plants so the plants of taramira (arugula) might have shaded the nearby plants with reduced sunlight subsequently plants of chickpea could not attain the height in alternate strip as was the case in chickpea alone strip. The other probable reason could be that two crops grown in the alternate strip would share common growth resources (nutrients, space and moisture etc.) with differential need and uptake pattern. As in the start, both crops are in competition of taking moisture, nutrients and light etc. for growth that could be one reason why height remains low in this strip. In chickpea- taramira (arugula)-lentil alternate strip, the plant height of chickpea was less than all other treatments. The reason could be that three crops grown in the form of alternate strip might have created competition between the crops which would have been of more concern in three alternate strips grown together than the two crops grown in the alternate strip for light, nutrients and moisture. Taramira (arugula) is tall height crop so the shading effect might have had an impact on chickpea and lentil. Due to this shading effect some plants of two crops not received sunlight properly. So the plants height remained lower than the other treatments.

Table 4.4.1.1: Effect of Chickpea Based Strip Intercrops on Plant Height of Chickpea

Treatments	**Plant Height (cm)**
Chickpea Sole Strip	38.04 A
Chickpea and Taramira (Arugula) alternate Strip	35.33 B
Chickpea and Lentil alternate Strip	33.21 C
Chickpea, Taramira (Arugula) and Lentil alternate Strip	30.75 D
Tukey's HSD value	1.6908

4.4.1.2. Number of Pods per Plant

Chickpea based strip intercrops showed a significant difference for number of pods per plant among all the treatments which are under study. The maximum number of pods (37.60) in chickpea were obtained in the plot where chickpea was grown alone. Whereas the alternate strip of chickpea-taramira (arugula) resulted in less number of pods in chickpea plant as compared to chickpea alone strip. Likewise the alternate strip of chickpea-lentil has less amount of chickpea pods than alternate strip of chickpea-taramira (arugula). The alternate strip where all the three crops were grown together showed that the number of pods of chickpea were less (30.33) in alternate strips as compared to the alternate strips of two crops i.e. chickpea-taramira (arugula) or chickpea-lentil. Significantly less number of pods per plant were observed in plots where all the three crops under study i.e. chickpea, taramira (arugula) and lentil were grown in alternate strips and highest number of pods were observed in chickpea alone strip as compared with the alternate strip of chickpea-taramira (arugula); chickpea-lentil and chickpea-taramira (arugula)-lentil alternate strip (Table 4.4.1.2). Our findings match with Das et al., (2017) who reported that the number of pods was highest in the sole cropping of chickpea when compared with the inter cropping of chickpea and mustard.

Because of equal distribution and utilization of resources for chickpea each plants received sufficient sun light. The taller plants observed in chickpea alone strip can be due to good growth and development. In chickpea-taramira (arugula) alternate strip, the number of pods of the chickpea were less than the pods number in chickpea alone strip. The probable reason might be that the height of taramira (arugula) plant is more than the height of chickpea plant so the plants of taramira (arugula) might have caused shade on the chickpea plants which could not receive sunlight properly resulting in reduced growth and number of pods per plant. The other reason could be sharing of growth resources (nutrients, sunlight, moisture etc) between chickpea, taramira (arugula) and lentil resulted in dilution effect for these resources. Subsequently, less number of pods per plants of chickpea were found.

In chickpea-lentil alternate strip, the number of pods was significantly less. As in the start, both crops were in competition of taking nutrients and light for growth that may be cause of low pods in this strip. The other reason might be difference in root system because as roots grew deep, moisture and nutrients can be taken up in better way for growth. In chickpea-taramira (arugula)-lentil alternate strip, the number of pods were statistically short from rest of the treatments. It could be attributed to resource sharing and shade, differential plant height and moisture extraction depths for chickpea, taramira (arugula) and lentil.

Table 4.4.1.2: Effect of Chickpea Based Strip Intercrops on Number of Pods per Plant of Chickpea

Treatments	**No. of Pods per Plant**
Chickpea Sole Strip	37.60 A
Chickpea and Taramira (Arugula) alternate Strip	35.24 B
Chickpea and Lentil alternate Strips	32.74 C
Chickpea, Taramira (Arugula) and Lentil alternate Strip	30.33 D
Tukey's HSD value	1.9390

4.4.1.3. Height to 1st Branch (cm)

Chickpea based strip intercrops resulted in significant differences among all the treatments employed. The tallest height to first branch was observed in the chickpea alone strip and the lowest height to 1st branch was observed in the alternate strip of chickpea-taramira (arugula)-lentil. The alternate strip of chickpea-taramira (arugula) resulted in the shorter height to 1st branch in chickpea plant than chickpea alone strip. Whereas alternate strip of chickpea-lentil showed significantly less height of chickpea than sole strip cropping of chickpea. On the other side, alternate strip of chickpea-lentil resulted in the shorter height to 1st branch than the alternate strip of chickpea- taramira (arugula). Likewise the alternate strip of chickpea-taramira (arugula)-lentil showed the short height as compared to the alternate strip of chickpea-taramira (arugula); chickpea-lentil alternate strip (Table 4.4.1.3).

The taller plants observed in chickpea alone strip can be due to good growth and development because of equal distribution and utilization of resources for chickpea plants each receiving sufficient sun light. The height to first branch of chickpea in alternate strip of chickpea- taramira (arugula) was lower than the height to first branch of chickpea alone strip. The reason could be differential height of taramira (arugula) plant and chickpea. Taramira (arugula) plants are higher than the chickpea plants so the plants of taramira (arugula) shaded chickpea plants which could not receive sunlight properly and could not attain the height as did the chickpea alone strip. The other reason could be that two crops grown in the alternate strip together required nutrients and moisture for their growth so competition between the crops for moisture and nutrients might have resulted in minimum height to 1st branch of chickpea in the chickpea taramira (arugula) alternate strip.

In chickpea-lentil alternate strip, height to first branch was significantly low. The other reason could be the varying root system of these crops because as roots grew deep, plants were able to extract moisture and nutrients from deeper soil layers. In chickpea-taramira (arugula)-lentil alternate strip, the height to first branch was least from all other treatments under study. Taramira (arugula) is tall stature crop so the shading effect might also have an impact on nearby rows of the other crops. Due to this shading effect, the plants in adjacent rows with strip inter crops might have not received sunlight properly. So the height to 1st branch might have remained minimum as compared to other treatments.

Table 4.4.1 3: Effect of Chickpea Based Strip Intercrops on Height to First Branch of Chickpea

Treatments	Height to 1st Branch (cm)
Chickpea Sole Strip	40.39 A
Chickpea and Taramira (Arugula) alternate Strip	37.57 B
Chickpea and Lentil alternate Strip	35.18B
Chickpea, Taramira (Arugula) and Lentil alternate Strip	32.26 C
Tukey's HSD value	2.6597

Means followed by same letters do not differ significantly at P= 0.05

4.4.1.4. Number of Branches per Plant

Chickpea based strip intercrops resulted in significant differences among all the treatments employed. The maximum number of branches in chickpea was obtained in the plots where chickpea was grown alone. Whereas, the alternate strip of chickpea-taramira (arugula) had the fewer number of branches as compared to the chickpea alone plots. Whereas alternate strips of chickpea-lentil showed significantly less number of branches of chickpea than sole strip cropping of chickpea. Likewise, the alternate strip of chickpea-lentil shows slightly less amount of branches than the alternate strip of the chickpea-taramira (arugula).

