Research Project Report

Soil Fertility Management Through Alternate Strip of Inter-crops in Spate Irrigated Areas of Dera Ghazi Khan, Pakistan

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A spate irrigation system uses hill torrents/ spate water, which originate from dry mountains as a result of rainfall occurrence for irrigation. Spate water is the second largest source of irrigation after canal water in Pakistan (Ahmad *et al.*, 2016). A major portion of the potential land for spate irrigation system i.e. about 13.25 mha, out of which 6.35 mha lying in the hilly areas and 6.9 mha in the plains, can be brought under cultivation through efficient utilization of this precious source of water.

There are many techniques to conserve agriculture resources like zero tillage, crop cover, crop residue cover, site specific nutrient management, laser land leveler, crop rotation, integrated farming system, growing legumes, rain water harvesting, off season tillage/ploughing, contour farming, strip cropping etc. A strip cropping is the form of mixed cropping in which different 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 in spate irrigated areas, the strip cropping can be used as 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. The growth of some or all the component plant types overlap in space and time in an inter cropping system (Elemo *et al.*, 1990). In an intercropping systems, two or more crops grow simultaneously on the same field such that the period connected is long enough to include the vegetative stage (Gomes and Gomez, 1983). Intercropping has long been practiced by small scale farmers in the tropics. Intercropping is receiving thought because it offers potential advantages for utilization of resource, decreased inputs and increased sustainability in crop production. 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. Maximum reduction in yield attributes was recoded 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). 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).

Legume crops also act as cover crop, which increased the fertility of soil (Cavigelli and Thien, 2003). Legume crops fix atmospheric nitrogen and decrease nitrogen fertilizer needs for next cash crops (Reeves, 1994). Legume crops conserve soil moisture (Morse, 1993), decrease soil erosion (Langdale *et al.*, 1991), improve physical properties of soil (Blevins and Frye, 1993) and increase retention of nutrient (Dinnes *et al.*, 2002). The contribution of nitrogen is 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 significant in describing the health of agricultural soils (Fageria, 2002). 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 by the farmers. Such crops suit well in spate irrigated areas, 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 Medic*) 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, no information is available on cultivation of lentil in spate irrigated areas of Punjab like Mithawan hill torrent command area of Dera Ghazi Khan.

Currently, in spate irrigated areas, there is lack of detailed studies on the effect of legumes and oilseeds crops grown in the form of alternate strip of inter crops for water conservation, soil fertility and yield. Hence, the proposed study was designed with an 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 areas of Punjab (Pakistan).

Materials and Methods

The experiment was conducted during the Rabi season 2017-18 at selected locations in

Mithawan Hill Torrent spate irrigated fields of Dera Ghazi Khan that lies between latitude 29.731° N to 29.862°N and longitude 70.314°E to 70.487° 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 of crops. The experiment was laid out in Randomized Complete Block Design, having three replications. The crops were sown on 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 sown in rows using seed drill machine. The net plot size was 44m × 5.45m. 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 time of sowing 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 harvest. Weeds damage was not significant on the study sites because chickpea and lentil crops being cover crops covered the soil more quickly and physically suppressed the weeds with subsequent competitive advantage over weeds. All the other agronomic procedures were kept normal and uniform for all the treatments.

Project Duration: September-October 2017 to September-October 2018

The applied experimental treatments 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

During the course of study following parameters were recorded:

Soil Moisture (%)

Periodic saoil moisture %age was measured by the gravimetric method (Anonymous, 2007).

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

Soil Properties

Pre-sowing and post-harvest analyses of soil were conducted 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, Available Phosphorus, Available Potassium, Saturation %.

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.

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) (%)

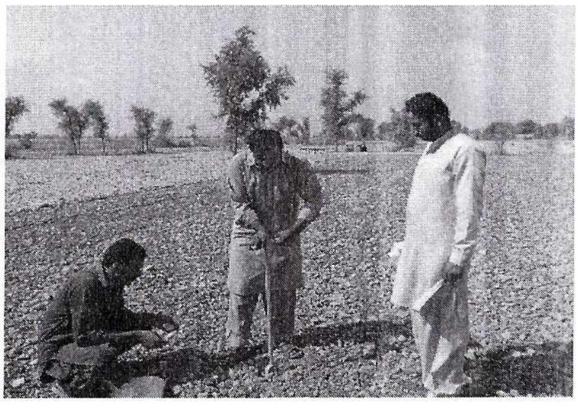
It was recorded for each plot using the formula:

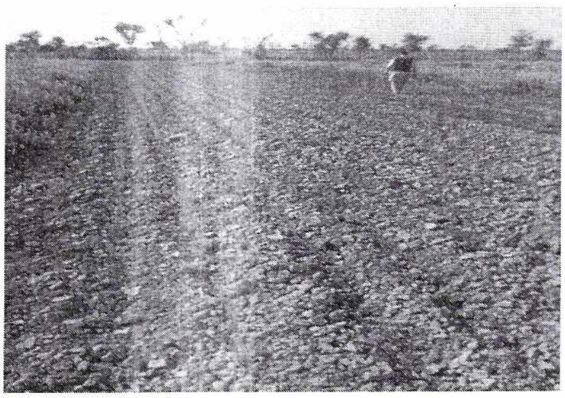
$$\text{HI \%} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw)}} \times 100$$

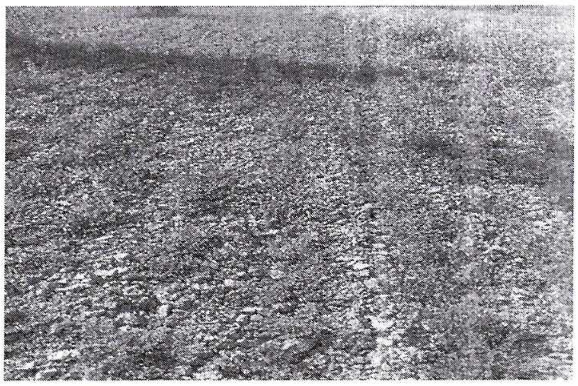
Statistical Analysis

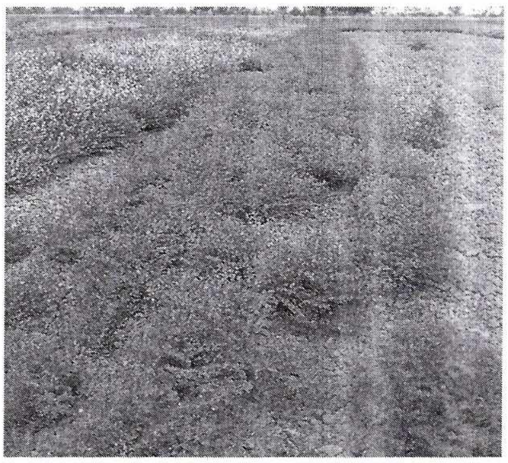
Data was analyzed through ANOVA technique and differences among the treatments were tested using HSD Tukey's test (Steel *et al.*, 1997).