The alternate strip where all the three crops grown revealed that the number of branches were less in these strips as compared to the alternate strips of two crops chickpea-taramira (arugula) and chickpea-lentil. The significantly less number of branches were observed in plots where all the three crops under study i.e. chickpea, taramira (arugula) and lentil were grown in alternate strips and highest number of branches were observed in chickpea alone strip when compared with other tested treatments than the alternate strips of chickpea-taramira (arugula) or chickpea-lentil and chickpea-taramira (arugula)-lentil (Table 4.4.1.4). Our results match with the outcomes of Das at el., (2017) who stated that the number of branches in sole crop is more than inter cropping of chickpea and mustard due to the less competition of plants.

The taller plants observed in chickpea alone strip can be due to good growth and development because of equal distribution and utilization of resources for chickpea plants each receiving sufficient sun light. In chickpea-taramira (arugula) alternate strip, the number of branches of chickpea were less than the number of branches of chickpea alone strip. The reason might be that chickpea and taramira (arugula) being two different crops vary for the plant height. Taramira (arugula) plants are taller than the plants of chickpea so the plants of taramira (arugula) had shading effect on chickpea plant. Chickpea plants could not receive sunlight properly and could not attain the potential height which however was not a case in chickpea alone strip. The other reason might be that two crops are grown in the strip both have required nutrient and moisture for their growth from common resource base so inter specific competition between crops for moisture and nutrients could be the reason for the minimum number of branches of chickpea in the chickpea-taramira (arugula) alternate strip.

In chickpea-lentil alternate strip number of branches was statistically and significantly lesser. The other reason could be the differential root system of these crops because as roots grew deep, plants can take moisture and nutrients differentially. In chickpea- taramira (arugula)-lentil alternate strip, the number of branches were statistically and significantly minimum, although it remained statistically at par with chickpea-taramira (arugula)-lentil alternate strip compared with all other treatments. The probable reason could be that three crops grown in alternate strip struggle for more space, light, nutrients and moisture etc than the two crops grown in alternate strip pattern. Taramira (arugula) has taller plants, so the shading effect could also have higher impact on the other crops especially the adjacent rows of crops under test viz chickpea and lentil. Due to this shading effect the plants in adjacent rows of other crops might have not received sunlight properly. Therefore, the number of branches remained minimum when compared with the other treatments than the alone chickpea strip.

Table 4.4.1.4: Effect of Chickpea Based Strip Intercrops on Number of Branches per Plant of Chickpea

Treatments	**No. of Branches per Plant**
Chickpea Sole Strip	7.38 A
Chickpea and Taramira (Arugula) alternate Strip	6.84 AB
Chickpea and Lentil alternate Strip	6.36 BC
Chickpea, Taramira (Arugula) and Lentil alternate Strip	5.82 C
Tukey's HSD value	0.8919

Means followed by same letters do not differ significantly at P= 0.0

4.4.1.5. 1000 Seed Weight (g)

Chickpea based strip intercrops resulted in significant differences among all the treatments employed. The maximum 1000 seed weight was observed in the plots where chickpea was grown as a sole crop. The alternate strip of chickpea-taramira (arugula) resulted in less 1000 seed weight in the plots than the chickpea alone. Whereas alternate strip of chickpea-lentil showed significantly less 1000 seed weight of chickpea than sole strip cropping of chickpea. On the other side, the seed weight of alternate strip of chickpea-taramira (arugula) was higher than the alternate strip of taramira (arugula)-lentil. Likewise the results showed that the alternate strip of chickpea-lentil had more 1000 seed weight than plots of alternate strip of chickpea-taramira (arugula)-lentil. The chickpea alone strip revealed maximum1000 seed weight than chickpea-taramira (arugula); chickpea-lentil; alone chickpea; taramira (arugula)-lentil alternate strip (Table 4.4.1.5). The obtained results are contradictory to the findings of Lesoing and Francis (1999) who noted a significant increase in seed weight in the edge rows of maize grown in strip cropping with soybeans. The taller plants observed in chickpea alone strip can be due to good growth and development because of equal distribution and utilization of resources for chickpea plants each receiving sufficient sun light.

In chickpea-taramira (arugula) strip, the seed weight of the chickpea was lower than the seed weight of chickpea alone strip. The probable reason might be that in chickpea-taramira (arugula) alternate strip the tallness of taramira (arugula) plant is more than the plant height of chickpea. Hence, the plants of taramira (arugula) could have shaded the chickpea plants and they could not have received ample sunlight and could not attain the height as was the case in chickpea alone strip. The other reason could be that two crops grown in the alternate strip could have resulted in inter specific competition for growth resources. In chickpea-lentil alternate strip, 1000 seed weight was statistically less. The probable reason could be the competition for nutrients, moisture and light between both the crops. The other reason could be the root system differences in these crops. As the roots grow deep, crop plants can take moisture and nutrients more efficiently from deeper soil layer. In chickpea-taramira (arugula)-lentil alternate strip, the 1000 seed weight was statistically minimum from rest of the treatments. It could be attributed to the fact that three crops grown in alternate strip may have resulted in the inter-specific competition for light, nutrients and moisture etc causing dilution effect and reduced assimilation partitioning in seeds of respective crops. Secondly, their might have been the shading effect of taramira (arugula) on chickpea and lentil. Reduced sunlight causes reduced photosynthesis and subsequently reduced photosynthates accumulation in seeds.

Table 4.4.1.5: Effect of Chickpea Based Strip Intercrops on 1000 Seed Weight of Chickpea

Treatments	**1000 Seed Weight (g)**
Chickpea Sole Strip	144.80 A
Chickpea and Taramira (Arugula) alternate Strip	133.27 B
Chickpea and Lentil alternate Strip	127.00 B
Chickpea, Taramira (Arugula) and Lentil alternate Strip	116.27 C
Tukey's HSD value	0.9683

Means followed by same letters do not differ significantly at P= 0.05

4.4.1.6. Biological Yield (kg ha^{-1})

Chickpea based strip intercrops resulted in significant differences among all the treatments employed. The maximum biological yield of chickpea was obtained in the plots where only chickpea was grown in the form of strip. The alternative strip of chickpea and taramira (arugula) revealed less biological yield as compared to chickpea alone strip. Whereas alternate strip of chickpea and lentil showed significantly less biological yield of chickpea than sole strip cropping of chickpea. Likewise, the alternate strip of chickpea and lentil showed low biological yield than the alternate strip of chickpea and taramira (arugula). The alternate strip where all the three crops were grown showed that the biological yield is low in these strips as compared to the alternate strips of two treatments i.e. chickpea-taramira (arugula) and chickpea-lentil. The significantly minimum biological yield was observed in plots where all the three crops under study i.e. chickpea, taramira (arugula) and lentil were grown in alternate strips. It could be due to increased competition among crop plants under study for light, water and nutrients. While the alternate strip of chickpea-taramira (arugula) or chickpea-lentil were intermediate for their effects on seed yield (Table 4.4.1.6). The results obtained by Głowacka (2010) who stated that strip cropping of maize, wheat and common bean resulted in a significant reduction in the yield of spring wheat are almost in consonance with our findings. The taller plants observed in chickpea alone strip can be due to good growth and development because of equal distribution and utilization of resources for chickpea plants each receiving sufficient sun light. Plants received sun light suitably that could be one reason why the biological yield in alone chickpea treatment was higher than the other treatments.

In chickpea-taramira (arugula) strip, the biological yield of the chickpea was lower than the biological yield of alone chickpea strip. The probable cause could be that the height of taramira (arugula) plant is more than the plant height of chickpea so the plants of taramira (arugula) shaded the chickpea plants and they could not capture sunlight appropriately. Hence could not attain the biological yield as did the chickpea alone strip. The probable reason could be that as in the start of the growing season crops grew together by sharing the common growth resources might have resulted in inter-specific competition for resources.

The differential growth resources and uptake potential of crops under test could be due to varying root activity; nutrient and moisture extraction depths. In chickpea-taramira (arugula)-lentil strip the biological yield was statistically minimum from rest of treatments. It can be attributed to the fact that three crops grown in one strip might have induced the inter-specific competition. Taramira (arugula) is tall statured crop so the shading effect on the other crops might also have an impact. Due to this shading effect, the plants of other crops i.e. chickpea and lentil might have not received sunlight properly. So the biological yield remained significantly lower than the other treatments.

Table 4.4.1.6: Effect of Chickpea Based Strip Intercrops on Biological Yield of Chickpea

Treatments	**Biological Yield (kg ha^{-1})**
Chickpea Sole Strip	3181.40 A
Chickpea and Taramira (Arugula) alternate Strip	2869.80B
Chickpea and Lentil alternate Strip	2741.20C
Chickpea, Taramira (Arugula) and Lentil alternate Strip	2559.10D
Tukey's HSD value	100.19

4.4.1.7. Seed Yield (kg ha^{-1})

Chickpea based strip intercrops resulted in significant differences among all the treatments tested. The maximum seed yield in chickpea was obtained in the plots where the chickpea was grown as an alone crop than the alternate crops. The seed yield of alternate strip of chickpea and taramira (arugula) was significantly less than the chickpea alone strip. Whereas alternate strip of chickpea-lentil showed significantly less seed yield of chickpea than sole strip cropping of chickpea. However, the seed yield was significantly higher in alternate strip of chickpea-taramira (arugula) than the alternate strip of the chickpea-lentil. Statistically minimum seed yield was obtained in the alternate strip of chickpea-taramira (arugula)-lentil. The seed yield was high in two alternate crop strips i.e. chickpea-taramira (arugula) and chickpea-lentil. This shows that the seed yield was significantly maximum in chickpea alone strip than the alternate strips (Table 4.4.1.7).

The results obtained are contrary to the findings of Głowacka (2011) who stated that strip cropping of dent maize, spring wheat and common bean may increase the marketable yield of bean seeds compared to single-species crops. Use of cover crops (living mulch) in Norwegian spring cereal production system significantly improved grain yield by 16–22% (Brandsæter, 2012). Whereas, the yield of subsequent spring barley was increased after using cover crops of clover crop in winter wheat because of leguminous nature of clover fixing nitrogen in soil (Bergkvist et al, 2011). The average yield of chickpea in spate irrigated system Mithawan hill torrent was 575.6 kg ha^{-1} (GOP, 2003) and 1991 kg ha^{-1} as reported by Ahmad et al., 2016. They further reported minimum seed yield for gram to be 618 kg ha^{-1}. The yield obtained by us is significantly greater than the minimum reported. Furthermore, the relatively lower seed yield than the current reported average as given by Ahmad et al., 2016 is understandable because year 2017 was dry year with less rains received in the Mithawan hill torrent command area.

The obtained results from the treatment of chickpea alone can be due to no intra specific competition. In chickpea-taramira (arugula) strip, the seed yield of the chickpea was significantly lower than alone chickpea strip. The likely cause could be the differential growth resource sharing and uptake potential and varying plant height. Taramira plants might have shaded the nearby chickpea plants and they could not receive sunlight properly. The other reason could be inter specific competition between chickpea and taramira (arugula) for significantly lower seed yield in the chickpea-taramira (arugula) alternate strip. As in start both crops were in competition of taking nutrients and light for growth that is why seed yield was low in this strip. The other reason could be the root system of crops because as roots grow deep they can take moisture and nutrients enhanced for growth. In chickpea-taramira (arugula)-lentil alternate strip, the seed yield was statistically minimum. The reason could be that three crops grown in alternate strip might have inter specific competition between the crops. Taramira (arugula) being taller crop, could have caused shading effect on the other crops. Due to this shading effect the plants of other crops not received light properly.

Table 4.4.1.7: Effect of Chickpea Based Strip Intercrops on Seed Yield of Chickpea

Treatments	**Seed Yield (kg ha^{-1})**
Chickpea Sole Strip	800.16 A
Chickpea and Taramira (Arugula) alternate Strip	787.73 B
Chickpea and Lentil alternate Strip	779.02 C
Chickpea, Taramira (Arugula) and Lentil alternate Strip	771.25 D
Tukey's HSD value	5.2694

4.4.1.8. Harvest Index (%)

Chickpea based strip intercrops resulted in significant differences among all the treatments investigated. Statistically highest harvest index for chickpea was obtained in the plots where only chickpea strip was grown. The alternative strip of chickpea and taramira (arugula) exhibited lower harvest index as compared to the chickpea alone strip. Whereas alternate strip of chickpea and lentil also showed significantly less harvest index of chickpea than obtained in sole strip cropping of chickpea. The alternate strip of chickpea and lentil also had significantly lower harvest index than the alternate strip of the chickpea and taramira (arugula). The plots where alternate strip of all the three crops were grown showed significantly minimum harvest index (Table 4.4.1.8).

The similar results have also been reported by Ancha and Ahlawat (1990), who stated that the harvest index of sole pigeon pea was higher than pigeon pea and mung bean inter cropping. The significantly higher harvest index obtained for chickpea alone treatment can be due to absence of inter-specific competition for resources and plant received sunlight and growth resources appropriately. That is why the plants attained potential height and resulted in better growth and development than strip inter crop treatments. Subsequently improved assimilates partitioning into economic part and higher seed yield in comparison to becoming part of plant general dry matter in the form of yield other than seed yield.

In chickpea and taramira (arugula) strip, the harvest index of the chickpea was significantly lower than the height of chickpea alone strip. The probable reason could be differential crop plants height so the plants of taramira (arugula) had shading effect on the chickpea plants which could not receive light properly hence could not reach the height as was the case in chickpea alone strip. The other likely reason could be inter-specific competition between chickpea and taramira (arugula). In chickpea-lentil alternate strip, the probable reason could be the competition for nutrients, moisture and light etc between chickpea and lentil.