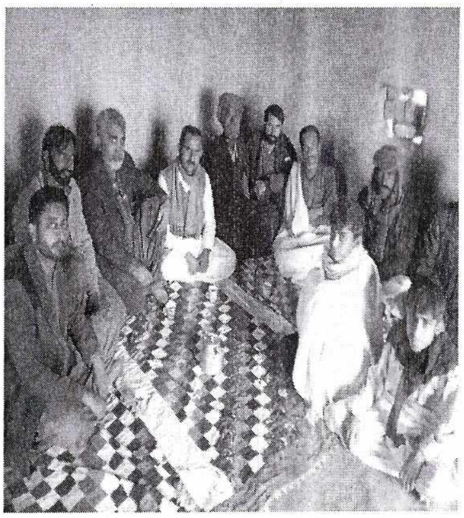
Pictorial Summary of the Project

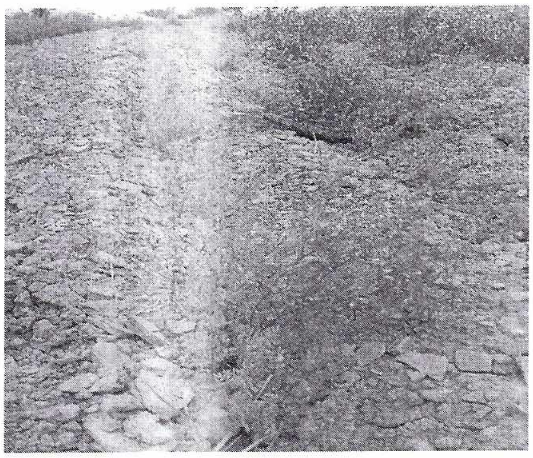


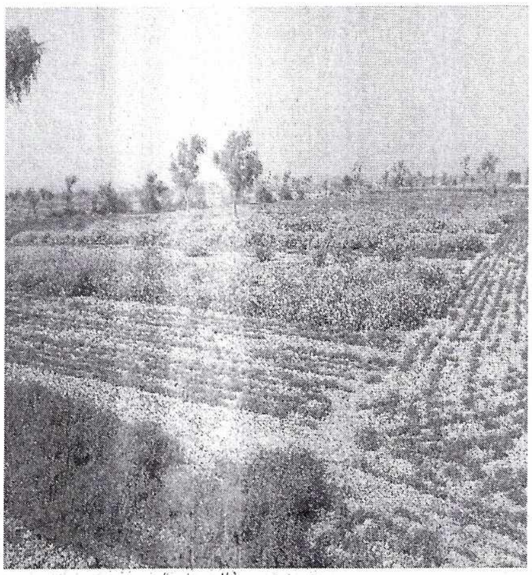










Results and Discussion

The main findings of project study are presented below:

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

1.1. Soil Moisture at 0-15 cm Soil Depth

The minimum soil moisture i.e. 2.2% (Table 1.1) lost in the chickpea and lentil strip. Water vaporization from soil surface was low probably due to spreading growth habit of chickpea that covered soil and reduced evaporation losses. The maximum soil moisture (4.32%) lost 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 might have used more moisture. 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 being leguminous, fix nitrogen (Singh *et al.*, 1992; Reeves, 1994) and improve soil organic matter, soil structure (Boyle *et al.*, 1989) which might have improved soil water holding capacity and conserved soil moisture (Morse, 1993) more efficiently.

Table 1.1. Total Soil Moisture (%) Lost Over Growing Season (at 0-15 cm Soil Depth)

Treatments	Soil Moisture Removed 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

1.2 Soil Moisture at 15-30 cm Soil Depth

At the depth of 15-30 cm, the maximum soil moisture was used in the alone strip of lentil (7.69%) (Table 1.2). The reason could be that lentil roots could not grow deeply in the soil and remain 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 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.

Table 1.2. Total Soil Moisture (%) Lost Over Growing Season (at 15-30 cm Soil Depth)

Treatments	Soil Moisture Removed 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

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. 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.

1.3. Soil Moisture at 30-45 cm depth

The Fig.1 represents the soil moisture percentage at soil depth of 30-45 cm from the time of sowing till February 2018. As the crops grew, the soil moisture measured in the second month November 2017 was increased primarily due to rainfall in study area. The increase in soil moisture during November and December was due to occurrence of rainfall. As the rain fell, the moisture of the soil increased and more moisture was available for uptake by plants.

A quick 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 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.

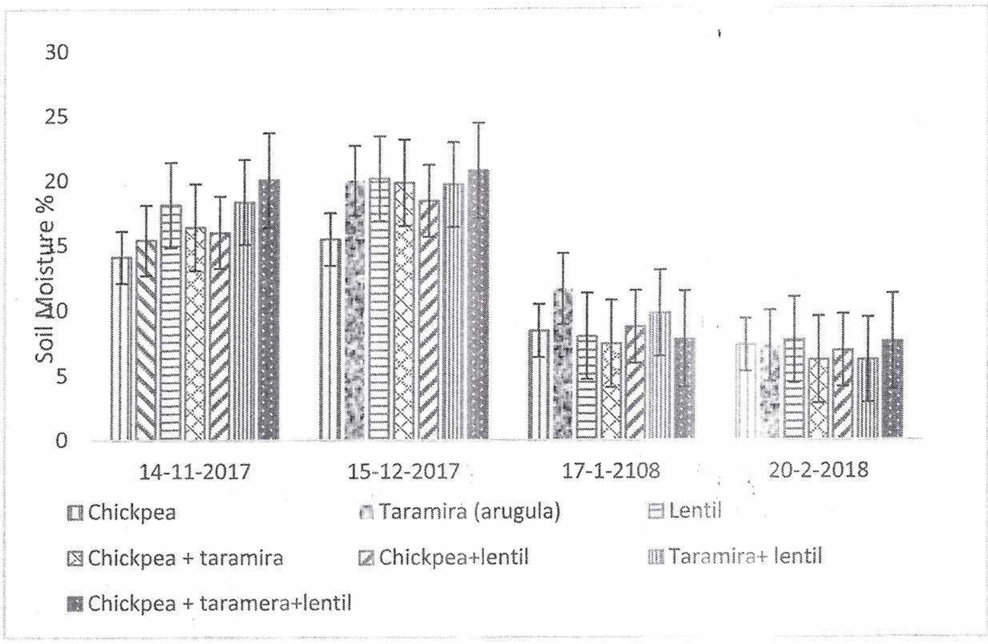


Fig.1. Effect of Sole and Intercropped Strips of Chickpea, Taramira (Arugula) and Lentil on Periodic Soil Moisture % at 30-45 cm Soil Depth