As in the start of the growing season both crops were in competition of taking nutrients and light for growth and development and dry matter partitioning and translocation to sink that is why harvest index was significantly less. Root system of these crops is also a differential factor because as roots grow deep (Chickpea plants) they can take moisture and nutrients better for growth than the shallow rooted crops like lentil and taramira (arugula). In chickpea-taramira (arugula)-lentil strip, the harvest index was significantly minimum as compared to all other treatments. The likely reason could be that three crops grown in alternate strip might have induced inter-specific competition between the crops. Taramira (arugula) is tall height crop when compared with chickpea and lentil. The shading effect might also have an impact on the other crops. Due to this shading effect, the plants of other crops might have not received sunlight properly resulting in reduced assimilates accumulation in sink, so the harvest index remained lower than the other treatments. Sole strip of chickpea performed better and it could possibly be due to acclimatization of the crop to the local condition of soil, climate, water and nutrient resources. Chickpea plants being deeper rooted are able to extract water from deeper soil layers more efficiently than does the other two crops under test i.e. taramira (arugula) and lentil.

Table 4.4.1.8: Effect of Chickpea Based Strip Intercrops on Harvest Index of Chickpea

Treatments	**Harvest Index %**
Chickpea Sole Strip	31.25 A
Chickpea and Taramira (Arugula) alternate Strip	28.76 B
Chickpea and Lentil alternate Strip	27.14 C
Chickpea, Taramira (Arugula)and Lentil alternate Strip	24.22 D
Tukey's HSD value	0.9388

4.4.2. Taramira (Arugula)

4.4.2.1. Plant Height (cm)

Taramira (arugula) based strip intercrops resulted in significant differences among all the treatments applied. The results showed that the significantly maximum height (92.41cm) of taramira (arugula) was attained in plots where taramira (arugula) plants were grown as an alone strip. Although it could not differ statistically from plots where alternate strips of chickpea and taramira (arugula) were grown. Significantly less height (88.04 cm) of taramira (arugula) was observed in chickpea-taramira (arugula) alternate strip than sole strip cropping of taramira (arugula). The alternate strip of taramira (arugula)-lentil resulted in significantly shorter plants (86.22 cm) of taramira (arugula) when compared with sole strip cropping of taramira (arugula). While the alternate strips of two crops whether chickpea-taramira (arugula) or taramira-lentil though statistically similar revealed relatively taller plants when compared with alternate strip cropping of three tested crops i.e. chickpea, taramira and lentil. Statistically minimum (83.82cm) plants of taramira (arugula) were observed in plots where all the three crops i.e. chickpea, taramira (arugula) and lentil were grown in alternate strip (Table 4.4.2.1). The results obtained could be due to lack of intra- specific or inter-specific competition. So the plants were significantly taller in alone strip of taramira (arugula) than alternate strip inter crops. Głowacka, (2008) also stated that strip cropping decreased height of maize in the edge rows of the strip.

In the alternate strip of two crops i.e. chickpea and taramira (arugula), the plant height was lower than alone strip of chickpea but it could not reach the level of significance. In the alternate strip of taramira (arugula)-lentil the height of the taramira (arugula) was significantly less than alone strip. The likely reason could be that two crops grown competed with each other for nutrients and moisture from the soil. When both crops competed with each other, the height remained low than the alone strip of taramira (arugula). In the alternate strip of chickpea-taramira (arugula)-lentil, the height was less because the three crops competed with each other for growth resources (nutrients, moisture, light) for their normal growth as chickpea roots move deeper in soil and use moisture more efficiently than does the taramira (arugula) plants.

Table 4.4.2.1: Effect of Taramira (Arugula) Based Strip Intercrops on Plant Height of Taramira (Arugula)

Treatments	**Plant Height (cm)**
Taramira (Arugula) Sole strip	92.41 A
Chickpea + Taramira (Arugula) alternate strip	88.04 AB
Taramira (Arugula) + Lentil alternate strip	86.22 B
Chickpea+ Taramira (Arugula) + Lentil alternate strip	83.82 B
Tukey's HSD value	4.3787

Means followed by same letters do not differ significantly at P= 0.05

4.4.2.2. Length of Siliquae (cm)

Taramira (arugula) based strip intercrops resulted in significant differences among the treatments applied. The statistically maximum length of siliquae (3.25 cm) was obtained in the plots where the taramira (arugula) plants were grown in a sole strip. Although it could not differ significantly with the alternate strips of chickpea-taramira (arugula). The alternate strip of taramira (arugula)-lentil also showed significantly the shorter length of siliquae (3.05 cm) as compared with the sole taramira (arugula) strip. But it is worth mentioning that the alternate strip of chickpea and taramira (arugula) could not differ significantly from alternate strip of taramira (arugula) and lentil. Significantly minimum length (2.98 cm) was obtained in the plots where the three crops viz chickpea, taramira (arugula) and lentil were grown in alternate strip (Table 4.4.2.2).

The results obtained can be attributed to better growth resources use in sole strip cropping. So the length of siliquae was high in alone strip of taramira (arugula) than other alternate strips. The plants of these crops were in competition for the growth resources (nutrients and moisture) from the soil. The roots of chickpea penetrated in soil deeper than did the taramira (arugula) roots and got more nutrients and moisture from the soil than the taramira (arugula) and length of siliquae of taramira (arugula) remained lower than the alone strip of taramira (arugula). In the alternate strip of taramira (arugula)-lentil, the length of siliquae of the taramira (arugula) was significantly lower than alone strip. The probable reason could be that when the two crops grown they competed with each other for nutrients and moisture from the soil. In the alternate strip of chickpea-taramira (arugula)-lentil, the length of siliquae was significantly minimum because three crops might have competed with each other for resources for their normal growth.

Table 4.4.2.2: Effect of Taramira (Arugula) Based Strip Intercrops on Length of Siliquae of Taramira (Arugula)

Treatments	**Length of Siliquae (cm)**
Taramira (Arugula) Sole strip	3.25A
Chickpea + Taramira (Arugula) alternate strip	3.18AB
Taramira (Arugula) + Lentil alternate strip	3.05BC
Chickpea+ Taramira (Arugula) + Lentil alternate strip	2.98C
Tukey's HSD value	0.1588

Means followed by same letters do not differ significantly at P= 0.05

4.4.2.3. Number of Siliquae per Plant

Taramira (arugula) based strip intercrops resulted in significant differences among all the treatments tested. The results showed that the significantly maximum siliquae (87.07) of taramira (arugula) was found in plots where taramira (arugula) plants were grown as a sole strip. The result obtained from the treatment could be due to no intra specific competition for sole strip of taramira (arugula). So the number of siliquae was higher in alone strip of taramira (arugula) than other alternate strips. Although the alternate strip of chickpea-taramira (arugula) was also statistically alike to the number of siliquae in alone strip of chickpea. The number of siliquae in the alternate strip of taramira (arugula)-lentil were significantly less than alone taramira (arugula) strip. Whereas alternate strip of chickpea-taramira (arugula) showed statistically similar results. Likewise, the alternate strip of taramira (arugula)-lentil resulted in significantly lesser siliquae number (80.47) of taramira (arugula) when compared with sole strip cropping of taramira (arugula). While the alternate strips of two crops whether chickpea-taramira (arugula) or taramira (arugula)-lentil revealed non-significant differences among themselves. Significantly minimum number of siliquae (78.20) were observed in plots where all the three crops under study i.e. chickpea, taramira (arugula) and lentil were grown in alternate strip (Table 4.4.2.3). Results reported by Ahlawat et al., 2005 are in contradiction to our findings when they said that the number of siliquae per plant were found highest in inter cropping as compared to sole rapeseed. This contradiction could be owing to differences of inter-crop species under test.

In the alternate strip of chickpea-taramira (arugula)-lentil, the number of siliquae was statistically minimum because the three crops have different growth habit, root system and resource use potential etc.

Table 4.4.2 3: Effect of Taramira (Arugula) Based Strip Intercrops on Number of Siliquae Plant $^{-1}$of Taramira (Arugula)

Treatments	**Number of Siliquae Plant^{-1}**
Taramira (Arugula) strip	87.07 A
Chickpea + Taramira (Arugula) alternate strip	82.87AB
Taramira (Arugula) + Lentil alternate strip	80.47 BC
Chickpea+ Taramira (Arugula) + Lentil alternate strip	78.20 C
Tukey's HSD value	4.2538

Means followed by same letters do not differ significantly at P= 0.05

4.4.2.4. Number of Seeds per Siliquae

Taramira (arugula) based strip intercrops resulted in significant differences among all the treatments applied. Plots where the taramira (arugula) plants were grown as a sole strip crop showed significantly maximum number of seeds per siliquae (19.67). The alternate strip of chickpea-taramira (arugula) also revealed similar statistical results. Likewise the alternate strip of taramira (arugula)-lentil could not reach the level of significance to alternate strip of chickpea-taramira (arugula). Statistically the minimum number of seeds per siliquae (16.93) were recorded in the alternate strip of chickpea-taramira (arugula)-lentil as compared to sole cropping of taramira (arugula) strip (Table 4.4.2.4). Our finding is similar to Das et al. (2017) who also found that sole rapeseed recorded significant higher yield attributing characters such as number of seeds per siliquae than the inter copping of chickpea and rape seed. The alternate strip of two crops chickpea-taramira (arugula) also revealed statistically alike results to alone strip of taramira (arugula). In the alternate strip of chickpea-taramira (arugula)-lentil, the number of seeds per siliquae were significantly minimum.

Table 4.4.2.4: Effect of Taramira (Arugula) Based Strip Intercrops on Number of Seeds Siliquae^{-1} of Taramira (Arugula)

Treatments	**Number of Seeds Siliquae^{-1}**
Taramira (Arugula) Sole strip	19.67 A
Chickpea + Taramira (Arugula) alternate strip	18.57 AB
Taramira (Arugula) + Lentil alternate strip	18.00 BC
Chickpea+ Taramira (Arugula) + Lentil alternate strip	16.93 C
Tukey's HSD value	1.1062

Means followed by same letters do not differ significantly at P= 0.05

4.4.2.5. 1000 Seed Weight (g)

Taramira (arugula) based strip intercrops resulted in significant differences among all the treatments employed. The results showed that the highest weight of (4.72 g) 1000 seeds of taramira (arugula) were noted in those plots where the taramira (arugula) plants were grown as the alone strip. Whereas the alternate strip of chickpea and taramira (arugula) was significantly similar to the sole strip of taramira (arugula). The 1000 seed weight of taramira (arugula)-lentil alternate strip was significantly less (4.59 g) than the sole strip of taramira (arugula). But the weight of alternate strip of chickpea-taramira (arugula) was slightly higher than the seed weight of alternate strip of taramira (arugula)-lentil though both alternate strip treatments were statistically similar.

The statistically lowest seed index (4.50 g) was observed in the alternate strip of three crops viz chickpea-taramira (arugula)-lentil. Alternate strip of taramira (arugula)-lentil also resulted in statistically lowest 1000 seed weight (Table 4.4.2.5).

Results of Lesoing and Francis (1999) stated increase in seed weight in edge rows of maize grown in strip cropping with soybean are contradictory to our findings. This can be attributed to differences in species used for inter-cropping. The taller plants observed in chickpea alone strip can be due to better growth and development and equal distribution and utilization of resources for chickpea plants. In chickpea-taramira (arugula) alternate strip, the 1000 seed weight of taramira (arugula) was lower than the seed weight of chickpea alone strip. The probable reason might be that chickpea and taramira (arugula) differ in their plant height. The tallness of taramira (arugula) plant is more so the plants of taramira (arugula) induced shade on the chickpea plants which could not receive sunlight properly and could not attain the height as did the taramira (arugula) alone strip. The other possible reason could be that two crops are grown in the alternate strip which might have resulted in inter-specific competition for growth resources. In chickpea-taramira (arugula) alternate strip, 1000 seed weight was statistically lesser.

Differential root system among selected crops could be the one reason. As the roots of chickpea can grow deep they can take moisture and nutrients more efficiently from deeper soil layer for better growth. In chickpea-taramira (arugula)-lentil alternate strip, the 1000 seed weight was statistically minimum from rest of the treatments. It could be due to the fact that three crops grown in one strip might have induced inter-specific competition for light, nutrients and moisture which could have resulted in dilution effect and reduced assimilates partitioning in seeds of respective crops. Secondly, there might have been the shade effect of taramira (arugula) on other two crops under test i.e. chickpea and lentil. Reduced sunlight might have caused reduced photosynthesis and subsequently reduced photosynthates accumulation in seeds.

Table 4.4.2.5: Effect of Taramira (Arugula) Based Strip Intercrops on 1000 Seed Weight of Taramira (Arugula)

Treatments	**1000 Seed Weight (g)**
Taramira (Arugula) Sole strip	4.72 A
Chickpea + Taramira (Arugula) alternate strips	4.66 AB
Taramira (Arugula) + Lentil alternate strips	4.59 BC
Chickpea+ Taramira (Arugula) + Lentil alternate strips	4.50 C
Tukey's HSD value	0.1073

Means followed by same letters do not differ significantly at P= 0.05

4.4.2.6. Seed Yield (kg ha^{-1})

Taramira (arugula) based strip intercrops resulted in significant differences among the treatments applied. The results obtained showed that the seed yield was higher (433.14) in the plots where taramira (arugula) was grown as a sole crop. The seed yield (414.36 kg ha^{-1}) was significantly lesser in the alternate strip of chickpea-taramira (arugula) as compared to the sole strip of taramira (arugula). The seed yield was significantly higher in the alternate strip of the chickpea-taramira as compared to the alternate strip of taramira (arugula)-lentil. The seed yield was found significantly minimum (375.23 kg ha^{-1}) in the alternate strip of three crops i.e. chickpea-taramira (arugula)-lentil (Table 4.4.2.6).