2. Soil properties

Pre-sowing (15-30 cm soil depth) and post-harvest (0-15 cm and 15-30 cm soil depth) chemical analysis of soil revealed non-significant differences among the tested treatments. The pre sowing electrical conductivity (EC) of the soil measured at the soil depth of 15-30 cm was 2.04 dsm^{-1}. Whereas post-harvest EC measured at the soil depth of 0-15 cm was 1.85 dsm^{-1} and at the soil depth of 15-30 cm was 1.93 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 change physical factors of soil such as pH, water holding capacity, temperature and aeration (Liebel and Worsham 1983; Putnam and DeFrank 1983; Weston *et al.*, 1989; 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%) at 0-15 cm soil depth probably owing to growing legumes and decaying biological activity of plants roots and falling leaves etc. 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 5.90 mg kg^{-1} at 15-30 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 owing to leguminous crops 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 *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 10.75 mg kg^{-1} at 15-30 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. Rao *et al.* (1999) also 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 physico-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 no significant difference among treatments) was probably because of growing legume plants (chickpea and lentil) and secondly strip cropping of the crops which kept soil integrity intact relatively more efficiently. 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 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

Table 3.1.2: 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

3.1.3. 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. This shows that the seed yield was significantly maximum in chickpea alone strip than the alternate strips (Table 3.1.3).

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 *et al.*, 2012). 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.

Table 3.1.3: 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

3.1.4 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 plots where alternate strip of all the three crops were grown showed significantly minimum harvest index (Table 3.1.4). 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.

Table1.4: 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

3.2. Taramira (Arugula)

3.2.1 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. 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 3.2.1). 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.

Table 3.2.1: 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

3.2.2. 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. 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 3.2.2). 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.

Table 3.2.2: 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

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

Taramira (arugula) based strip intercrops resulted in significant differences among the treatments applied. The results obtained shows that the seed yield was higher (433.14) in the plots where taramira (arugula) was grown as a sole crop. 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 3.2.3). 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.

Table 3.2.3: 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

3.2.4. 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. The lowest harvest index (20.27 %) was observed in the alternate strip of three crops i.e. chickpea, taramira (arugula), and lentil (Table 3.2.4). 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 3.2.4: 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

3.3. 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 can be attributed to limited roots proliferation within soil and limited water uptake under water scarce situation. The reduction in lentil yield can be also 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. Furthermore water shortage at flowering stage could have badly damaged the development and yield of lentil plants. Anyhow, different recorded parameters from fewer lentil plants reaching maturity have been presented below.

3.3.1. 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. 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 3.3.1). Fortin *et al.* (1994) explained that plant height decreased in inter cropping of maize and lupin than in sole crops.

Table 3.3.1: 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

3.3.2. 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 show significant differences 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 was statistically lowest (0.147 g) in the alternate strip of chickpea-taramira (arugula)-lentil (Table 3.3.2). 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 3.3.2: 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

4. Intercropping parameters

4.1 Land Equivalent Ratio (LER)

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). 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 (Fig. 4.1.1). Wasaya *et al.* (2013) also reported a clear increase of LER in wheat-fenugreek intercropping. 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.