The results obtained are similar to the findings of Giri et al., (1980) who reported that intercropping of fast growing pearl millet reduced the growth or seed yield of pigeonpea. Hedge and Safar (1982) also observed that the seed yield is reduced in various intercropping systems. Yield of succeeding crop can be increased by incorporating legume living mulch (Bollero and Bullock 1994; Decker et al., 1994). The treatment varied significantly among each other. Significantly minimum seed yield was recorded in plots where three crops (i.e. chickpea, taramira (arugula) and lentil) under test were grown in alternate strip.

Table 4.4.2.6: Effect of Taramira (Arugula) Based Strip Intercrops on Seed Yield of Taramira (Arugula)

Treatments	Seed Yield (kg ha^{-1})
Taramira (Arugula) Sole strip	433.14 A
Chickpea + Taramira (Arugula) alternate strip	414.36 B
Taramira (Arugula) + Lentil alternate strip	395.46 C
Chickpea+ Taramira (Arugula) + Lentil alternate strip	375.23 D
Tukey's HSD value	5.9414

4.4.2.7. Biological Yield (kg ha^{-1})

Taramira (arugula) based strip intercrops resulted in non-significant differences among all the treatments applied. The maximum biological yield was obtained in the plots where taramira (arugula) was grown in sole strip. On the other side the minimum biological yield was obtained in the plots where the three crops chickpea, taramira (arugula) and lentil were grown in alternate strip (Table 4.4.2.7). The results obtained by Garcia-Préchac, 1992; Lesoing and Francis, 1999 who stated that the effects of strip cropping on the yield of maize are inconclusive. However, several authors have noted increased maize yield (by about 10-30%) in this system compared to the cultivation of maize alone, are similar to our findings. The obtained result from the treatment could be due to no intra-specific competition between taramira (arugula) plants in sole crop.

Table 4.4.2.7: Effect of Taramira (Arugula) Based Strip Intercrops on Biological Yield of Taramira (Arugula)

Treatments	Biological Yield (Kg ha^{-1})
Taramira (Arugula) Sole strip	1854.70 **ns**
Chickpea + Taramira (Arugula) alternate strip	1851.30
Taramira (Arugula) + Lentil alternate strip	1851.10
Chickpea+ Taramira (Arugula) + Lentil alternate strip	1838.40
Tukey's HSD value	50.523

ns: Non significant

4.4.2.8. Harvest Index (%)

Taramira (arugula) based strip intercrops resulted in significant differences among all the treatments applied. The results revealed that harvest index was significantly higher (23.35 %) in those plots where taramira (arugula) was grown as an alone crop. Whereas the alternate strip of chickpea-taramira (arugula) resulted in significantly lower harvest index (22.53 %) than the taramira (arugula) alone strip. Likewise the alternate strip of taramira (arugula)-lentil also showed significantly lower harvest index (21.37 %) as compared to taramira (arugula) alone strip. The alternate strip of taramira (arugula)-chickpea showed the higher harvest index than the alternate strip of taramira (arugula)-lentil. The lowest harvest index (20.27 %) was observed in the alternate strip of three crops i.e. chickpea, taramira (arugula), and lentil. The harvest index of alternate strip of chickpea-taramira (arugula) and taramira (arugula)-lentil showed the higher harvest index than the alternate strip of three crops which were under test i.e. chickpea, taramira (arugula) and lentil (Table 4.4.2.8). Similar results have also been reported by Ancha and Ahlawat (1990) who stated that harvest index of mung bean and pigeon pea intercropping system is low than the sole pigeon pea.

Table 4.4.2.8: Effect of Taramira (Arugula) Based Strip Intercrops on Harvest Index of Taramira (Arugula)

Treatments	**Harvest index (%)**
Taramira (Arugula) Sole strip	23.35 A
Chickpea + Taramira (Arugula) alternate strip	22.53 B
Taramira (Arugula) + Lentil alternate strip	21.37 C
Chickpea+ Taramira (Arugula) + Lentil alternate strip	20.27 D
Tukey's HSD value	0.6916

4.4.3. Lentil

The lentil crop failed in the agro normals of the spate irrigated settings under test for productivity and could not establish. Lentil plants emerged quite well in the field but could not succeed to grow efficiently. The lentil growth was quite slow during the growing season and few plants could reach maturity stage with very much limited photosynthates accumulation and yield related components. It could be owed to non-availability of sufficient soil moisture at the critical stages of growth thereby badly affecting pollination, fertilization and seed setting. It can also be attributed to limited roots proliferation within soil and limited water uptake potential under water scarce situation. The reduction in lentil yield can be owed to minimum plant population per unit area and reduced growth. Alkaline soil pH may also had an adverse effect on growth and development of lentil plants. Less number of seeds at pH 8.5 and light seed weight of lentil resulted in lower seed yield (Horiuchi and Hara, 1989) Furthermore water shortage at flowering stage could have badly damaged the yield of lentil. Anyhow, different recorded parameters from fewer lentil plants reaching maturity have been presented below.

4.4.3.1. Plant Height (cm)

Lentil based strip intercrops resulted in significant differences among all the treatments applied. The result showed that the statistically maximum height (30.60 cm) of lentil was attained in plots where the lentil was grown as an alone strip. Whereas alternate strip of chickpea-lentil showed significantly smaller height (29.28 cm). Likewise the alternate strip of taramira (arugula)-lentil resulted in significantly shorter plants (24.70 cm) of lentil as compared with sole strip cropping of lentil but could not vary significantly from chickpea-lentil alternate strip. While the alternate strip of two crops whether chickpea-lentil or taramira (arugula)-lentil revealed significantly taller plants when compared with alternate strip cropping of three selected crops viz chickpea, taramira (arugula) and lentil. The significantly shortest plants (22.39 cm) were observed in plots where all the three crops under study i.e. chickpea, taramira (arugula) and lentil were grown in alternate strip (Table 4.4.3.1). Fortin et al., (1994) explained that plant height decreased in inter cropping of maize and lupin than in sole crops.

In the alternate strip of chickpea-lentil, the height of lentil plants was lower than that found in alone strip of lentil because chickpea and lentil plants differ in their plant height. Whereas in taramira (arugula)-lentil grown in alternate strip, adjacent lentil plants rows might have come under shade of taramira (arugula) plants thereby reducing growth and potential plant height.

Table 4.4.3.1: Effect of Lentil Based Strip Intercrops on Plant Height of Lentil

Treatments	**Plant height (cm)**
Lentil Sole strip	30.60A
Chickpea + Lentil alternate strip	29.286AB
Taramira (Arugula) + Lentil alternate strip	24.70BC
Chickpea+ Taramira (Arugula) + Lentil alternate strip	22.39C
Tukey's HSD value	4.9574

Means followed by same letters do not differ significantly at P= 0.05

4.4.3.2. Number of Branches per Plant

Lentil based strip intercrops resulted in non-significant differences among all the treatments applied. However, the maximum number of branches per plant in lentil was obtained in the plots where the lentil was grown alone. The alternate strip where all the three crops grown resulted in minimum number of branches. Rest of the treatments were intermediate for their effect on number of branches per plant of lentil (4.4.3.2). Our findings are similar to Das at el. (2017) who stated that the number of branches in sole crop is more than inter cropping of chickpea and mustard due to the less competition of plants.

Table 4.4.3.2: Effect of Lentil Based Strip Intercrops on Number of Branches Plant $^{-1}$ of Lentil

Treatments	**No. of Branches Plant^{-1}**
Lentil Sole strip	10.63 ns*
Chickpea + Lentil alternate strips	10.22
Taramira (Arugula) + Lentil alternate strips	7.20
Chickpea+ Taramira (Arugula) + Lentil alternate strips	6.48
Tukey's HSD value	4.8720

*** ns: Non-significant**

4.4.3.3. Number of Pods per Plant

Lentil based strip intercrops resulted in significant differences among the treatments applied. The results showed that the maximum number of pods per plant were obtained in the plot where the lentil was grown as an alone crop. The alternate strip of chickpea-lentil had the fewer number of pods than the number of pods of the alone lentil strip. However it could not differ significantly among each other. Likewise, the alternate strip of taramira (arugula)-lentil produced significantly less number of pods than the sole strip of lentil. The alternate strip of chickpea-lentil produced significantly more number of pods per plant than the alternate strip of taramira (arugula)-lentil. The alternate strip of chickpea-taramira (arugula)-lentil had significantly minimum number of pods per plant (Table 4.4.3.3). Our results are in agreement with the findings of Singh et al., (2000) who reported that sole lentil recorded significantly superior number of pods and values of dry-matter accumulation than Indian mustard + lentil intercropping system. It may be due to shading effect of Indian mustard on lentil in intercropping system.

Table 4.4.3.3: Effect of Lentil Based Strip Intercrops on Number of Pods per Plant of Lentil

Treatments	Number of pods plant^{-1}
Lentil Sole strip	32.57 A
Chickpea + Lentil alternate strip	30.66 A
Taramira (Arugula) + Lentil alternate strip	25.66 B
Chickpea+ Taramira (Arugula) + Lentil alternate strip	23.29 B
Tukey's HSD value	4.5797

Means followed by same letters do not differ significantly at P= 0.05

4.4.3.4. Seed Yield per Plant (g)

It must be remembered that although overall seed yield per plant obtained was almost negligible. However, comparison among the treatments significant differences were observed in lentil based strip intercropping. The results showed that maximum seed yield per plant (0.17 g) was produced from the strip where lentil plants grown in a sole crop. The yield of alternate strip of chickpea-lentil produced significantly the lower yield as compared to the yield of lentil alone strip. Likewise the yield of alternate strips of taramira (arugula)-lentil, though could not bring significant changes in yield per plant from plots where chickpea and lentil were grown in alternate strip; was low than the alone strip of lentil. The yield was statistically lowest (0.147 g) in the alternate strip of chickpea-taramira (arugula)-lentil (Table 4.4.3.4). Similar result was obtained by Tiwari et al., (1992) who stated that seed and straw yields of Indian mustard was not affected significantly by Indian mustard paired row (30/90 cm) + lentil (2 rows) intercropping. Whereas lentil seed and straw yields were reduced significantly under intercropping system. The reduction in lentil yield was mainly due to reduced plant population per unit area and lower values of growth parameters (Tiwari et al., 1992).

Table 4.4.3.4: Effect of Lentil Based Strip Intercrops on Seed Yield per Plant of Lentil

Treatments	Seed Yield per Plant (g)
Lentil Sole strip	0.17 A
Chickpea + Lentil alternate strip	0.16 B
Taramira (Arugula) + Lentil alternate strip	0.15 BC
Chickpea+ Taramira (Arugula) + Lentil alternate strip	0.14 C
Tukey's HSD value	0.0125

Means followed by same letters do not differ significantly at P= 0.05

The sediments and nutrients laden runoff water from the uplands of dry contains command area in lowlands may vary in their composition and spread over the fields as a result of varying management and land preparation. Therefore the soil physical properties may change over years. Hence the yield of crops may also show different response over years. Difference in silt distribution and incorporation in soil may also have an impact on the yield components, soil physical properties, soil moisture, storage potential and use by crops.

Summary

The experiment was conducted during the Rabi season 2017-18 at selected location in Mithawan Hill Torrent spate irrigated fields of Dera Ghazi Khan. The physico-chemical analysis of soil was carried out before sowing and after harvest using standard procedures. The experiment was laid out in RCBD, having three replications. The sowing time was October 08, 2017. Seed rate used for lentil, chick pea, and taramira (arugula) crops was 20, 90 and 5 kg ha^{-1}, respectively. Seeds of lentil, chickpea and taramira (arugula) were line sown using seed drill. The net plot size was 44 m×5.45 m. Lentil rows were kept 30 cm apart, chickpea 45 cm apart with plants spaced at 23 cm for both crops whereas taramira (arugula) rows spaced at 45 cm with plants within row spaced at 15 cm. Urea, DAP and SOP fertilizers were applied at the sowing time at 17 kg urea and 50 kg each of DAP and SOP per acre, respectively. Conserved soil moisture and rainfall received during the growing season were the only source of water available for crops to grow till maturity and harvest. All the other agronomic procedures were kept normal and uniform for all the treatments. The harvesting of taramira (arugula) was done in end of March, 2018. Whereas Chickpea was harvested in April, 2018.

The experimental treatments applied in the experiments were

S_1: Chickpea Sole strip

S_2: Taramira (arugula) Sole strip

S_3: Lentil Sole strip

S_4: Chickpea + Taramira (Arugula) alternate strip

S_5: Chickpea + Lentil alternate strip

S_6: Taramira (Arugula) + Lentil alternate strip

S_7: Chickpea+ Taramira (Arugula) + Lentil alternate strip

The results obtained are summarized below.

Chickpea lentil alternate strip conserved maximum soil moisture and utilized minimum soil moisture with least evaporation losses at soil depth of 0-15 cm while minimum soil moisture was conserved in taramira (arugula) sole strip. At the soil depth of 15-30 cm, the chickpea sole strip resulted in maximum moisture conservation with least losses. Monthly soil moisture utilization among treatments at 30-45 cm soil depth during the growing season revealed that chickpea in combination with taramira and lentil

strip intercrop in general resulted in improved moisture conservation. Strip intercropping resulted in overall more moisture conservation than sole strip cropping under the agro normals of spate irrigated settings of Mithawan hill torrent command area.

At 0-15 cm soil depth, the order of moisture conservation from highest to lowest among the treatments is as follows:

Chickpea-lentil>chickpea-taramira>taramira-lentil>chickpea-taramira-lentil>sole chickpea>sole lentil>sole taramira

At 15-30 cm soil depth, the order of moisture conservation from highest to lowest among the treatments is as follows:

Sole chickpea>sole taramira>chickpea-taramira>chickpea-taramira-lentil> chickpea lentil> taramira-lentil> sole lentil

Physico-chemical analysis of experimental soil (pre sowing and post-harvest) suggests that there have been slight improvements after crop harvest in organic matter and nitrogen, whereas electrical conductivity and pH of soil was slightly decreased. However available phosphorus and available potassium diminished in soil over time. There was also a differential response of soil properties with increasing soil depth.