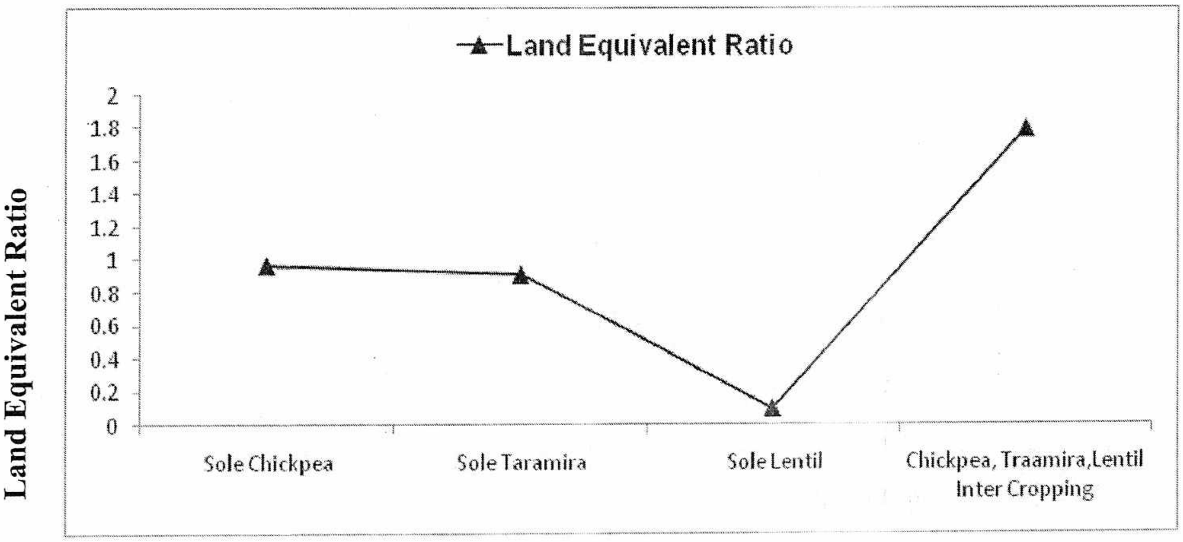


Fig. 4.1.1. Land Equivalent Ratio of Sole and Inter-cropping Systems of Chickpea, Taramira (Arugula) and Lentil in Spate Irrigated Area.

4.2 Relative Crowding Coefficient (RCC)

Relative Crowding Coefficient plays an important role in determining the competition effect and advantages in an intercropping system. 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 one 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.

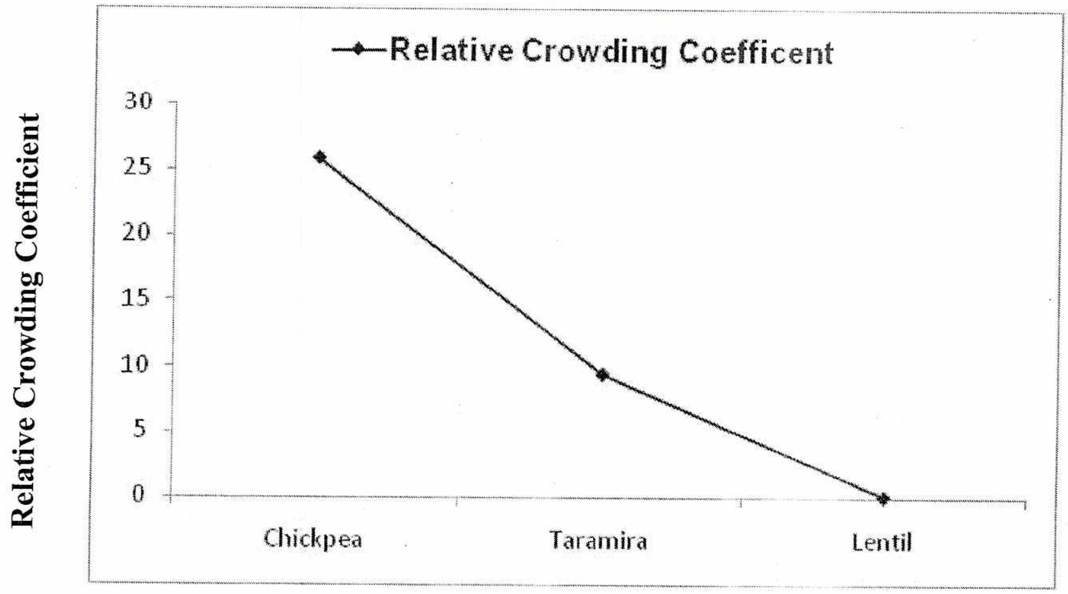


Fig. 4.2.1 Relative Crowding Coefficient of Sole Systems of Chickpea, Taramira and Lentil in Spate Irrigated Area

4.3 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 was 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.

Key Findings

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

A poster presented entitled "Rod kohi system development for enhancing productivity in marginal environments" in an International Conference on Climate Smart Agriculture; The Way of Farming in 21st Century dated October 08-09, 2018 (Proof attached).

Radio Talk on FM-101 Multan

For creation of awareness among community and stakeholders the PI had interactive session through Radio talk on FM-101.

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