The land equivalent ratio was better in strip inter cropping systems of chickpea, taramira and lentil as compared to sole strip cropping of either chickpea, taramira or lentil. The Relative crowding coefficient values suggested that chickpea and taramira grown in intercropping system are advantageous. However lentil was disadvantageous in inter cropping system under the agro normals of spate irrigated settings of Mithawan hill torrent command area.

In the chickpea based strip intercropping, yield and yield related parameters of chickpea were statistically maximum in the sole strip cropping and minimum in the plots where three crops were sown together in alternate strips of chickpea, taramira and lentil. Seed yield and harvest index of chickpea in sole strip was statistically followed by chickpea-taramira alternate strip making it a promising option for farmers keeping in view its advantages for moisture conservation with additional slight improvement in organic matter and soil properties.

Likewise in taramira based strip intercropping systems, yield and yield related parameters of taramira were statistically maximum in the sole strip of taramira. Whereas minimum in plots where the alternate strip of three crops viz chickpea, taramira and lentil were grown. Most of the yield related parameters of taramira were statistically similar to chickpea-taramira alternate strip. However seed yield of taramira sole strip was followed by seed yield of taramira in chickpea-taramira alternate strip. This again supports the promising option for farmers who want to make soil moisture available for longer time.

Lentil could not succeed in agro normals of spate irrigated conditions of Mithawan hill torrent command area at selected locations because of poor stand establishment. However, the data recorded from fewer plants reaching maturity revealed maximum yield and yield related parameters in the sole strip cropping of lentil. On the other side, minimum values for above parameters were recorded in the alternate strip cropping of chickpea, taramira and lentil.

Conclusion

Farmers can conserve soil moisture, bring improvement in soil physico-chemical properties by growing chickpea-taramira in the form of alternate strip inter-crops besides getting comparable yield of chickpea and taramira (arugula) on sustainable basis under the spate irrigated conditions of Mithawan hill torrent command area of Dera Ghazi Khan. Farmers who want to conserve more soil moisture with increasing soil depth for subsequent efficient use by crops during the growing season should grow chickpea and lentil winter legumes in the form of strip. Continuous and sustainable use of strip intercropping of chickpea-taramira by the farmers of spate irrigation system can bring improvement in soil physical properties, organic matter, nitrogen status and can increase soil moisture at increasing soil depth for plant growth and development. Based on this study it can also be concluded that the farmers of Mithawan hill torrent command area of Dera Ghazi Khan should not grow lentil for yield purpose under the present conditions of soil, climate and management systems.

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Appendices

ANOVA of Chickpea

Table 1. ANOVA of Plant Height of Chickpea

Source	DF	SS	MS	F	P
R	2	52.531	26.2656		
Treat	3	86.534	28.8447	80.66	0.0000
Error	6	2.146	0.3576		
Total	11	141.211			

Table 2. ANOVA of Number of Pods of Chickpea

Source	DF	SS	MS	F	P
R	2	52.531	26.2656		
Treat	3	86.534	28.8447	80.66	0.0000
Error	6	2.146	0.3576		
Total	11	141.211			

Table 3. ANOVA of Height to First Branch of Chickpea

Source	DF	SS	MS	F	P
R	2	43.717	21.8586		
Treat	3	107.616	35.8719	40.54	0.0002
Error	6	5.309	0.8848		
Total	11	156.642			

Table 4. ANOVA of Number of Branches per Plant of Chickpea

Source	DF	SS	MS	F	P
R	2	0.31500	0.15750		
Treat	3	3.99600	1.33200	13.39	0.0046
Error	6	0.59700	0.09950		
Total	11	4.90800			

Table 5. ANOVA of 100 Seed Weight of Chickpea

Source	DF	SS	MS	F	P
R	2	1.5186	0.75931		
Treat	3	12.8061	4.26871	36.40	0.0003
Error	6	0.7037	0.11729		
Total	11	15.0285			

Table 6. ANOVA of Biological Yield of Chickpea

Source	DF	SS	MS	F	P
R	2	5273	2637		
Treat	3	618146	206049	164.11	0.0000
Error	6	7533	1256		
Total	11	63095			

Table 7. ANOVA of Seed Yield of Chickpea

Source	DF	SS	MS	F	P
R	2	28.52	14.259		
Treat	3	1384.04	461.347	132.83	0.0000
Error	6	20.84	3.473		
Total	11	1433.40			

Table 8. ANOVA of Harvest Index of Chickpea

Source	DF	SS	MS	F	P
R	2	0.7736	0.3868		
Treat	3	78.2189	26.0730	236.53	0.0000
Error	6	0.6614	0.1102		
Total	11	79.6540			

ANOVA of Taramira (Arugula)

Table 1. ANOVA of Plant Height of Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	121.470	60.7352		
Treat	3	118.694	39.5646	16.50	0.0027
Error	6	14.389	2.3982		
Total	11	254.553			

Table 2. ANOVA of Length of Siliquae of Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	0.07170	0.03585		
Treat	3	0.14124	0.04708	14.92	0.0034
Error	6	0.01893	0.00315		
Total	11	0.23187			

Table 3. ANOVA of Number of Siliquae of Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	165.620	82.8100		
Treat	3	129.370	43.1233	19.05	0.0018
Error	6	13.580	2.2633		
Total	11	308.570			

Table 4. ANOVA of Number of Seeds per Siliquae Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	3.9217	1.96083		
Treat	3	11.6892	3.89639	25.46	0.0008
Error	6	0.9183	0.15306		
Total	11	16.5292			

Table 5. ANOVA of 1000 Seed Weight of Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	0.01767	0.00884		
Treat	3	0.08558	0.02853	19.80	0.0016
Error	6	0.00864	0.00144		
Total	11	0.11189			

Table 6. ANOVA of Seed Yield of Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	24.63	12.31		
Treat	3	5568.77	1856.26	420.41	0.0000
Error	6	26.49	4.42		
Total	11	5619.89			

Table 7. ANOVA Biological Yield of Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	4821.23	2410.62		
Treat	3	465.55	155.18	0.49	0.7043
Error	6	1915.69	319.28		
Total	11	7202.48			

Table 8. ANOVA of Harvest Index of Taramira (Arugula)

Source	DF	SS	MS	F	P
R	2	4821.23	2410.62		
Treat	3	465.55	155.18	0.49	0.7043
Error	6	1915.69	319.28		
Total	11	7202.48			

ANOVA of Lentil

Table 1. ANOVA of Plant Height of Lentil

Source	DF	SS	MS	F	P
Rep	2	7.947	3.9737		
Treat	3	133.125	44.3752	14.44	0.0038
Error	6	18.444	3.0740		
Total	11	159.517			

Table 2. ANOVA of Number of Branches of Lentil

Source	DF	SS	MS	F	P
Rep	2	3.0398	1.5199		
Treat	3	39.5869	13.1956	4.44	0.0572
Error	6	17.8136	2.9689		
Total	11	60.4402			

Table 3. ANOVA of Number of Pods of Lentil

Source	DF	SS	MS	F	P
Rep	2	5.910	2.9550		
Treat	3	166.903	55.6344	21.21	0.0014
Error	6	15.740	2.6234		
Total	11	188.553			